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The Adoption of Conservation Tillage in a Hillside Maize Production System in Motozintla, Chiapas

Olaf Erenstein and
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NRG
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Paper 97-01

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Abstract

Data from a 1994 survey of 82 farmers who grow maize on steep hillsides in Motozintla, Chiapas, provided information on agricultural practices, including the adoption of conservation tillage practices; the profitability of the local maize-bean intercropping system; and factors affecting diffusion of conservation tillage practices. Adoption of conservation tillage appears promising: farmers no longer burn crop residues but leave them in the field as mulch, and 66% of survey farmers had adopted the no-tillage component of the technology. At present, however, only 29% of farmers are true adopters of both components of conservation tillage. Farmers who adopt both components obtain more favorable yields and farm budgets. Adopters of the mulch component of the technology appear to be less exposed to production risks. Results of a multivariate logistic model indicate that adoption of the mulch component can largely be explained by the slope of the maize field, which affects access of livestock to the field for grazing on crop residues. Adoption of the no-tillage component was explained by the availability of cash and farm size. Communal livestock pressure had a significant effect on adoption of both components, as did the availability of family labor. State agricultural policy also stimulated adoption, particularly the distribution of incentives, in combination with the local law against burning. However, because farmers still use local varieties, system productivity remains low. In addition to improving the productivity of the system, the use of improved varieties could also increase the availability of residues for forage or mulch.

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Acronyms and Abbreviations

AU	Animal unit
c.c.	Correlation coefficient
CIMMYT	Centro Internacional de Mejoramiento de Maíz y Trigo [International Maize and Wheat Improvement Center]
FIRCO	Fideicomiso de Riesgo Compartido [Shared Risk Trust]
FOSOLPRO	Fondos de Solidaridad para la Producción [Solidarity Funds for Farm Production]
INIFAP	Instituto Nacional de Investigaciones Forestales y Agropecuarias [National Institute of Forestry, Agriculture, and Livestock Research]
masl	Meters above sea level
Mx$	Mexican pesos; average exchange rate for 1993 was M$ 1 = US$ 3.1 (source: International Monetary Fund)
n	Number of cases
na	Not available
ns	not significant
prob.	Probability
PL	Potential labor
PRONASOL	Programa Nacional de Solidaridad [National Solidarity Program]
SAG	Secretaría de Agricultura y Ganadería [Ministry of Agriculture and Livestock, State of Chiapas]
SAGAR	Secretaría de Agricultura, Ganadería y Desarrollo Rural [Federal Ministry of Agriculture, Livestock, and Rural Development]
SARH	Secretaría de Agricultura y Recursos Hidráulicos [Federal Ministry of Agriculture and Water Resources; now SAGAR]
sd	Standard deviation
SDRE	Secretaría de Desarrollo Rural y Ecología [Ministry of Rural Development and Ecology, State of Chiapas; now SAG]

The Adoption of Conservation Tillage in a Hillside Maize Production System in Motozintla, Chiapas

Olaf Erenstein and
Pedro Cadena Iñiguez

Introduction

The degradation of the soil and water resources dedicated to agriculture in the State of Chiapas, Mexico, is especially serious in hillside areas. The declining quality of these resources, caused by increased erosion and diminished soil fertility, is alarming, for it threatens the present and future productivity of the region's agricultural systems. The hillside areas are also a strategic zone in Chiapas for capturing water. Resource degradation in this zone has already seriously affected the supply of potable water, state infrastructure, and the potential for hydroelectric energy. Continued degradation of the resources devoted to agriculture will reduce the well-being of people throughout the region over the short and long term.

Soil degradation is particularly severe when farmers sow annual crops on hillsides using traditional production practices. Under these conditions, annual crops offer little protection to the highly erodable soils, which are more exposed to the elements that cause erosion. Perennial crops such as coffee offer greater protection for the soil, because they form a more complete and permanent canopy. But in Chiapas, as in many other places, annual crops such as maize and beans meet the greater part of the local population's demand for food. Resource-poor farmers are reluctant to stop planting the crops that make them self-sufficient in food production, even if other crops may yield better returns or degrade the soil less. If these farmers continue to plant annual crops to meet their food needs, they will have to attempt to reduce the resource degradation that this practice implies or face the consequences of a declining resource base.

Several analysts agree that one of the most efficient ways to reduce the soil degradation that results from producing annual crops on steep slopes is to increase soil cover (Shaxson et al. 1989; Lal 1989; Hudson 1995). An appropriate cover protects the soil against the direct impact of rainfall and improves the infiltration of water, which in turn reduces runoff and soil erosion. In conservation tillage, farmers use the residues of the previous crop as a protective mulch on the soil and practice minimal cultivation of the soil to avoid destroying the mulch. Conservation tillage technology conserves water as well, which reduces the risk of drought. An additional advantage of the technology is that farmers must stop burning crop residues to prepare land for planting, thereby reducing the risk of forest fires. At the beginning of the 1990s in Chiapas, agricultural activities caused an estimated 55% of forest fires (Sandoval 1994:55).

Various institutions in Chiapas have experience in developing and promoting conservation tillage practices. The Sierra Madre of Chiapas was one of the first areas where this technology was extended on a large scale: the first pilot program to extend conservation tillage practices was conducted in this mountainous area in 1983. The number of programs promoting the technology grew in subsequent years, peaking between 1989 and 1993 (Cadena 1995:3-7). Among the institutions that promoted conservation tillage were the Secretaría de Agricultura y Recursos Hidráulicos (SARH, the Federal Ministry of Agriculture and Water Resources); the Secretaría de Desarrollo Rural y Ecología (SDRE, the Ministry of Rural Development and Ecology, State of Chiapas); and the Fideicomiso de Riesgo Compartido (FIRCO, the Shared Risk Trust). By the end of 1992, a state law that regulated agricultural burning came into effect, which facilitated (or perhaps forced) the adoption of conservation tillage.

The Sierra Madre of Chiapas is characterized by steeply sloping hills, which prevent mechanization of the maize-bean intercropping system. Previously, farmers prepared land and controlled weeds with a hoe; before planting, farmers burned the residues left over from communal grazing by livestock. The promotion of conservation tillage in these cropping systems encouraged farmers not to burn residues and to replace the manual weed control with herbicides. Incentives such as herbicide sprayers and credit were provided to reduce the cost of switching from traditional practices to conservation tillage, which required a sprayer for applying herbicide and some means to purchase equipment and inputs. Farmers could obtain these items only on the condition that they stop burning residues. At the same time, the benefits of conserving residues rather than burning them were strongly emphasized to farmers.

Despite the great effort to promote conservation tillage in the Sierra Madre of Chiapas and other areas in the state, information on the adoption of the technology is relatively scarce.[1] What is the current level of adoption? What practices changed with the adoption of conservation tillage, and which remained nearly the same? Which factors encouraged farmers to adopt the technology, and which ones limited adoption? This study seeks to answer these questions for one specific study area in the Sierra Madre of Chiapas.[2]

The specific objectives of the study were to:
- Describe the agricultural production systems, giving special attention to the production system characteristic of the study area;
- Identify which factors influenced the adoption of conservation tillage in these systems; and
- Quantify those factors in economic terms from the farmers' point of view.

This information can help develop useful recommendations for policy makers and research and extension managers interested in assessing the potential advantages and disadvantages for poor, semisubsistence farmers to adopt conservation tillage in areas highly subject to resource degradation.

In the next section of this paper, we describe the study area, the methods used to conduct the study, and the typology of the data. The third section of the paper discusses the farm-level production system, particularly cropping and livestock production practices, labor use, and links between the farm and the external environment. The fourth section of the paper discusses the maize-bean intercropping system at the field level, and the fifth section focuses on

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[1] See van Nieuwkoop et al. (1994) for one of the few studies examining the adoption of conservation tillage in another area of Chiapas.

[2] Preliminary results of this study are presented in Cadena (1995).

the economics of maize-bean intercropping. The sixth section gives closer attention to factors influencing the adoption of different components of the conservation tillage technology. The last section consists of a summary and conclusions.

Methodology and Classification

The Study Area

The study area is located in the easternmost part of the Sierra Madre of Chiapas in the municipality of Motozintla, near Mexico's frontier with Guatemala (Figure 1). The municipality encompasses 325 km^2 of mostly mountainous terrain and belongs to Rural Development District No. 7 (Distrito de Desarrollo Rural No. 7 Sierra). Despite its mountainous topography, 90% of the area in the municipality is dedicated to agriculture, 7% to natural pasture, and only 3% to forest. Coffee, the main crop, occupies 52% of the arable area, especially in relatively lower areas. Maize occupied 19% of the arable area in the spring-summer cycle[3] of 1991; beans, 5%; and perennial crops other than coffee, 7%. The remaining 17% of the arable area was not cultivated in the 1991 summer cycle. Of the total area in the municipality, 59% was *ejido* land,[4] 34% belonged to smallholders, and the rest was communal or public land. The municipality has 40 *ejidos* (INEGI 1994).

The study area was restricted to the *ejidos* of El Carrizal and Tuixcum, which are located, respectively, about 7 km directly northwest and 5 km directly southeast of the city of Motozintla. Motozintla, the main city in the municipality, has about 50,000 persons and is located at the bottom of a valley which lies at about 1,300 masl. The elevation of the two *ejidos* is about 2,000 masl (1,800-2,200 masl), near mountains of about 3,000 masl. The villages of both *ejidos* are located on the relatively flat tops of the mountains. Both *ejidos* are mainly agricultural, and farmers' fields are located on hillsides with slopes ranging from 40% to 100%. Both *ejidos* can be reached by dirt roads, although it takes about an hour to drive to them from Motozintla.

The higher part (>2,000 masl) of the *ejidos* is classified by Köppen as C(m)(w): a humid temperate climate with abundant rain from

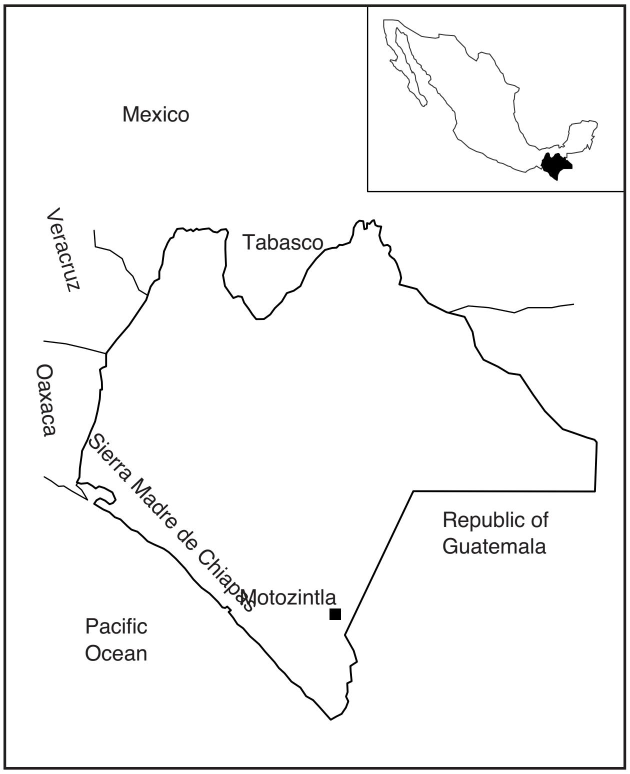

Figure 1. Location of the Motozintla study zone, Chiapas, Mexico.

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[3] The spring-summer cycle, which we refer to as the "summer cycle" or "summer season," is the principal growing season for maize in the study area.

[4] *Ejido* land is agricultural land whose distribution, use, and sale were previously heavily controlled by the Mexican government. *Ejido* members had usufructuary rights to *ejido* land, but the government retained ownership. Recent constitutional reforms conferred ownership of the land on the individual *ejido* members.

May to November; an average temperature of 12-18°C; and an average temperature in the coolest month between 3°C and 18°C. The lower part of the *ejidos* is classified by Köppen as A(C)m(w): a semihot, humid climate with abundant rain from May to November; an average temperature of 18-22°C; and an average temperature in the coolest month of >18°C. Because the zone is mountainous, rainfall is quite variable, reaching an annual total of 1,500-3,000 mm (SPP 1981). The combination of low temperatures and high humidity makes the climate quite favorable for maize production. However, solar radiation can be relatively low because of cloudiness. The low temperature also reduces the speed at which organic matter decomposes in the soil (Bolaños, pers. comm.).

The *ejido* of El Carrizal was established in 1935, whereas that of Tuixcum was founded in 1928. El Carrizal is relatively larger than Tuixcum, with a population of 1,639 persons belonging to 302 families, who occupy 229 residences. The *ejido* of Tuixcum has only 677 inhabitants (142 families living in 129 residences) (Cadena 1995).

It is important to note at the outset that this case study was done in a small part of a highly variable mountainous area and that information generated by the study cannot necessarily be extrapolated to other communities in the Sierra Madre. For example, the two *ejidos* are characterized by their steep slopes and relative accessibility — two characteristics that may not be found together in other communities of the Sierra.

Methodology

Motozintla was one of the pilot areas where conservation tillage was promoted in the Sierra Madre of Chiapas. El Carrizal was one of the first *ejidos* to participate in the extension campaign for conservation tillage, partly because many of the *ejidatarios* produced maize on steep slopes and because the *ejido* was relatively accessible. Tuixcum was chosen for this study to avoid limiting the study to just one *ejido*. Tuixcum is agroecologically and socioeconomically similar to El Carrizal.

The data presented in this paper were gathered through a formal survey conducted at the beginning of the 1994 summer cropping cycle. The sample was drawn from a list of the farmers belonging to each *ejido*; from a total of 443 farmers (El Carrizal, 318; Tuixcum, 125), 82 were selected for the survey (El Carrizal, 52; Tuixcum, 30). The sample was stratified by *ejido* and the average sampling fraction was 18.5%.

Farm-level as well as field-level data were obtained for each of the sample farmers. The field was selected on the basis of two criteria: size (the largest) and cropping system (maize intercropped with beans or, if the farmer did not intercrop, monocropped maize). Most of the survey questions focused on current practices, although some retrospective data were collected. Aside from requesting specific information through the questionnaire,[5] the enumerators also used visual aids (Appendix A) to estimate the slope of the selected fields and soil cover after planting.

Classification of Adopters

"Conservation tillage" is a rubric given to a wide number of agricultural practices, and many definitions of the term exist, ranging from extremely general to quite specific. However, conservation tillage generally refers to a reduction in tillage operations, combined with the conservation of crop residues, to

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[5] See Cadena (1995) for the complete questionnaire.

preserve and/or improve soil.[6] The hillside production system used by farmers in this study was classified as a conservation tillage system if it met two criteria:

1. **The reduced tillage criterion:** Soil is tilled only for sowing; land preparation and weed control exclude any cultivation of the soil. Given the steep slopes of the fields in the study area, the criterion of reduced tilled was limited to *no-tillage only*. Adoption of this component of the conservation tillage technology was determined based on land preparation and weed control practices reported by farmers for the 1993 summer cycle in the selected field.

2. **The soil cover (mulch) criterion:** At least 30% of the soil surface had to be covered by crop residues immediately after sowing (this level corresponds to 2 t/ha of maize stover used as mulch; see Tripp and Barreto 1993).[7] To determine adoption of this component of the technology, the enumerator estimated the amount of mulch on the selected field at planting in the 1994 summer season, using a device developed by Tripp and Barreto (1993) (see Appendix A). It is assumed that the amount of mulch on the field at the start of the 1993 summer cycle was similar.

If farmers are to benefit from conservation tillage, they must meet both criteria, for the use of one component of the technology without the other can generate unexpected results. The farmer can meet one or both criteria or neither, so it is possible to distinguish four categories of adopters: nonadopters, adopters of either of the components by itself, and adopters of both components (Figure 2). “Nonadopters” are farmers who meet neither of the two conservation tillage criteria, whereas “adopters of both components” have met both criteria and thus are considered to have completely adopted conservation tillage technology. We also refer to “adopters of the mulch component” (farmers who have met the mulch criterion) and “adopters of the no-tillage component” (farmers who have met the no-tillage criterion).

The distinctions between these three categories is are important for understanding the adoption of conservation tillage technology. In this paper, we will present information for the entire sample of farmers and for the different categories of adopters when the differences between them are significant.

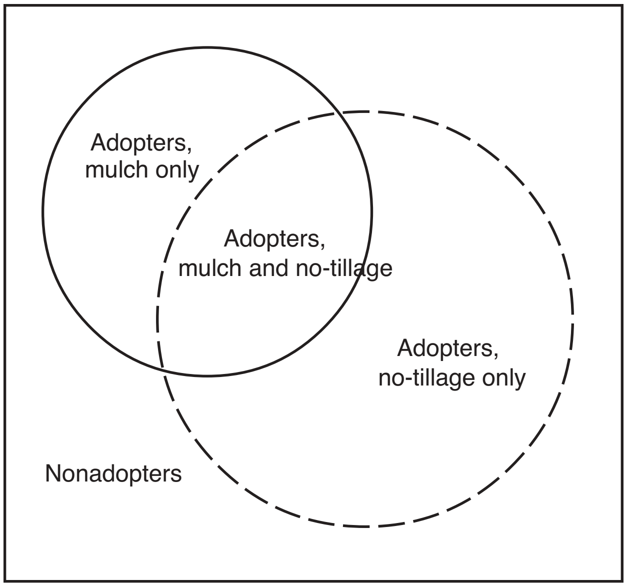

Figure 2. Venn diagram of groups of adopters and nonadopters of conservation tillage practices (not to scale).

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[6] In simplified terms, the soil improves when organic matter is added at a greater rate than it decomposes (Bolaños, pers. comm.).

[7] The 30% threshold was developed initially in the United States for mechanized production systems (CTIC 1994). Some researchers contend that in tropical and/or hillside production systems a higher threshold must be considered, although several sources suggest that the response in terms of reduced erosion is similar in these environments (see, for example, Shaxson et al. 1989). Even so, a higher degree of soil cover would imply less soil degradation.

The Production System (Farm Level)

The Land Resource and Its Use

The average farm size among sample farmers was 2.8 ha. Of this area, only 2.2 ha were cultivated during the 1993 summer cycle (Table 1) and 0.6 ha were left fallow. Maize occupied nearly all of the cultivated area and was usually intercropped with beans (an average of 2 ha); occasionally maize was monocropped (0.2 ha on average; 27% of the sample). On the remaining 0.05 ha of cultivated area, beans were solecropped (by 13% of the sample) or the land was planted to other crops such as cabbage, potatoes, and faba beans (13% of sample). Farmers have grown virtually these same crops over the past decade. Some producers also have a few fruit trees, such as peaches, apples, citrus, or plums, in their fields.

The different groups of adopters differ significantly in farm size and cultivated area. Adopters of both components of the conservation tillage technology (that is, complete adopters of conservation tillage) have significantly larger farms and cultivated area than nonadopters and those who only use mulch. Farmers who have adopted only the no-tillage component of the technology lie between the two extremes, although the size of their farms and cultivated area is still significantly greater than that of the nonadopters. These differences appear to indicate that adoption of the no-tillage component (alone or in conjunction with the mulch component) is related to the size of a farmer's cultivated area. This conclusion seems reasonable if we consider that the no-tillage component saves labor.

Most farmers (72%) have the same amount of cultivated land as they did ten years ago (data obtained through restrospective questioning). One-fourth (24%) of the sample farmers increased their cultivated area in relation to the availability of labor and herbicides. Only 4% had reduced their cultivated area because they transferred part of their land to someone else.

Fallowing continues to be a common practice: 55% of the sample farmers leave part of their land fallow for an entire year, so that on average one-fifth (21%) of the farm area was in fallow in the 1993 summer season. Nevertheless, fallow fields also serve as pastures for livestock during the cropping cycle.[8] The 51 farmers who fallowed (or had

Table 1. Farm area (ha) by adopter group and land use, Motozintla, Chiapas

	Total sample		Type of adopter				
	Average (ha)	Standard deviation	Non-adopter	Mulch only	No-tillage only	Both components	Probability
Total area	2.76	± 1.26	2.11 a	2.30 ab	2.85 bc	3.34 c	.01
Cultivated area, 1993 summer cycle	2.18	± 0.90	1.68 a	1.81 ab	2.10 b	2.82 c	.00
Maize (solecropped or intercroppped with beans)	2.13	± 0.89	1.62 a	1.81 ab	2.04 b	2.79 c	.00
Other crops (including bean solecrop)	0.05	± 0.10					ns
Fallow area, 1993 summer cycle	0.59	± 0.74					ns

Note: Figures followed by different letters are significantly different (Duncan 0.1, row comparison); ns = not significant.

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[8] After the cropping season, all area dedicated to producing annual crops is left fallow and serves as animal pasture until the subsequent cropping cycle.

done so in the past) cited the following reasons for doing so:

- recovery of the soil (37%);
- the need to pasture livestock during the cropping season (27%);
- lack of labor or herbicide (24%); and
- prevention of soil diseases (12%).

Fallowing appears to have been slightly more common ten years ago. It is interesting to note that most farmers who reported that they had completely abandoned fallowing in the previous decade were short of labor and had adopted the no-tillage component.

Livestock Resources

Most farmers (87%) have at least one head of cattle, while the average size of the livestock herd is 5.2 head per farm. The herd is composed chiefly of sheep and horses, with a few goats, pigs, and cows (Table 2). Although on average half of the herd consists of sheep, only 29% of the producers have sheep. Ownership of horses is relatively more common (81% of the survey farmers have at least one horse), mostly because horses are used as pack animals in the *ejido*, especially to carry inputs to — and remove the harvest from — relatively inaccessible fields.

During the past decade, the livestock herd has decreased by an average of 2.0 head per farm (prob.: .04). This reduction has probably occurred because of the increasing human population, the limited land area, and the use of land to produce food for home consumption. Shrinking livestock herds are the result of two opposing forces: on the one hand, the numbers of sheep and cows have declined; on the other, the numbers of horses and pigs have grown. Fluctuations in livestock numbers per farm were different among the groups of adopters. Most reductions occurred among adopters of both components of the technology, whereas livestock herds increased mostly for farmers who did not adopt the mulch component — a result that one would expect.

To obtain an aggregate number of livestock for each farm, the herd was converted into animal units (AU) (adapted from Gittinger 1982).[9] On average, each farm had 2.6 AU, resulting in a

Table 2. Livestock indicators, Motozintla, Chiapas

	Total sample		Type of adopter				
	Average	Standard deviation	Non-adopter	Mulch only	No-tillage only	Both components	Probability
Herd composition (head/farm)	5.15	± 6.12					ns
Sheep	2.59	± 5.25					ns
Horses	1.72	± 1.15	1.38 a	1.86 ab	1.57 a	2.17 b	.10
Goats	0.30	± 2.76					ns
Pigs	0.30	± 1.12					ns
Cattle	0.23	± 0.84					ns
Livestock pressure/farm (AU/cultivated ha)	1.27	± 1.11	1.47	1.28	1.30	1.06	ns
Communal livestock pressure (AU in *ejido*/cultivated area in *ejido*)	1.13	± 0.45	1.26 a	1.16 a	1.26 a	0.85 b	.00

Note: Figures followed by different letters are significantly different (Duncan 0.1, row comparison); ns = not significant; AU = animal units.

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[9] Where the number of animal units (AU) per farm is calculated as:
AU = (# cattle) + 0.17 * (# sheep + # goats) + (# horses) + 0.5 * (# pigs).

pressure of 1.3 AU per cultivated hectare or 1.0 AU per hectare of farm area. The AU per cultivated hectare is the best indicator of livestock numbers if one considers that the fallow area usually serves as pasture during the cropping season. By the end of the summer cropping cycle, little biomass is left in these fallow fields. During the dry season, animals graze in fields that were cultivated in the cropping season and thus retain a substantial amount of crop residues and weeds. Furthermore, in the study area there are few alternative sources of forage to substitute for maize residues during the dry season. Although there are no significant differences in livestock ownership among the categories of adopters, there is a tendency for livestock pressure to be lower among adopters of the mulch component (alone or with the no-tillage component; see Table 2).

Nevertheless, communal grazing during the dry season continues to be common in both *ejidos*, which means livestock other than those owned by the farmer may graze on the crop residues in his fields. To take this into account, communal livestock grazing pressure was used as an additional indicator of livestock pressure. This indicator was calculated based on livestock pressure for the *ejido* as a whole, corrected for the fencing of fields (free grazing is limited when parcels are well enclosed).[10] Calculated in this way, communal livestock pressure tends to be less for adopters of the mulch component than for those who did not adopt mulch, although the difference is only significant among those who adopted both components of the technology (Table 2).

Family Characteristics, Labor, and Outmigration

Average family size[11] is 5.9 persons, composed of 2.3 adult men, 1.9 adult women, and 1.6 children (Table 3). In general, men perform most of the agricultural work. Women help with the field work in 60% of the cases, while children help occasionally. Women participate mostly in sowing, fertilization, and harvest operations (±90%) and less (35%) in weed control operations. Women's contribution to chemical weed control is usually limited to carrying water. In most instances (70%), women's participation in agricultural activities has remained relatively unchanged over the past ten years. The remaining 30% of farmers reported that women's involvement had generally declined. Changes in women's participation were related to changes in family structure (for example, child care responsibilities, growth of children and their participation in agriculture) and in no case were they related directly to changes in agricultural production.

The head of the family is generally male, literate, 44 years old on average, and has farmed for 30 years. Farmers who adopted the mulch component of the technology

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[10] Communal livestock pressure for the *ejido* is calculated as follows:

$$\text{Pressure}_e = \frac{\sum (\text{AU})_{fe}}{\sum (\text{Area})_{fe}}$$

($\sum$ for $f = 1,\ldots,n$ in *ejido* e),
where AU_f is the number of animal units for farm f and Area_f is the total area of farm f.

Communal livestock pressure for the farm is calculated as:

$$\text{Pressure}_f = \text{Pressure}_e * \text{Factor}_f,$$

where Factor_f is the correction for fencing on farm f (1 = not fenced; 0 = fenced; and 0.5 = partially fenced).

[11] A family is defined as the group of persons living on the farm and depending on it for their livelihood.

(alone or together with the no-tillage component) usually have much more farming experience (an average of ten years) and are older (by an average of five years) than nonadopters.

The amount of family labor available on the farm is estimated based on the composition of the family and the participation of the family members.[12] On average, there are 3.4 units of potential labor (PL) available per farm (1.8 PL per cultivated hectare or 1.5 PL per hectare per farm). Labor availability per hectare of cultivated area tends to be less among adopters of the no-tillage component, although differences in labor availability are significant only among nonadopters and adopters of both components of the technology (Table 3).

Half (51%) of the survey farmers reported that they hired labor to complement family labor. About 15% of the labor dedicated to maize-bean intercropping each season is hired. Hired labor (expressed as a percentage of total labor) is negatively correlated to the availability of family labor per unit of cultivated area (c.c.: -.32; prob.: .00). Adopters of the no-tillage component (alone or in conjunction with the mulch component) hire in relatively more labor (about 20% of the total) than nonadopters (less than 7% of the total; Table 3). It is probable that the diminished availability of labor, along with the need for hiring in additional labor, have encouraged farmers to adopt the no-tillage component, because this implies a reduction in the labor needed to produce the maize and bean crops.

Outmigration of at least one family member is quite common (79%) in the study area, and outmigrants generally provide economic support to family members remaining on the farm. Forty-one percent of sample farmers

Table 3. Family characteristics and family labor, Motozintla, Chiapas

	Total sample		Type of adopter				
	Average	Standard deviation	Non-adopter	Mulch only	No-tillage only	Both components	Probability
Family size (per farm)	5.85	± 1.79	5.29	5.57	5.90	6.38	ns
Men	2.30	± 1.13	1.90 a	2.14 ab	2.17 a	2.88 b	.02
Women	1.91	± 1.01					ns
Children	1.62	± 1.41					ns
Head of household:							
Years as farmer	30.0	± 12.0	25.3 a	37.4 b	27.4 a	35.0 b	.01
Age	44.4	± 10.9	40.7 a	49.4 bc	42.9 ab	48.2 c	.06
Literacy (% cases)	96.3	na	100	85.7	93.3	100	na
Availability of family labor (potential labor/cultivated ha)	1.80	± 0.92	2.16 a	1.97 ab	1.78 ab	1.47 b	.09
Use of family labor (% of total)	85.3	± 20.4	94.2 a	93.3 ab	82.1 b	79.3 b	.05

Note: Figures followed by different letters are significantly different (Duncan 0.1, row comparison); ns = not significant; na = not applicable.

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[12] Where potential labor (PL) per farm is calculated as:

(PL) = (# men) + (# women * 0.5 * factor) + (# children * 0.3).

The factor corrects for women's assistance with field work (1 = yes, helped with field work; 0 = did not help). Weights (0.5 for women, 0.3 for children) were applied to account for potential participation in field work, based on other activities and characteristics of women (cooking, caring for children) and children (school, age).

reported that it was the head of the household/ farmer who left, whereas for 47% of the sample it was another family member who left (alone or with the household head). There is a marked difference in the areas to which these two groups migrate in search of work. Most heads of households (73% of those who leave the farm) remain relatively nearby, working along the coast of Chiapas. Most (82%) of the other family members who leave in search of work travel relatively far away (to Mexico City, the United States, or port cities outside of Chiapas); only 8% work somewhere along the Chiapas coast. This difference is related to the form of outmigration, which generally is seasonal in the case of the head of household and more extended in the case of other family members who emigrate. Heads of households are normally responsible for establishing the crop in the field (including fertilization and weed control), and afterwards they are free from field work to a certain extent until harvest time. It is during this period that many farmers leave for off-farm work, especially to pick coffee in areas along the Chiapas coast.

Outmigration by household heads appears to be related to the adoption of the mulch component but not the no-tillage component of the technology. Fewer farmers who adopted the mulch component (24%) emigrated (prob.: .05) compared to nonadopters (46%). This is understandable if one recalls that the head of the household has primary responsibility for agricultural activities and that his absence can limit the control of communal grazing during the dry season. On the other hand, the financial resources obtained through outmigration can enable a family to acquire the herbicides needed to adopt the no-tillage component of the conservation tillage technology. However, outmigration is so common that it is not a sufficiently distinguishing characteristic among groups of adopters.

Migration is strongly related to the availability of labor. Families whose members do not emigrate have less available labor (2.6 PL per farm) than those whose members leave (3.6 PL per farm; prob.: .00). The type of migration is also related to the availability of labor. A family in which only the household head emigrates has less available labor (3.2 PL per farm) than a family in which another family member emigrates (3.9) or in which several members emigrate (4.0).

Links with the External Environment

Some 13% of the survey farmers were visited by an agricultural extension agent before or during the 1993 summer cycle. Most of these visits were made by agents of SARH in the 1993 summer cycle. Nonadopters were visited less (5%) than adopters of just one component (13-14%) or both components (21%) of the technology.

Nine percent of the survey farmers are members of the *Unión de Ejidos,* and all of them are adopters of the no-tillage component (alone or in conjunction with the mulch component), possibly because this organization, among others, markets inputs. Almost 20% of the producers occupied some post within the *ejido* (for example, on the *ejido* council or the security committee).

About 36% of the maize production is sold immediately after harvest, while the rest is used primarily for home consumption on the farm, to feed livestock on the farm (especially chickens, horses, and pigs), or — occasionally — sold later in the year. The groups of adopters differ markedly in their maize marketing practices. Adopters of both technology components sell 53% of their production on average, whereas nonadopters sell only 15% (Table 4). Those who adopted only one component of the technology are in the middle of these two extremes, with sales fluctuating around the general average. Differences in maize marketing are related mainly to cultivated maize area, which in turn determines total production. Average consumption levels are similar for the different groups of adopters.[13] The differences among adopters suggest that the production of maize for sale encourages the adoption of the components of conservation tillage. This is not surprising, given that the adoption of both components generally requires a greater amount of cash (for inputs for the no-tillage component, for example, or for fencing materials for the mulch component).

In the case of beans, about 31% of the production is sold immediately after the harvest, whereas the rest is chiefly used for home consumption. Differences among groups of adopters are similar to those for maize production.

The Maize-Bean Intercropping System (Field Level)

Field Characteristics

Maize is the most important food crop in the study area, and the survey gathered detailed information about farmers' management of the maize crop. This information was obtained by focusing on a single maize field belonging to each survey farmer. The overwhelming majority of sample farmers (96%) produce a maize-bean intercrop in the selected field, whereas the remainder grow a maize solecrop. In general, the same crop had been sown on the selected field during the previous cycle and selected fields had been cultivated for more than 48 years on average.

As noted earlier, these fields were located mostly on steep slopes. The average slope was 71%, but it is interesting to observe the great differences in the slopes of the fields cultivated by different groups of adopters. Adopters of the mulch component (alone or with the no-tillage component) had fields with a slope of about 85%. The slope of nonadopters' fields was slightly less, at about 65% (Table 5), which seems to indicate that adoption of the mulch component is closely related to the slope of the field. This relationship makes sense when one considers that steep slopes make it difficult for livestock to gain access to the land for grazing. Adoption of mulch on the steepest fields may also be related to the fact that conserving crop residues on such fields can markedly reduce soil erosion.

Table 4. Crop sales immediately after harvest, Motozintla, Chiapas

	Total sample		Type of adopter				
	Average	Standard deviation	Non-adopter	Mulch only	No-tillage only	Both components	Probability
Maize sales (% of production)	36.0	± 28.7	14.7 a	35.1 bc	37.5 b	53.2 c	.00
Bean sales (% of production)	31.4	± 29.5	9.1 a	21.4 ab	35.0 b	49.2 c	.00

Note: Figures followed by different letters are significantly different (Duncan 0.1, row comparison).

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[13] On average, 3-4 t of maize are stored per farm. This implies a hypothetical per capita consumption of 1.5-1.9 kg per day (hypothetical because it includes consumption by animals and sporadic sales). This figure corresponds to similar calculations of home consumption of 1.5 kg per capita per day for the State of Chiapas (López Báez, pers. comm.).

Crop Establishment

Virtually all of the farmers surveyed (99%) prepared their land and sowed maize by hand, using a hoe. In general, these activities are combined in a form of reduced tillage, known locally as sowing "*cajeteada*" (a *cajete* is a shallow clay bowl). A small area, about 20 x 20 cm (a *cajete*), is cleared and 3-5 seeds are sown in the middle of the area. These *cajetes* are prepared in such a way that each mound forms a small terrace. In clearing the *cajete*, all vegetation is removed, along with the residues of the previous crop. This ensures that the germinating plants are practically free of weeds and facilitates the capture of water. Land preparation and sowing require an average of 24 days/ha.

Given that producers already practice some form of reduced tillage, no significant differences exist in the number of days that each group of adopters needs for land preparation and sowing. Because all farmers have stopped burning crop residues, all of them can be considered potential adopters of conservation tillage, although many do not leave enough residues on the field to create an effective mulch. On the other hand, despite the fact that farmers practice a form of reduced tillage, a considerable number continue to till the soil during the crop cycle. In most cases (82%), however, land preparation and sowing have not changed over the past decade, with the exception that farmers have stopped burning crop residues.

More than ten years ago, farmers used other land preparation practices, some of them in combination, such as:

- **Clearing ("slashing") with a machete:** This practice was used to clear land, particularly land that had been left fallow and become quite overgrown.
- **Burning:** This practice, once an important component of land preparation, included the burning of crop residues from the previous harvest or of bushy fallow regrowth. Depending on the amount of biomass in the fallow field, the cleared residues and vegetation were sometimes piled up to make them easier to burn.
- **Scraping with a hoe:** The surface of the entire field was cleared by scraping ("shaving") it with a hoe to leave it barren of vegetation.
- **"Plowing" with a hoe:** In this intensive land preparation practice, a hoe was used to turn over all of the soil in the field.

Table 5. Characteristics of the field selected for the farmer survey, Motozintla, Chiapas

	Total sample		Type of adopter				
	Average	Standard deviation	Non-adopter	Mulch only	No-tillage only	Both components	Probability
Area intercropped with beans, 1993 summer cycle (%)	94.2	± 20.9					ns
Field planted to maize-bean intercrop, 1992 summer cycle (% of cases)	96	na	90	100	100	96	na
Years field cultivated	>47.8	± 12.9	>45.7	>44.1	>46.1	>52.9	.14
Average slope of selected field	71.3	± 23.1	61.4 a	87.1 b	64.6 a	83.6 b	.00

Note: Figures followed by different letters are significantly different (Duncan 0.1, row comparison); ns = not significant and na = not applicable.

Seed

Most farmers (85%) grow yellow maize; the remainder grow white varieties. All of the yellow maize varieties and most of the white ones (92%) are local materials. The yellow varieties generally originated in the region, where they have been grown since before anyone can remember. Apparently the yellow varieties are better adapted to the very high locations in the study area (>1,500 masl) and are more resistant to diseases and pests, whereas the white varieties are more common in the lower locations in the study area.[14] The absence of improved varieties in farmers' fields results partly from a lack of improved materials suited to the zone, which has probably occurred for several reasons. First, the local preference for yellow materials is unusual in a country where white materials predominate. Second, the inherently high agroecological variability of this mountainous zone, where elevation, rainfall, temperature, soils, wind, and other factors can vary widely, makes it quite difficult to adapt as well as disseminate materials for each agroecological niche. Indeed, maize improvement in Mexico has traditionally focused on the lowland tropics (<1,200 masl) (López Báez, pers. comm.).

In the higher parts of the study area, maize is sown in May; in the lower parts, in June. Farmers use about 16 kg/ha of seed. Generally, beans are sown a month after the maize so that the bean plants do not become entangled with the maize seedlings. According to some farmers, this delay also diminishes damage to the beans from *Diabrotica balteata* (the banded cucumber beetle), a chrysomelid beetle that feeds on bean leaves but also on other species such as maize. Unlike maize, beans are sown with a dibbling stick. An average of 9 kg/ha of seed is used. All of the bean varieties are local; the most common one, sown by 74% of the survey farmers, is called "negro de vara."

Fertilizer Use

Almost all farmers (98%) used chemical fertilizers in the 1993 summer cycle, and 4% used chemical fertilizers in combination with organic ones. Chemical fertilization consists mainly of nitrogen (N) applications — farmers applied an average of 79 kg/ha of N in the 1993 summer cycle. Phosphorus (P_2O_5) was applied only by 12% of the farmers, and potassium (K_2O) only by 11%, resulting in an average rate of only 4 kg P_2O_5/ha and 3 kg K_2O. Adopters of the no-tillage component applied more N on average (87 kg/ha) than nonadopters (65 kg/ha; prob. = .05). Similarly, the use of P_2O_5 and K_2O was more common among adopters of the no-tillage component (no-tillage alone or with mulch). Recent research results from other areas of Mesoamerica suggest that the levels of N used by the farmers in the study area are probably low for conservation tillage in relation to the immobilization of N by the mulch (Zea et al. 1997).[15]

Most farmers (61%) applied fertilizer in two doses, whereas 38% applied fertilizer only once. Two applications were more common (prob.= .08) among adopters of the no-tillage component (alone or with the mulch component) than among nonadopters. On average, 58% of all N applied was applied in the first dose. The most common source of N was ammonium sulfate (21-0-0), followed by urea (46-0-0). The chief source of P_2O_5 and K_2O was Triple 17 (17-17-17).

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[14] White maize is more commonly grown by adopters of the no-tillage component (either alone or with the mulch component).

[15] According to Zea et al. (1997), under low levels of N there is a negative interaction between the net effect of the mulch and grain yield, with the equilibrium for N application at a level near the average in the study area.

Most farmers (62%) applied fertilizer by hand at the base of the maize plant ("*mateada*"). The rest of the farmers who applied fertilizer incorporated it with a hoe to reduce the risk of runoff. This practice has the additional advantage of reducing volatilization of N, but has the disadvantage of requiring about 50% more labor than is needed to apply N at the base of the maize plant (eight days) (Table 6). Recent research elsewhere in Mesoamerica has shown that incorporating N can raise maize yields by 140 kg/ha over simply applying N at the base of the plant, by increasing the N use efficiency of the maize plant (Larios et al. 1997). Assuming a similar response in the study area, the practice of incorporating N would be economic for survey farmers, providing a marginal rate of return of 190%.[16] No relationship appears to exist between the two kinds of fertilizer application and the different groups of adopters. In any event, the number of days needed to apply fertilizer is high, mainly because it is difficult to access steeply sloping fields.

A local alternative to chemical fertilizers is the use of organic fertilizers, which are basically composts of animal dung (particularly sheep dung) and vegetative waste (such as stover and dead leaves). About one-third of farmers (28%) have prepared such fertilizers in the past, although their use is not very common at present. Farmers maintain that the principal advantages of organic fertilizers are the savings on chemical fertilizers (64%) and higher yields (34%). Nevertheless, these advantages do not seem to compensate for the main disadvantages of organic fertilizers, which include the considerable amount of labor needed to prepare them (58%) and the limited availability of compost in relation to cropped area (40%).

Weed Control

Most survey farmers (96%) weed twice (either chemically or manually) after the maize crop emerges, and the remainder weed once. Only one farmer applied a herbicide before emergence. Most farmers (67%) relied on herbicides alone, applied with a pump sprayer, to control weeds; one-fourth (24%) of survey farmers used both chemical and manual weed control; and 9% weeded their maize only by hand, using a hoe.

In general, the use of herbicide was limited to paraquat (Gramoxone), which is one of the most toxic herbicides but is popular because of its cost (it is cheaper than other herbicides) as well as its apparent efficiency (effects are visible after application). The high use of paraquat is a cause for concern when one

Table 6. Labor for fertilizer application, maize-bean intercropping system (days/ha), Motozintla, Chiapas

	First application			Second application			Both		
	Avg.	sd	n	Avg.	sd	n	Avg.	sd	n
Fertilizer incorporated	11.2	±4.8	30	12.1	±4.7	18	24.2	±9.7	18
Fertilizer at base of plant	7.7	±5.0	51	7.9	±4.6	32	15.8	±9.3	32
Probability			.00			.00			.00

Note: Avg. = average; sd = standard deviation; n = number of cases.

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[16] Based on a yield adjustment of 20% (CIMMYT 1988) and field prices (Appendix B).

considers the costs of health risks for the farmer.[17] Farmers generally took no additional precautions when they applied herbicide, and this can be quite problematic because it is difficult to apply herbicide safely on steeply sloping fields. On average, farmers applied 2.9 l/ha (±1.14; n = 73) of commercial product in each application, and there was no significant difference between the two applications.

Chemical weed control provides a significant labor savings, amounting to a 43% reduction over the 22-23.5 days required to weed by hand (Table 7). Just as with fertilizer application, the time needed for weeding is high, primarily owing to the steeply inclined fields. The need to transport water for herbicide applications to relatively inaccessible fields further complicates chemical weed control.

Controlling weeds manually with a hoe is the main factor that distinguishes adopters from nonadopters of the no-tillage component. For this reason, it is not surprising that the groups of adopters differ significantly in the number of days needed to perform the first weeding (see Table 12). Nevertheless, this difference is not important for the second weeding, given that the use of herbicides for the second weeding is common in all groups of adopters. Ten years ago, all farmers controlled weeds manually using a hoe, whereas 20% used a machete as well as a hoe.

Harvest

Harvesting usually takes place in January or February and the maize is not doubled over beforehand. Farmers harvest by hand, taking an average of 21 days/ha, which generally includes transporting the harvest to the house. There are no significant differences in harvest practices among the groups of adopters. Most farmers (63%) used animals to transport the harvest, mostly their own animals (90%). One-third of the survey farmers (34%) used a local form of manual transport known as a "*mecapal*."[18] Only 2% of farmers transported the harvest in a pickup truck.

Yields

Average yields[19] in the 1993 summer season were 2.67 t/ha for maize and 270 kg/ha for beans. There is a nonsignificant tendency for maize yields to be higher among adopters of conservation tillage than for other groups of

Table 7. Labor for weeding, maize-bean intercropping system (days/ha), Motozintla, Chiapas

	First weeding			Second weeding			Both		
	Avg.	sd	n	Avg.	sd	n	Avg.	sd	n
Hoe only	23.5	±4.9	27	22.0	±6.8	6	44.2 a	±11.2	5
Hoe and herbicide application							33.0 b	±5.1	21
Herbicide only	10.0	±4.1	55	9.4	±3.5	73	19.6 c	±7.9	53
Probability			.00			.00		.00	

Note: Avg. = average; sd = standard deviation; n = number of cases. Note: Figures followed by different letters are significantly different (Duncan 0.1, column comparison).

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[17] Paraquat is immediately immobilized in the soil upon being absorbed by inert colloids (Tasistro 1989).

[18] A *mecapal* is a band of cloth or tanned leather, which enables a person to carry a 75 kg bag of maize cobs on his or her back. The band is used to support the bag of maize and passed around the wearer's forehead to counterbalance the weight of the maize on the back.

[19] From farmers' estimates of yield per field.

farmers (Table 8). To facilitate comparisons, we obtained estimates of maize yields in "good," "normal," and "poor" years (respectively, 3.2, 2.3, and 1.5 t/ha on average). Significant differences were found among groups of adopters. Adopters of both components of the conservation tillage technology obtained higher yields than nonadopters of the mulch component, regardless of whether the year was a good, normal, or poor one for the maize crop. Conservation tillage appears to offer a yield advantage of 25% over the yields of nonadopters, regardless of the type of crop year. Farmers who adopt only the mulch component obtain yields that are intermediate between those of full adopters and nonadopters, suggesting that it is the mulch component that has the greatest influence on maize yield levels.

Yields for good and poor years can also be expressed in relation to yields in a normal year. On average, the maize yield in a good year is 140% of the yield in a normal year, and only 66% in a poor year. The 1993 summer cycle was thus a good year, with a relative yield of 120%. According to the literature, farmers who adopt conservation tillage practices can expect a reduction in risk as well as a reduction in yield variability. However, this potential reduction in risk has primarily been found to be related to the effect of moisture conservation, and moisture is not much of a problem in the study area. In the study area, risk seems to be mostly related to the incidence of wind (see below). Nevertheless, the relative yields obtained in the 1993 summer cycle by adopters of the mulch component versus other groups of adopters suggest that there has been a reduction in risk for mulch adopters. In relative terms, the maize yield in the 1993 summer cycle was 11-15% better than the yield in a normal year for adopters of the mulch component (alone or with the no-tillage component), but 25-26% higher relative to yields obtained by nonadopters in a normal year. In absolute terms, however, the yields obtained by adopters of the mulch component were slightly higher than yields obtained by nonadopters, suggesting a reduction in risk that could be an additional advantage for mulch adopters.

With regard to bean yields in the 1993 summer cycle, groups of adopters differ significantly. Adopters of both components obtained higher bean yields than farmers who did not adopt the

Table 8. Yields, maize-bean intercropping system, Motozintla, Chiapas

	Total sample		Type of adopter				
	Average	Standard deviation	Non-adopter	Mulch only	No-tillage only	Both components	Probability
Maize yield (t/ha)							
1993 summer cycle	2.67	± 0.61	2.61	2.66	2.55	2.87	ns
Good year	3.17	± 0.80	2.91 a	3.2 ab	2.95 a	3.66 b	.00
Normal year	2.26	± 0.52	2.12 a	2.37 ab	2.06 a	2.61 b	.00
Poor year	1.49	± 0.46	1.40 a	1.54 ab	1.38 a	1.71 b	.04
Bean yield (kg/ha)							
1993 summer cycle	267	± 88	239 a	213 a	272 ab	301 b	.04
Good year	318	±107					ns
Normal year	212	± 90	208 ab	152 a	201 a	248 b	.05
Poor year	115	± 70	104 ab	50 a	113 b	148 c	.01

Note: Figures followed by different letters are significantly different (Duncan 0.1, row comparison); ns = not significant.

no-tillage component. Average yields in good, normal, and poor years were 320, 210, and 120 kg/ha, respectively, and differences in yields obtained by groups of adopters were found only for normal and poor years. In these sorts of years, adopters of both components generally obtained higher yields, whereas those who adopted only the mulch component obtained lower yields. In relative terms, the bean yields in the 1993 summer cycle were 129% (±33) of bean yields in a normal year. In good and poor years, bean yields were on average 151% and 51%, respectively, of yields in a normal year. Bean yields were more variable than maize yields.[20]

Of all the factors that negatively affect yields in poor years, wind seems to be the most important, as much for maize (88% of farmers) as for beans (85% of farmers) (Table 9). Given the height of the maize plants and the characteristics of the study zone, it is not surprising that maize is vulnerable to damage from strong winds. Maize fields are generally found on the higher parts of the hillsides in the study area, where they are exposed to the elements. The vulnerability of beans to wind damage can be deduced from the fact that beans are not solecropped but instead intercropped with maize. Wind seems to be a fairly frequent problem: in most cases (77% of farmers affected by the problem), it seems to occur each year. Compared to farmers who did not adopt the no-tillage component, adopters of that component (alone or in conjunction with mulch) reported more frequent wind damage to their crops. This finding is in agreement with the assumption that maize grown under reduced or no tillage is more susceptible to lodging because it has more shallow roots.

Another factor that depresses yields in poor years is diseases and pests, as much in maize (26% of cases) as in beans (15%). The chief maize pest was white grub (*gallina ciega*) (*Phyllophaga* spp.), cited by 79% of the farmers who reported disease and pest problems. Farmers rarely apply any kind of control measures for these problems, which are more common among nonadopters than among adopters of both components of the technology. This finding contradicts the assumption that under conservation tillage there is greater potential for soil pests such as *gallina ciega*, because farmers work the soil less and birds have fewer opportunities to control pests

Table 9. Factors affecting yields in poor years, maize-bean intercropping system, Motozintla, Chiapas

		Type of adopter				
	Total sample (average)	Non-adopter	Mulch only	No-tillage only	Both components	Probability
Maize[a]						
Wind (% cases)	87.8	76.2	71.4	90.0	100	na
Pests (% cases)	25.6	42.9	28.6	26.7	8.3	na
Beans						
Wind (% cases)	85.4	85.7	57.1	86.7	91.7	na
Pests (% cases)	14.6	14.3	42.9	13.3	8.3	na

Note: na = not applicable.

[a] Figures do not sum to 100 because in some instances both factors affected yield.

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[20] Coefficient of variation for bean yields was 33-61%; for maize, 23-31%.

naturally (Bolaños, pers. comm.). Nevertheless, this finding is consistent with information reported by Ortega (1989) in reviewing other studies. Bean pests are mostly foliar pests (mentioned by 83% of farmers affected by disease problems), especially *D. balteata*

The yield-mulch relationship — The findings described in the previous section seem to indicate that the mulch component of the conservation tillage technology has a greater effect on yield than the no-tillage component. This section describes the effects of mulch on yield in more detail. Although farmers were considered to have adopted the mulch component only if they had at least 2 t/ha of residues on their fields, the survey gathered data for four levels of crop residues (Appendix A): two below the threshold and two above it. Figure 3 shows the positive relation between maize yield and amount of mulch. This relationship is very significant and presents significant correlation coefficients of 0.3 for the 1993 summer season and up to 0.4-0.5 for the different kinds of years. Although there are not great differences in average yields for the first two levels of mulch applications (level 1 is <1 t/ha and level 2 is 1-2 t/ha of mulch), the average yield for level 3 (2-4 t/ha) does differ significantly from the first two and, in turn, differs from level 4 (>4t/ha). This seems to indicate that below the threshold level of 2 t/ha it is difficult to discern any effect of mulch on yield. Over the threshold level there is a positive response to incremental increases in the amount of mulch applied. This response may have something to do with the steep slopes in the study area, and shows that for areas with similar slopes it may be useful to raise the threshold level of mulch to 4 t/ha of crop residues. Nevertheless, the viability of such a high threshold level depends greatly on the availability of crop residues for mulch and the opportunity cost.

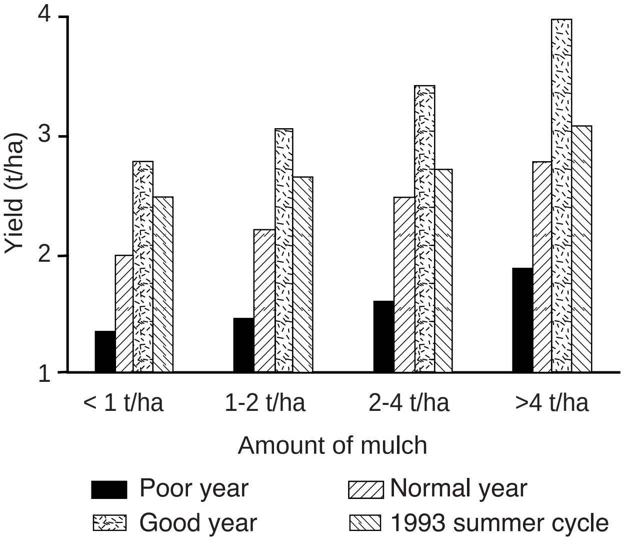

Figure 3. Relationship between maize yield and amount of mulch.

It is worth noting a few points about the positive interaction between mulch and maize yields. In the first place, the interaction can be mutual: a greater amount of mulch not only raises yields (through improving the soil), but higher yields can also increase the availability of residues to be used as mulch, all things being equal. However, the condition of "all things being equal" implies a similar management of residues, and, as we will see later in this paper, this is not the case in the study zone. Earlier we described the positive correlation (c.c.: 42; prob.: .00) between the degree of slope and the conservation of residues (for example, steeply sloping fields are grazed less), whereas there is no interaction between slope and yield (although one would expect a negative relationship). However, the interaction between bean yield and mulch is difficult to disentangle from the available data.

For beans there is also a positive interaction between yield and mulching, although generally less significant and of lesser magnitude. For example, for the 1993 summer cycle, the correlation coefficient reaches 0.2 (prob. = .10).

Multiple regression analysis — A linear regression was done to analyze the factors influencing maize and bean yields in the 1993 summer cycle. The equations with the best fit explain approximately one-third of the variation (see Table 10 for results for maize and Table 11 for beans). Most of the variables in both equations are related to the current management of the field.

In the case of maize, several variables related to current management practices are significant in explaining observed variability in maize yields. The application of N seems to increase yield by nearly 12 kg for each kilogram of N applied. Even so, because N application interacts strongly with the incidence of lodging, the use of N is subject to an interaction with wind. When there are strong winds, the interaction with N becomes negative. It is also important to note that conservation tillage practices increased yields in the 1993 summer cycle by about 350 kg/ha on average. This effect seems to be related primarily to the mulch component of the technology, since an adequate mulch (>2 t/ha of residues at sowing) produces a similar yield effect.[21] Fallowing also has beneficial effects on production: producers who fallow

Table 10. Factors affecting maize yields in the maize-bean intercropping system, 1993 summer cycle, Motozintla, Chiapas

Variable	Description	Coefficient	t-value	Probability
Dependent				
MZYIELD93	Maize yield (kg/ha), 1993 summer cycle			
Independent				
NITROGEN	Amount of nitrogen (kg/ha)	12.0	2.2	.029
N*WIND	Nitrogen-wind interaction	-14.6	-2.9	.006
ADOPCT	Dummy for adoption of conservation tillage	347	2.6	.013
EARLYWEED	Dummy for early weeding	121	0.9	ns
FERTINCORP	Dummy for incorporating fertilizer	-192	-1.5	ns
FALLOW	Dummy for fallow	248	2.0	.051
Constant		2,580	15.1	.000

Note: R multiple = 0.50; R^2 = 0.25; adjusted R^2 = 0.19; degrees of freedom, 73; "enter" method; ns = not significant.

Table 11. Factors affecting bean yields in the maize-bean intercropping system, 1993 summer cycle, Motozintla, Chiapas

Variable	Description	Coefficient	t-value	Probability
Dependent				
BNYIELD93	Bean yield (kg/ha), 1993 summer cycle			
Independent				
BNSEED	Quantity of bean seed (kg/ha)	9.2	5.4	.000
ADOPCT	Adoption of conservation tillage	29.7	1.9	.07
EARLYWEED	Dummy for early weeding	24.8	1.5	ns
EARLYFERT	Dummy for early fertilizer application	56.7	3.9	.000
NITROGEN	Amount of nitrogen (kg/ha)	0.24	1.6	ns
WINDPROB	Dummy for wind problem	-4.2	-0.2	ns
Constant		103.2	3.4	.001

R multiple = 0.67; R^2 = 0.46; adjusted R^2 = 0.41; degrees of freedom, 69; "enter" method; ns = not significant.

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[21] The two components of conservation tillage were not considered separately because there is an interaction between them, such as the interaction between the no-tillage component and some other variables, which makes it difficult to consider them simultaneously in the equation.

obtain an average of 250 kg/ha more yield than those who do not.

The other two variables (early weeding and the practice of incorporating fertilizer) were not significant. Other variables of interest were not very discriminatory (for example, the use of improved versus local varieties) or were closely interrelated. The interaction among some variables made it difficult to interpret results of the equation, so they were left out of the equation. For example, the variables related to fertilizer use (quantity, elements applied, and number of applications) were closely interrelated and were also related to herbicide use (and thus to adoption of the no-tillage component). On the other hand, some characteristics of the field (such as slope) were closely related to the management of the crop.

For beans, three variables related to current management practices help explain the variation observed in yields. The first is related to the amount of bean seed used; the others are related to fertilizer use and conservation tillage. The equation demonstrates that there is a strong correlation between seed rate and bean yield. For the 1993 summer cycle, each additional kilogram of bean seed raised average yield by about 9 kg/ha. Planting density therefore seems to be a limitation on the production of the intercrop. The early application of fertilizer to maize (at the three-leaf stage at the latest) raised average bean yields in the 1993 summer cycle by almost 60 kg/ha. This increase may be related to good establishment of the intercrop. It is interesting to note that in the 1993 summer cycle the use of conservation tillage raised bean yields 30 kg/ha on average. This effect could be related to the no-tillage component, as it produces a similar effect. Apparently the beneficial effects of the technology on the intercrop (soil and water conservation, for example) compensate for many of the deleterious effects (such as the "burning" caused by herbicides).

The three other variables in the equation — early weeding, the amount of N applied to maize, and wind damage — were not significant. Even so, it is important once again to emphasize that other variables of interest interact strongly among themselves or with other variables in the equation, and so were excluded from consideration.

Residue Management

All farmers left crop residues in the field after harvest. Almost half of the farmers (49%) mentioned that the residues prevented the soil from eroding, and most reported that the residues served as an organic fertilizer (84%).[22] However, maize residues generally have a high ratio of carbon to nitrogen (C:N), so the effect of maize residues as an organic fertilizer is rather limited in terms of a greater availability of nutrients in the short run (in fact, it is more likely that N will be immobilized). On the other hand, the bean and weed residues (especially if they are still green) have higher C:N ratios and thus act as more of an organic fertilizer.

Although all producers leave residues on the field, the amount that remains by planting time varies considerably. The varying quantity of mulch is reflected in the groups of adopters, given that adopters of the mulch component (alone or with the no-tillage component) by definition have more than 2 t/ha of residue in the field at sowing. Two factors that influence

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[22] The number does not add to 100% because 43% of farmers mentioned the organic fertilizer as well as prevention of erosion, and 8% mentioned other reasons for leaving residues on the field.

this quantity of residue are the "treatment" of residues[23] and grazing by livestock.

Treatment of residues — Farmers leave residues on the field in different ways. The most common practice (60% of farmers) is to leave the maize plant standing after the harvest without any special management. The rest of the farmers chop the residues with a machete and leave them on the field (21%) or double the maize stalks at a height of about 1 m (20%). There are advantages and disadvantages for each treatment, although most farmers who leave the residues standing in the field did not perceive any. One-third, however, commented that their animals consume less stover when it is left standing in the field. The principal advantage of not leaving the maize stalks standing appears to be that they decompose better and prevent soil erosion better. The main disadvantage of chopping the residues is that more labor is needed to do so.

The groups of adopters differ markedly in the frequency with which they leave the stover standing or chopped up. Most farmers (75%) who did not adopt the mulch component (alone or with the no-tillage component) left their stover standing, whereas fewer than 5% chopped it up (Figure 4). Most farmers (86%) who adopted only mulch chopped their residues, and no-one left it standing in the field. Among adopters of both components, 42% chopped residues and 38% left them standing. The frequency of the practice of doubling the maize stalks is similar among all groups of adopters.

Grazing by livestock — Most fields (60%) were grazed by livestock, either owned by the farmer or by others, during the cropping season. The fields of adopters of the mulch component (alone or with the no-tillage component) were relatively less exposed to grazing (<45% of farmers) than those of nonadopters of this component (>65%, prob. =.00). None of the adopters of the mulch component (alone or with the no-tillage component) considered crop residues to be an important source of forage for animals, whereas more than 40% of the nonadopters of this component thought they were.

The great majority (95%) of farmers dislike having their fields grazed, and the only advantage they saw in this practice was that it satisfied the demand for animal forage. The main disadvantages of grazing included the fact that the soil remains unprotected (45% of farmers) and that the soil becomes loose or falls apart (32%). Most farmers (63%) considered that fencing their fields was a good option for discouraging grazing. Twenty percent mentioned the possibility of creating local prohibitions to communal grazing (for example, a law within the *ejido* to prohibit free

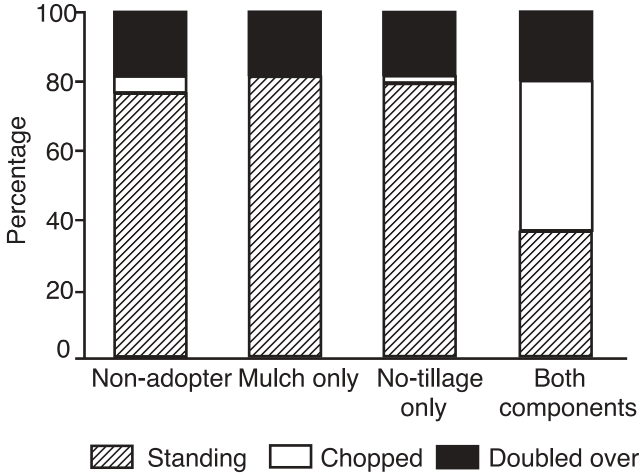

Figure 4. Treatment of residues by farmers in Motozintla, Chiapas.

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[23] The "management" of residues is the more common term. Nevertheless, management of residues generally includes grazing, and here we refer to management other than grazing.

grazing of livestock, or a rule that each person must care for his or her own animals). With regard to these options, there is not much difference among the different classes of adopters.

Nine percent of farmers had fenced their fields before the 1993 summer cycle harvest, whereas 12% of farmers were thinking about doing so.[24] Most farmers who had already enclosed their fields were adopters of both components of the technology. Only one farmer among those who had fenced their land had adopted only the no-tillage component — and in fact he had not enclosed his field sufficiently.[25] Of the farmers who had enclosed their fields adequately, 83% had more than 4 t/ha of mulch. This indicates once again that livestock belonging to others, and not so much the farmer's own stock, limit the availability of mulch. It is also useful to recall that the slope of the field is another factor that restricts the access of livestock to the field.

Most of the farmers who are considering fencing their fields have adopted only the no-tillage component of the technology. Nevertheless, the fact that they are contemplating fencing their fields does not mean that they will actually do so in the short or medium term. Various factors make it difficult for farmers to enclose their fields, including the limited availability of fence posts (owing to the state law that prohibits the cutting of trees) and of financial resources (to purchase wire). In relation to this last factor, 44% of the farmers who considered fencing their land mentioned that they needed credit to do so.

Figure 5 summarizes some of the factors that influence whether farmers can conserve sufficient residues in fields accessible to livestock.

Economics of the Maize-Bean Intercropping System

Resources Dedicated to the Cropping System

Table 12 summarizes crop operations for the entire sample and for the different types of adopters. On average, farmers spend 84 days/ha on the maize-bean intercropping system, although there are significant differences among the groups of adopters. Adopters of the no-tillage component (alone or with mulch) use less labor than nonadopters. The difference can be as much as 11-16 days/ha, and it is significant in comparison with nonadopters (of any component). This difference is related primarily to weed control practices, because for the other crop operations there is no significant difference among groups of adopters. The difference is even more pronounced (14-16 days) and significant if we compare weed control among groups of adopters. The only significant difference in input use among the different groups of adopters is also related to weed control.

Valuation of Production Factors

In the sections that follow we present some of the issues related to valuing factors of production.[26] Because the valuing of residues is more problematic, this issue will be discussed separately.

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[24] This includes one farmer (an adopter of the no-tillage component alone) who had just finished fencing his field at the start of the 1994 summer cycle.

[25] The farmer had only fenced the field using two rows of barbed wire. Although the field was less accessible, sheep could still enter to graze.

[26] In 1993 Mexican pesos (Mx$). The average exchange rate for 1993 was Mx$ 3.1 = US$ 1 (source: International Monetary Fund).

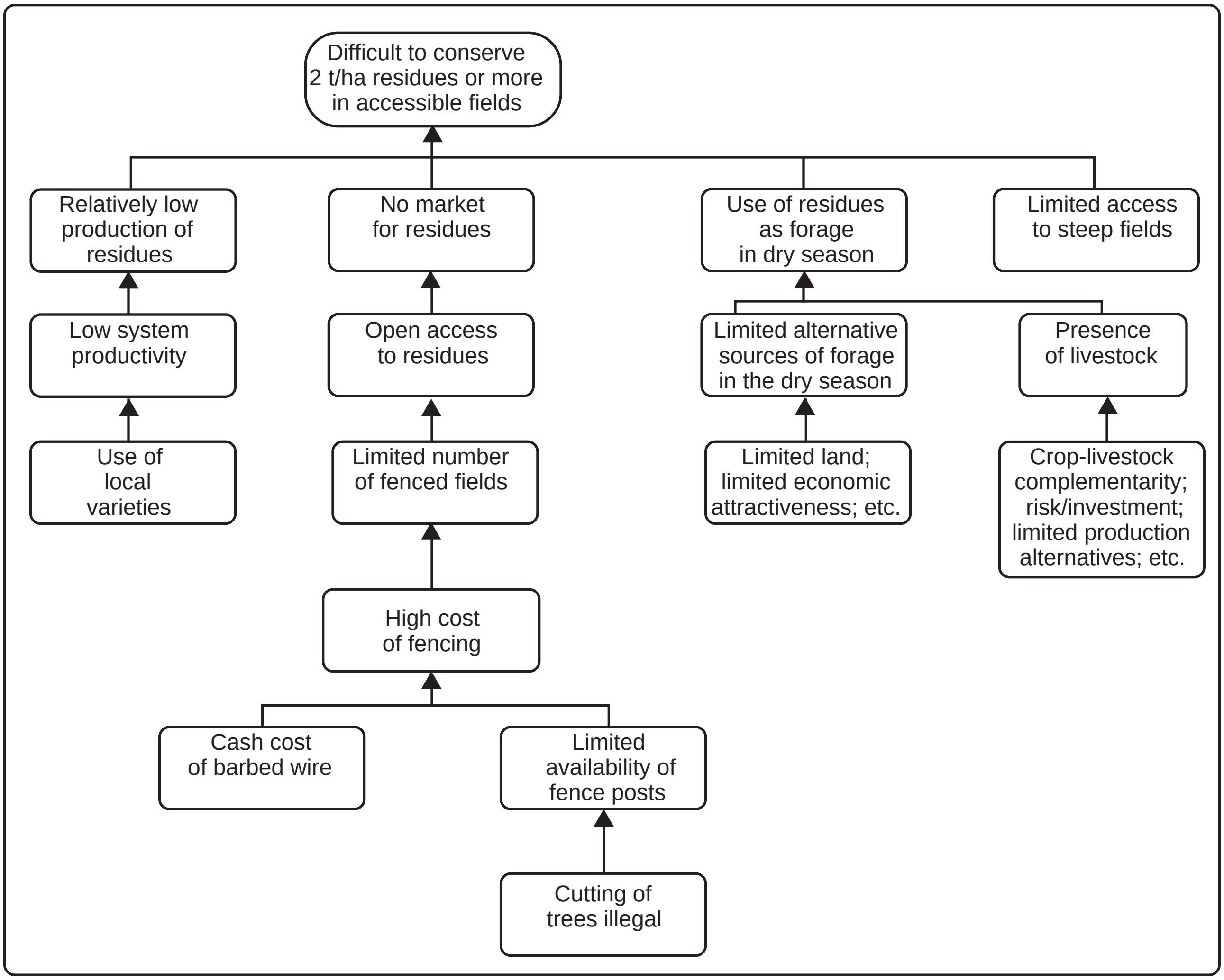

Figure 5. Factors and interactions affecting the likelihood that sufficient crop residues will be conserved in accessible fields, Motozintla, Chiapas.

Table 12. Labor use (days/ha) by operation and type of adopter, maize-bean intercropping system , Motozintla, Chiapas

	Total sample		**Type of adopter**				
	Average	**Standard deviation**	**Non-adopter**	**Mulch only**	**No-tillage only**	**Both components**	**Probability**
Land preparation and sowing	23.7	± 6.5					ns
Fertilizer application (total)	14.7	±10.0					ns
First	8.9	± 5.3					
Second	5.9	± 6.0					
Weeding	24.4	± 10.7	34.1 a	34.2 a	18.5 b	20.4 b	.00
First	14.4	± 7.7	22.3 a	24.5 a	9.8 b	10.5 b	.00
Second	10.0	± 5.4					ns
Total pre-harvest labor	62.8	±16.5	73.9 a	66.9 ab	58.5 b	57.3 b	.00
Harvest	20.8	± 7.3			*ns*		
Total post-harvest labor	83.6	± 20.2	94.6 a	89.5 ab	78.9 b	78.2 b	.02

Note: Figures followed by different letters are significantly different (Duncan 0.1, row comparison); ns = not significant.

Inputs and outputs — Purchased inputs have a relatively visible cost, although there are slight differences depending on the point of sale (for example, depending on whether the input was purchased at the *Unión de Ejidos*, in the market, and so on). It is important to take transport costs into account when calculating the farm price of an input, given that the study area is relatively distant from the market and that transport costs are considerable (for example, they add about 12% to the cost of ammonium sulfate). Appendix B presents farm-level prices of the most common purchased inputs. Maize and bean seed is usually seed of local varieties, retained from the previous harvest. The opportunity cost was calculated using the most common sale price for local seed within the *ejidos*.

Output prices are based on the sale price, adjusted for transport costs and the cost of shelling maize. It is important to recall that on average more than half of the production is destined for home consumption. For that reason, transport price has a net positive effect on the output price (in other words, owing to the relative importance of maize for home consumption, the value of the output is closer to the value of the purchase price than it is to the sale price).

Labor — It is relatively common for farmers to hire labor. Most hired laborers are paid Mx$ 8/day and provided with food (reported by 72% of farmers). If food is not provided, the daily rate for labor rises to Mx$ 10 (19%). There are other, less common, forms of payment, such as payment in kind. This includes arrangements whereby one farmer will work for another in exchange for similar assistance on another day (7%), or loans of land in exchange for labor (2%). In this study we value farm labor at Mx$ 10/day, for hired labor as well as family labor (opportunity cost).

Land — Arriving at an adequate valuation of land presents some difficulties in places where land markets are not very developed. In the study area, land rental is not a common practice; in only five instances (5%) did farmers rent part of their land. However, in each case the rent paid was similar, and Mx$ 250/ha/cycle was chosen as a reasonable approximation of the opportunity cost of land. This rent represents 12% of the average gross benefit.

Capital — The cost of capital is reflected in the interest rates charged for loans. However, these rates vary considerably and depend greatly on the source of the loan.[27]

We did not obtain reliable data on the cost of capital, but we estimate that a 2.5% monthly rate is an adequate approximation of the average cost of capital. The real cost for the farmer depends on many factors, and for this reason we included a sensibility analysis on the farm budgets for different interest rates.

Residues — An adequate valuation of residues is difficult in areas where there is hardly any market for crop byproducts. Residues are a secondary product of maize production, and during the study we did not encounter any farmer who had marketed residues — either selling the harvested residues or selling the residues that were still standing in the field.

To solve the problem of valuing crop residues in the study area, it is important to consider the nature of the product. Residues in a field can be

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[27] For example, bank loans at commercial interest rates; state credit provided without interest; and loans from other family members or from middlemen.

an exclusive or nonexclusive product. In an enclosed field, crop residues are an exclusive product: the person who is not prepared to pay for their use is easily excluded from using them.[28] In an unfenced field, residues are not an exclusive product. It is difficult to exclude users who do not want to pay, especially when the practice of free grazing is common, as in the study area. In the study area, residues can be considered a quasi-private product (a nonexclusive and divisible product — see Turner et al. 1993:77), for which valuations based on the market price do not work well. The next sections of this paper will explore in greater detail how exclusivity or nonexclusivity influences the valuation of residues.

Residues as an exclusive product — There is no market for crop residues in the study zone, which means that no-one is prepared to pay for residues in present circumstances. Therefore, if we consider residues to be an exclusive product, we would only need to consider supply and demand for residues within the farm itself. Although residue yields were not estimated during the survey, they can be estimated from harvest index (estimated at 35%) and grain yield (Erenstein 1996). Residue yields were estimated at 5 t/ha on average. We estimate that demand for residues as forage to feed the farmer's own livestock is 1.5 t of residues per hectare per year.[29] If weathering of residues during the dry season does not surpass 10%,[30] 3 t/ha of residues will be available for other uses on the farm. Presently the only additional use of residues is as mulch, so 3 t/ha of residues are available for mulch, amply exceeding the 2 t/ha required for an effective mulch. If residues are an exclusive product, there is no conflict in demand for their use as forage and as mulch. In addition, given that residues used to form an effective mulch have no alternative use, the opportunity cost is practically zero.[31]

Residues as a nonexclusive product — When residues are a nonexclusive product, it does not matter that there is no market for residues — in fact, the nonexclusivity of the product partly explains why there is no market. However, there are many users of the product, although under present circumstances they are not inclined to pay (why pay for something that you can get for free?). For the nonadopters of the mulch component, this does not have great consequences. The pressure of livestock owned by others is still limited, so there are still sufficient resources for the farmer's own livestock. And even if the residues on the farmer's field run out, there will be enough in

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[28] At least where it is socially acceptable for fields to be enclosed and where the enclosure is respected. This seems to be the case in the study area.

[29] Based on the following assumptions: energy requirements of 45 MJ/day/AU; an energy value of 8 MJ/kg dry matter of residues (Euroconsult 1989: 603-607); a 13% moisture content in the residues; residues as the only source of energy during the dry season; consumption of residues limited to the dry season (six months); and an average livestock density of 1.3 AU per hectare of maize.

[30] Estimate based on the following assumptions: the average yield for producers in level 4 for mulch for the 1993 summer cycle was 3.07 t/ha of grain, which is equivalent to an estimated yield of 5.7 t/ha of residues at harvest time. The great majority (89%) of these farmers do not graze livestock on their fields and had an estimated average 5 t/ha of residues at sowing in the 1994 summer cycle. This implies a weathering of 0.7 t of residues (12%).

[31] Recall that beyond threshold level for mulch of 2 t/ha there is still a favorable yield response as the amount of mulch increases (Figure 3). However, to obtain more than 3 t/ha of residues it is necessary to reduce the use of residues for forage. In this case there is obviously a conflict between the use of residues as mulch and as animal forage, which substantially raises the opportunity cost of the residues. At the same time, the use of residues as forage also has an opportunity cost: by using residues for forage, the farmer cannot obtain the benefits of applying more than 4 t/ha of mulch.

neighboring fields, since under present circumstances the supply of residues still exceeds demand for forage.

However, for farmers who have adopted the mulch component, there is a problem. How can a farmer ensure that enough residues remain in a field to meet the threshold level needed for a good mulch? There are several options, each with its own cost and implications.

- **Each farmer cares for his own animals.** All responsibility for conserving residues lies with the livestock owners. For this reason, this option does not appear very viable unless there is some kind of positive or negative inducement, such as severe consequences for those who disobey this option; a limited number of politically weak livestock owners; or a strong social organization in which people are motivated to follow the rules for the good of the community. In the Tuixcum *ejido*, the *ejido* committee tried to impose a local law in 1993 that required everyone to care for his or her own animals. However, the law was not enforced. Several *ejido* members who owned livestock violated the law. At present this option does not seem to be a good means of controlling the use of crop residues.

- **Each producer takes care of his/her crop residues.** All responsibility for conserving crop residues lies with the owner of the residues. If the cost is not too high, the user may even be willing to pay to conserve his own crop residues. There are several alternatives here:
    1. *Personally ensure that livestock belonging to others do not graze the field.* This method could be effective for fields that are close to farmers' homes, but it is not a very reliable or cheap option, especially for distant fields. A daily visit to the field can take an hour. Over six months, at an opportunity cost of labor of Mx$ 10/day and a field of one hectare, this would come to Mx$ 228/ha. The need to visit the field daily also limits the farmer's options for working outside the farm, which further raises the opportunity cost of labor for checking fields. Even a daily visit will not necessarily ensure that enough residue remains ungrazed in the field. The option of permanently watching the field would be safer but even more expensive.
    2. *Store the residues.* This option does not appear very feasible given the amount of work required (collecting, transporting, storing, and then returning considerable quantities of residues to the field).
    3. *Enclose the field.* This method is quite effective but, as observed earlier, requires a considerable investment, driven up further by the law prohibiting people from cutting trees. The cost of fencing a field is estimated at about Mx$ 850/ha.[32] A useful life of ten years and an opportunity cost of capital of 30% implies fixed costs of depreciation at Mx$ 213/ha/yr. The real cost per hectare, of course, depends on the characteristics of the field. It is relatively cheaper to fence large fields or fields that border on fields that have already been fenced.

A final option would be to purchase residues to meet the threshold needed for mulch, but it generally is not cost effective to do so (Lal 1989:94). Such a cost could be prohibitive in the study zone: approximately Mx$ 450 would be

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[32] Using a price of barbed wire of Mx$ 0.4/m, three rows of wire for the enclosure, Mx$ 2/post/2.5 m, and 5 days to install the fence.

needed to cover one hectare with 2 t of residues.[33] Even if 1 t/ha of residues remains from the previous harvest, the cost of conserving enough residues is lower than the cost of buying them.

The opportunity cost of the residues needed to satisfy the threshold of 2 t is assumed to be reflected in the annual cost of fencing the field. Once the field is enclosed, the residues can be considered an exclusive product and their availability for forming an effective mulch will be assured, at virtually no opportunity cost. However, the opportunity cost could increase in the future if the number of enclosed fields grows considerably. This would limit the availability of residues for community grazing and would facilitate the creation of a market for residues.

Budgets

Table 13 presents budgets for different groups of adopters. To facilitate interpretation and comparisons, the inputs that did not differ significantly among adopters were kept constant. Components of the budgets are discussed in the following sections.

Income — Income (gross benefits) is similar for nonadopters and adopters of only one component of the technology, reaching nearly Mx$ 2,000/ha. However, income is considerably higher (12-14%) for adopters of both components. The budgets reveal the economic importance of the bean crop, which provides about 20% of the gross benefit.

Variable costs — For variable costs, we distinguish between costs of inputs and labor. Input costs are much higher for adopters of the no-tillage component (alone or with the mulch component) owing to the higher cost of the herbicides (Mx$ 70-80/ha plus Mx$ 10-12 in interest per cycle). Labor costs are substantially higher for those who did not adopt the no-tillage component, owing to the greater labor requirement for controlling weeds (almost Mx$ 150/ha). As a result, total variable costs are slightly lower for adopters of the no-tillage component. It is important to recall that the cost of residues used for mulch (in fact a variable cost) was calculated as part of the cost of fencing (a fixed cost), so that residues could be considered an exclusive product with a minimal opportunity cost.

Fixed costs — Fixed costs comprise the opportunity cost of land and the fixed cost of capital. The opportunity cost of land is assumed to be equal for all groups of adopters, whereas the fixed cost of capital varies for the different groups. The cost of capital for nonadopters of the mulch component (alone or with the no-tillage component) includes the costs of depreciation and interest on the equipment used (sprayer, hoe, machete, and file). The cost of capital for adopters of the mulch component is substantially higher and includes the cost of depreciation and interest on the enclosure as well as the equipment used.

Returns — The budgets present indicators of the returns received by different groups of farmers. The *value added* is the gross benefit minus the expenses for inputs (that is, the return to cover the investment in land, labor, and capital resources). Value added is relatively similar for nonadopters and adopters of only one component of the technology but is considerably higher for adopters of both components (11-16%), reaching Mx$ 1,760/ha for the latter group.

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[33] Assuming Mx$ 5/bale (including the cost of transport) and 22 kg/bale.

The *net benefit* is the gross benefit minus the cost of all resources invested, that is, the profit for the farmer. On average, all farmers (regardless of their classification as adopters) obtained a small profit in the 1993 summer cycle, although this varied from a minimum of Mx$ 100/ha for adopters of mulch only to a maximum of Mx$ 430/ha for adopters of both components. However, it is important to point out that the bean crop makes an important contribution to this profit. In all cases, the gross benefit of the bean crop exceeds the net benefits from the maize-bean intercropping system. For this reason, assuming that there is no interaction between the maize and bean crops, the cultivation of maize alone would give an approximate net benefit of zero (from negative to slightly positive). The low profitability of the maize crop can be related to the production of maize for home consumption and the sale of any surplus. It could be that farmers give a higher value to maize for home consumption than its estimated opportunity cost.

Table 13. Budgets for the maize-bean intercropping system, 1993 summer cycle, Motozintla, Chiapas

					Type of adopter							
					Nonadopters		Mulch only		No-tillage only		Both components	
		Unit	Unit price (MX$)	Units/ ha	Units/ ha	Mx$/ha	Units/ ha	Mx$/ha	Units/ ha	Mx$/ha	Units/ ha	Mx$/ha
A. Benefits												
	Maize	kg	0.60		2,610	1,566	2,660	1,596	2,550	1,530	2,870	1,722
	Beans	kg	1.62		239	387	213	345	272	441	301	488
Total gross benefit						***1,953***		***1,941***		***1,971***		***2,210***
B1. Inputs												
Seed	Maize	kg	1	15.6		16		16		16		16
	Beans	kg	3	9		27		27		27		27
Fertilizer	Sulfate	50 kg	28	7.39		207		207		207		207
	Triple 17	50 kg	48	0.42		20		20		20		20
Herbicide	Gramoxone	lit	21		1.97	41	2.46	52	5.78	121	5.64	118
Credit (6 mo.)		%/mo.	2.5%		311	47	321	48	391	59	388	58
Total inputs						*358*		*370*		*450*		*446*
B2. Labor												
Land preparation/sowing		day	10	23.7		237		237		237		237
Fertilizer application		day	10	14.7		147		147		147		147
Weeding		day	10		34.1	341	34.2	342	18.5	185	20.4	204
Harvest		day	10	20.8		208		208		208		208
Total labor		day			*93.3*	*933*	*93.4*	*934*	*77.7*	*777*	*79.6*	*796*
Total variable costs						***1,291***		***1,304***		***1,227***		***1,242***
C. Fixed costs												
Land		ha	250	1		250		250		250		250
Capital (depreciation, interest)			30%			76		289		76		289
Total fixed costs						***326***		***539***		***326***		***539***
D. Returns												
Value added [A-B1]		Mx$/ha				1,595		1,571		1,521		1,763
Net benefit [A-B-C]		Mx$/ha				336		99		418		428
Costs per kg maize		Mx$/kg				0.609		0.682		0.598		0.611
Labor productivity		kg maize/day				28.0		28.5		32.8		36.1
Return per day		Mx$/day				13.6		11.1		15.4		15.4

The low profitability of the maize crop can also be seen by calculating the *costs per kilogram of maize*, excluding costs and benefits of the bean intercrop.[34] With the exception of farmers who adopted only the mulch component, the costs per kilogram of maize are similar, quite close to the field price of maize, indicating that the profit for the farmer is practically zero. Those who adopted only the mulch component actually incurred losses — their costs were greater than the price of the output.[35] For adopters of the no-tillage component alone, costs were slightly lower and yields similar to those obtained by nonadopters. Adoption of the mulch component substantially raised costs, which were only recovered if the farmer also adopted the no-tillage component and benefited from the increased maize yields. However, it is important to note the low international competitiveness of maize production in the study area: for all farmers, the costs of producing a kilogram of maize are substantially higher than the international maize price.

The budgets also include *labor productivity* in physical and monetary terms. In physical terms, the productivity of labor, expressed as kilograms of maize per day of labor, is similar for farmers who did not adopt the mulch component and considerably higher for those who adopted both components. Labor productivity for farmers who adopted only the no-tillage component is between the two other groups.

These relationships change slightly when labor productivity is expressed in monetary terms (Mx$/day). Labor productivity is the lowest (Mx$ 11/day) for those who only adopted the mulch component. Labor productivity for adopters of the no-tillage component, alone or with the mulch component, is the highest, about Mx$ 15/day. Nonadopters are in second place, at Mx$ 14/day. However, it is important to note that labor productivity is higher than the local wage for hired labor.

Sensitivity to cost of capital — The budgets assume an interest rate of 2.5% per month as the cost of capital. However, this is one of the most variable costs. In the following paragraphs we summarize results of the sensitivity analysis for different interest rates (see also Appendix C).

Interest rates influence the cost of working capital and fixed capital. A low interest rate would be advantageous for components of the conservation tillage technology that require more spending on inputs (as in the no-tillage component) and/or more investment in fixed capital (as in the mulch component). One can expect that budgets for adopters of both components of the conservation tillage technology would be most sensitive to changes in interest rates, followed by budgets for adopters of a single component, and that the budget for nonadopters would be least sensitive to such changes.

If we consider a cost of capital of only 1% per month, the budget for adopters of both components becomes even more attractive. The net benefit increases by more than Mx$ 100 to nearly Mx$ 580/ha; the cost of producing one kilogram of maize falls to less than Mx$ 0.56/kg and labor productivity rises to more than Mx$ 17/day. The situation also improves for adopters of the mulch component alone. Most of these improvements are related to the lower cost of the mulch component, given that the fixed cost of the

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[34] Assuming that there is no interaction between the two crops. This indicator sums all costs (minus the costs of bean seed) and divides them by maize yield.

[35] The loss implies that the return on the factors of production invested does not cover their opportunity cost.

enclosure now is Mx$ 136/ha. However, in relative terms the situation does not change much: indicators for those who adopted only the mulch component remain low, whereas nonadopters and adopters of only the no-tillage component occupy second place.

If one assumes an interest rate of 5% per month, the economic advantages for adopters of both components disappear. The net benefit for this group of farmers falls by Mx$ 150/ha to Mx$ 280/ha, the cost of producing one kilogram of maize rises to more than Mx$ 0.66/kg, and labor productivity falls to Mx$ 13.5/day. As a result, the budget for adopters of only the no-tillage component becomes relatively more attractive. The situation for adopters of mulch alone becomes worse: the net benefit becomes negative and labor productivity falls below the wage rate for hired labor.

As noted earlier, the interest rate of 2.5% is an approximation of the average rate. Various factors specific to the individual farmer can influence this rate. For example, access to state credit or some other kind of subsidized credit scheme can substantially reduce the interest rate for the farmer. In the same way, cash income (obtained through outmigration, for example) can reduce the cost of capital if the alternatives for investment are limited. On the other hand, falling behind on loan payments can raise the interest rate by limiting possible sources of credit and increasing the risk of providing credit.

Sensitivity to changes in yield — The budgets represent an approximation of costs and benefits in the 1993 summer cycle. However, this was a relatively good cropping season. What would the budgets look like at lower yield levels? Results of a sensitivity analysis done for yield levels reported for good, normal, and poor years are described briefly here (see also Appendix C). Note that all production costs remain constant (that is, independent of yield levels). The levels reported for the 1993 summer cycle are assumed to be representative for all years.

In all types of years, adopters of both components obtained the best economic results. The opposite occurred for farmers who adopted only mulch. Those who did not adopt the mulch component are in the middle of the range. Only adopters of the no-tillage component surpassed the nonadopters (of either component).

Compared with the budgets for the 1993 summer cycle, the budgets for a normal year are not very attractive for the different classes of adopters, with the exception of the adopters of both components. For nonadopters and adopters of no-tillage alone, the net benefits are approximately zero; the cost per kilogram surpasses Mx$ 0.7 and labor productivity comes close to the daily wage rate for hired labor. The situation is worse for adopters of mulch alone. However, for adopters of both components the situation is much more advantageous: a net benefit of approximately Mx$ 225/ha; a production cost of Mx$ 0.66/kg; and a return on labor of almost Mx$ 13/day.

In a bad year, the situation is difficult for all farmers, with losses of Mx$ 500-800/ha, production costs of Mx$ 1.00-1.16/kg, and labor productivity of only Mx$ 1.4-4.0/day. In such years it is very difficult for farmers to meet their financial obligations and avoid falling behind on their loan payments.

In a good year the situation is relatively good for all farmers, with a considerable advantage for adopters of both components.

The Adoption of Conservation Tillage

Adoption

Table 14 shows the distribution of the survey farmers by class of adopter. Of the 82 farmers surveyed, 29% had adopted both components of the technology (that is, they were full adopters of conservation tillage). Twenty-six percent of farmers had adopted neither component; 37% had adopted only the no-tillage component, and 9% had adopted the mulch component alone.

The distribution of cases in the adoption matrix also shows how relatively more farmers have adopted the no-tillage component (66%) than the mulch component (38%). This suggests that it is more easy or more attractive to adopt the no-tillage component. It is important to note that although 34% of the sample farmers had not adopted the no-tillage component, all farmers practiced some form of reduced tillage. In addition, the great majority of farmers used as least one application of herbicide to control weeds. For this reason, the difference between farmers who adopted the no-tillage component and those who did not is almost hypothetical, for the benefit of adopting this component is minimal.

The situation is somewhat similar for adoption of the mulch component. Although 62% of the sample farmers did not adopt the mulch component, all producers had stopped burning crop residues. The fact that they did not adopt the mulch component of the technology does not necessarily mean that these farmers left no residues as mulch on their fields, completely exposing their fields to the elements, but that the quantity of residues remaining on the field at planting was not enough to be considered an effective mulch. Furthermore, there is a continuous soil conservation response as the amount of soil cover increases, although this is subject to the law of diminishing returns (Figure 6). All of these factors directly influence the effects of adopting mulch.

To illustrate this more clearly, we present three hypothetical farmer cases (X, Y, and Z) in Figure 6. Farmer Z is an adopter of mulch, for 35% of his field is covered with maize residues. Farmers X and Y are not adopters of the mulch component, given that their fields have a 0% and 15% coverage, respectively. However, the

Table 14. Adoption matrix for conservation tillage in the manual hillside production systems of Motozintla, Chiapas

		Adopted no-tillage component		
		No	Yes	∑
Adopted mulch component	No	Nonadopter (25.6%)	Adopted no-tillage only (36.6%)	62.2%
	Yes	Adopted mulch only (8.5%)	Adopted both components (conservation tillage) (29.3%)	37.8%
	∑	34.1%	65.9%	100%

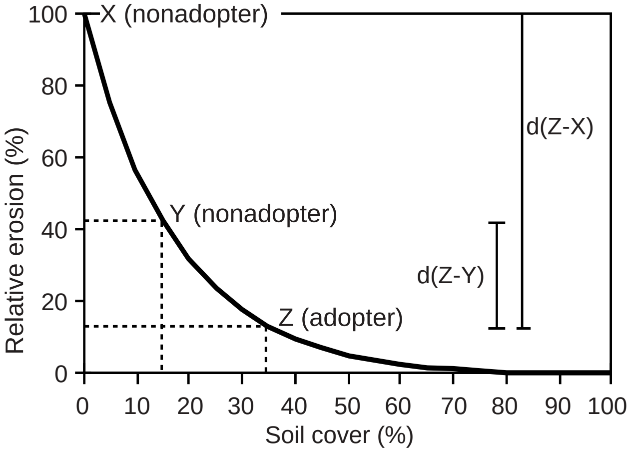

Figure 6. Relationship between relative erosion and soil cover.
Source: Adapted from Shaxson et al. (1989).

fact that Farmer Y has some mulch on his field influences the level of erosion in the field. For that reason, the difference in the relative levels of erosion in these farmers' fields is much less between the fields of Z and Y (only 30%) than between those of Z and X (87%).

This problem partly explains why some of the differences between groups of adopters are less marked than one would expect. However, as this paper shows, there are even differences in the relevant indicators of technology adoption, which can be explained by various factors that influence the farmer. The effects of the no-tillage component as well as the mulch component would have been much greater if they had been compared to farmers' "traditional" (original) practices, before farmers stopped burning their fields. However, times have changed, and what is considered "traditional" practice has changed with them. The impact of adopting conservation tillage technology may in fact be higher than results of this study would suggest.

Adoption over Time

Conservation tillage technology can be thought of as a package of technology consisting of two basic components: no-tillage and mulch. As Byerlee and Hesse (1986) documented in the Mexican highlands, different components of a technology package can have independent patterns of adoption. This has occurred in the study area, where some farmers have adopted one, two, or none of the components of conservation tillage, and the components were not adopted at the same time. However, it is problematic to determine the real level of adoption of the mulch component, and it is even more complicated to try to determine when farmers first began using mulch. Our ability to determine the historical framework for the adoption of the no-tillage component is similarly limited, but we can use other variables as approximate indicators of the adoption of both components. The decision to stop burning residues can be seen as a proxy for mulch adoption; similarly, adoption of herbicide is a proxy for adoption of the no-tillage component.

The actual component is usually adopted at the same time or after the indicator has been adopted. It is obvious that mulch cannot be adopted until the farmer stops burning residues, so disadoption of burning is a necessary though not sufficient condition for adoption of the mulch component. The relationship between herbicide use and adoption of the no-tillage component is similar. For comparative purposes in our discussion below, we also include data on fertilizer adoption.

Disadoption of burning — Farmers stopped burning crop residues for land preparation about ten years ago (data from retrospective questioning). Adopters of only the mulch component stopped burning even longer ago than that (14 years on average). Most farmers (62%) stopped burning after local regulations forbade the practice, whereas the remainder stopped burning once they saw the advantages of abandoning burning. Most farmers (67%) first heard about the practice of not burning from government extension agents.

Herbicide adoption — On average, sample farmers have used herbicides for eight years. Most (70%) began to use herbicides because of the labor savings involved — herbicides enabled farmers to cover more area in a shorter time. Most farmers learned to use herbicides from neighbors or family members (84%) and bought their herbicide in the market the first time they used it (99%). This suggests that farmers generally taught themselves how to use herbicides (learning by doing), which indicates that not all farmers may know about the risks inherent in using these chemicals. This is especially problematic when one considers that the most frequently used herbicide, paraquat, is relatively toxic.

Fertilizer adoption — On average, farmers have 11-12 years of experience in using fertilizers.[36] Most farmers (80%) began to use fertilizers to raise yields of maize grown in exhausted soils. The majority learned to use fertilizer from neighbors and family members (83%); the first time they used fertilizer, they purchased it in the market (95%).

Figure 7 shows the initial diffusion of the three technologies (not burning; using herbicide; using fertilizer) in the study zone. The pattern of adoption reflects a logistic curve based on observed data (CIMMYT 1993):

Not burning: $Y_t = 1/(1 + e^{+[867.7 - 0.4376*t]})$ $[R^2: 0.88]$;

Herbicide: $Y_t = 1/(1 + e^{+[1426 - 0.7184*t]})$ $[R^2: 0.92]$;

Fertilizer: $Y_t = 1/(1 + e^{+[1339 - 0.6757*t]})$ $[R^2: 0.94]$;

where Y_t is the cumulative percentage of farmers who adopted the technology in time t.

Figure 7 indicates that the practice of not burning residues diffused less rapidly than the other two practices. The figure also shows that 60% of farmers stopped burning between 1981 and 1987 (7-13 years ago). Fertilizer adoption was about three years ahead of herbicide adoption and the rate of adoption was similar for the two technologies. Between 1981 and 1985, 60% of farmers started to use fertilizer (9-13 years ago), whereas 60% started to use herbicides between 1984 and 1988 (6-10 years ago).

One notable feature of Figure 7 is that the adoption curve for the no-burning practice flattens out near the 50% adoption level around 1985 and that after 1985 adoption grew more rapidly as it neared 100%. The local regulation against burning was promulgated in 1985, pre-dating the state law, which may explain the sudden jump in adoption of the no-burning practice. It is also useful to remember that estimation of the logistic curve is based on certain assumptions about the diffusion of technology and that the fixed parameters estimated for the curve imply that the environment has remained constant in the period to which the curve is fitted (CIMMYT 1993:13). Thus it is more precise to present a logistic curve for the years up to 1985, and another for the years after 1985:

To 1985: $Y_t = 0.5/(1 + e^{+[923.7 - 0.4664*t]})$ $[R^2: 0.96]$;

After 1985: $Y_t = 1/(1 + e^{+[2411 - 1.215*t]})$ $[R^2: 0.97]$.

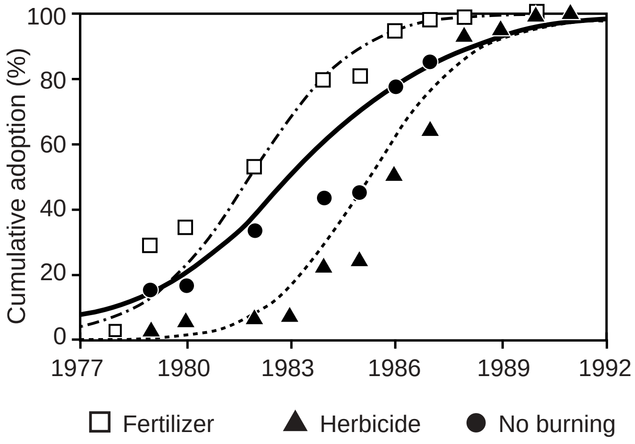

Figure 7. Diffusion of fertilizers, herbicides, and the abandonment of burning, Motozintla, Chiapas.

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[36] Farmers who apply fertilizer around the base of the maize plant have been using fertilizer longer (12.3 years on average) than farmers who incorporate fertilizer (10.6 years; probability = .03).

Figure 8 shows the results if the local law against burning is taken into account. Before the local law entered into effect, the diffusion of the no-burning practice was slower than that of fertilizer and herbicide use. Once the law was promulgated, the no-burning practice spread at a more rapid rate than that achieved by the other technologies. According to Figure 8, 60% of farmers stopped burning between 1979 and 1986 (8-15 years ago).

After the local law against burning came into effect, diffusion of the no-burning practice was not a matter of choice but of compulsion, given that burning residues would have serious consequences. Presently a farmer who is caught burning residues without permission is arrested. He is required to pay the municipality of Motozintla a fine equaling 50 days of the minimum wage in the Federal District of Mexico City or to serve 50 days in jail. Occasional burning permits are issued only so farmers can clear land that has been fallowed for more than two years (Cadena 1995:5). The data from this study suggest that the law was fairly effective at discouraging burning, probably because it was really enforced at the local level. The data also suggest that the state law forbidding burning, passed at the end of 1992, had relatively little effect in the study area, for by that time adoption of the no-burning practice was complete.

Specific incentives for the adoption of conservation tillage — To promote conservation tillage practices, and particularly to encourage farmers to stop burning residues, the federal and state governments offered various incentives (backpack sprayers, cash credit, and inputs) to farmers in Chiapas, including the study area. Altogether, 96% of the sample farmers received one of these incentives (Figure 9).

The great majority of farmers (94%) received a backpack sprayer , and most of these sprayers were distributed by SARH in 1990 (according to 92% of the survey farmers who received them). Most farmers (81%) thought that the sprayers were given to them as a way of encouraging them not to burn crop residues. Because nearly all farmers received a sprayer, ownership of a sprayer was not a discriminatory variable among the different groups of adopters. However, it is important to emphasize that farmers who did not receive

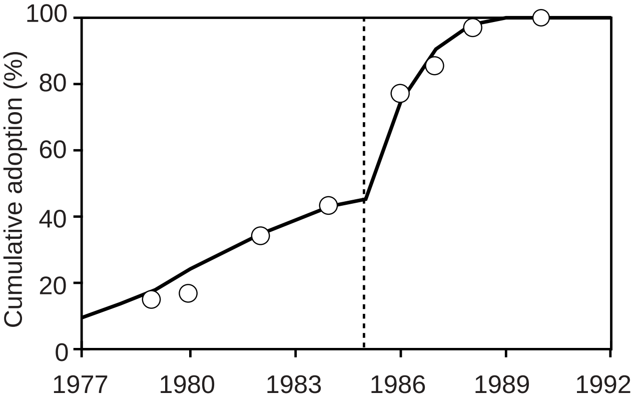

Figure 8. Diffusion of the practice of not burning residues, taking into account the 1985 law against burning, Motozintla, Chiapas.

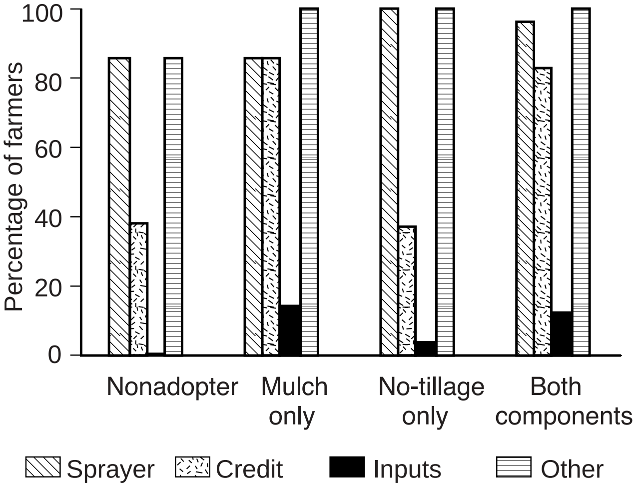

Figure 9. Incentives for adoption of conservation tillage, Motozintla, Chiapas.

this incentive are concentrated among the groups who did not adopt the no-tillage component.

Slightly more than half of all farmers surveyed (55%) have received a state credit (called "*credito de palabra*") at least once as an incentive. This credit is awarded in cash and no guarantees are needed: the farmer's word (*palabra*) is sufficient to guarantee repayment. If farmers repay the credit at harvest, they are offered a similar credit for the next cropping season. Most farmers (91% of those who received such credit) obtained it starting in 1992 through the FOSOLPRO program (Fondos de Solidaridad para la Producción — Solidarity Funds for Farm Production) of the SDRE. It is important to note that adopters of the mulch component (alone or with the no-tillage component) received credit more frequently (>80% of farmers) than nonadopters (<40%, prob. = .00). This difference is probably related to the conditional nature of the credit. Most farmers believed that they were awarded the credit so that they would leave crop residues in the field and not till the soil, whereas the remainder believed that credit was awarded primarily to discourage farmers from burning residues (36%).

Sixty percent of the farmers who said they received credit obtained it during three cropping cycles (the 1992 to 1994 summer cycles); 27% received it in only two cycles (1992 and 1993); and the remainder in one cycle. Most producers who did not obtain credit over the three cycles had been unable to pay their debts. In the summer 1994 cycle, the amount of credit varied from Mx$ 125/ha to Mx$ 400/ha. The proportion of farmers who received credit three times varies in the different groups of adopters. Among adopters of both components of the technology who obtained credit, 75% obtained it for three years, compared to 50-55% of adopters of only one component and 38% of nonadopters. Compared to nonadopters, adopters of both components apparently have fewer problems paying their debts.

A small percentage of farmers (6%) received inputs as a stimulus, including herbicides and/or fertilizers. Although so few farmers received inputs, it is clear that adopters of the mulch component (alone or with the no-tillage component) received inputs more often (>10%) than nonadopters (<5%).

Factors Influencing Adoption

In the previous sections of this paper we described several factors that appear to be related to the adoption of different components of the conservation tillage technology. Some of these factors are a consequence of adoption, whereas others have favored the adoption process. For a more detailed analysis of the factors influencing adoption, we developed a multivariate logistic regression model which predicts the probability that a farmer will adopt only one component (partial adoption) or both components (total adoption) of the conservation tillage technology, based on a series of farm or farmer characteristics (CIMMYT 1993; Nagy and Ahmad 1993; and Sain and Herrera 1996). The model is described below.

Dependent variable: partial or total adoption —The dependent variable in the equation is a qualitative variable that classifies farmers into four groups: nonadopters; the two groups of farmers who adopted only one component of the technology; and farmers who adopted both components. Table 15 summarizes the characteristics of the dependent variable for these categories. The calculation of the probability that a farmer will adopt only one or both components is normalized on nonadoption.

Independent variables — Table 16 lists the independent variables used in the model, as well as the expected effect of each variable on adoption of both components of the conservation tillage technology. By definition, adoption of conservation tillage requires the no-tillage component and the mulch component to be adopted at the same time. "Partial adoption" refers to adoption of only one component of the technology, whereas "total adoption" refers to adoption of both components. In general, different variables are expected to influence adoption of each component, whereas a combination of all of those variables would influence total adoption. For that reason, it is expected that some variables that help explain the probability of adopting one component will also help explain the probability of adopting the package of technology in which it is included. Next we will list the independent variables and explain the rationale behind them.

Table 15. Dependent variable, logit analysis of adoption of conservation tillage practices in Motozintla, Chiapas

Value (Y_i)	Category	Mulch	Tillage	Percent of sample
0	Nonadopter	X	X	26
1	Adopter, mulch only	√	X	9
2	Adopter, no-tillage only	X	√	37
3	Adopter, both components	√	√	29

- *Slope (SLOPE):* All of the fields in the study area are quite steep, but even so, it is expected that ease of access, for livestock and farmers, will negatively affect the probability that farmers will adopt both components of the technology. Access for livestock is related to grazing intensity, and thus with the probability of adopting the mulch component. Livestock prefer to graze level fields rather than sloping fields (if there is sufficient forage in accessible fields, why graze steep fields?). Access for farmers is related primarily to the ease of tillage, and thus to the probability of adopting the no-tillage component. It is much easier to work the soil of a level field than of a sloping one; on such steeps slopes it is difficult to move across the field at all. The no-tillage component considerably facilitates land preparation and weed control. Slope can also be expected to affect soil conservation: the greater the slope, the greater the erosion, and the greater the soil conservation effect if mulch is used. However, given the difficulty of maintaining enough residues without fencing the field, it is probable that the effect of slope is more closely related to access to the field.

Table 16. Independent variables in the logit analysis and their hypothetical effects on adoption of each component of the conservation tillage technology in Motozintla, Chiapas

		Predicted effect on adoption	
Variable	Description	Mulch	No-tillage
SLOPE	Average slope of field (%)	+	+
COMLIVE	Communal livestock pressure (AU per planted ha, modified for fencing)	-	+/-
FSIZE	Total farm area, 1993 summer cycle (ha/farm)	+/-	+
FAMLAB	Availability of family labor (potential labor/farm)	+/-	+
DMONMAIZE	Dummy variable if farmer grew a maize monocrop	+/-	+
DBUSINESS	Dummy variable if farmer had another business	+/-	+

- *Farm size (FSIZE):* Farm size is expected to contribute positively to the probability of adopting the no-tillage component. Farm size is an indicator of the amount of work required on the farm. When there is more work on the farm, there is a greater probability that the farmer will adopt a component that saves on labor and permits him to complete farm operations more rapidly.

  Farm size is also a good indicator of income and the other resources on which the farmer depends. For example, there is a positive relationship between farm size and several indicators of cash flow on the farm, such as maize sales (c.c.: .42; prob.: .00), sales of other agricultural products (c.c.: 19; prob.: .09), and the farmer's use of state credit (c.c.: .21; prob.: .06). A greater flow of cash on the farm makes it easier for the farmer to purchase the inputs that are required. There is also a positive correlation between farm size and resources such as information (for example, visits from extension; c.c.: .27; prob.: .01) and the livestock herd (c.c.: .52; prob.: .00).

  Farm size also influences the hiring of labor. There is a positive correlation between farm size and the hiring of day laborers (c.c.: 20; prob.: .07), and a negative correlation between farm size and the farmer's need to work as a day laborer in the fields of other producers in the zone (c.c.: -.21; prob.: .06). One would expect that hiring of day laborers would favor adoption of the no-tillage component, given that hired laborers are generally paid in cash. One cash expense (hired labor) would be replaced with another (inputs for the no-tillage component), and the potential savings would determine the potential for adoption. On the other hand, it is expected that the need to go out and work on other farmers' fields would limit adoption of the no-tillage component. This need is closely related to the scarcity of income and thus with difficulty in acquiring the inputs needed for the no-tillage component.

- *Communal livestock pressure (COMLIVE):* Communal livestock pressure is expected to contribute negatively to the probability of adopting the mulch component. The likelihood that a farmer can conserve sufficient residues depends greatly on the pressure on the residues as forage during the dry season (and on whether fields are enclosed, which eliminates external pressure).

  Communal livestock pressure reflects only the external pressure on a farmer's residues related to free grazing. In addition, the pressure of the farmer's own livestock reflects the internal needs of the production system. However, the size of the farmer's herd is linked as much to farm size (see earlier) as to the availability of family labor (c.c.: .27; prob.: .01). The pressure of the farmer's own livestock (per cropped hectare) is also closely linked to communal livestock pressure (c.c.: .31; prob.: .00). Thus these variables related to internal livestock pressure cannot be included in the same model.

- *Availability of family labor (FAMLAB):* It is expected that the availability of family labor will influence the probability of adopting the no-tillage component. When more family labor is available, there is less need to adopt labor-saving technologies, but as we have seen earlier, availability of family labor is closely linked to outmigration (c.c.: .36; prob.: .00). In other words, there are opportunities outside the farm to use the labor that has been saved. This raises the opportunity cost of family labor, which can encourage the decision to replace labor with herbicides for weeding. On the other hand, it is expected that outmigration will raise cash resources: through seasonal outmigration for off-farm work, the family can sell some of its labor for cash, thereby making it easier to buy the required inputs.

- *Monocropped maize (MONMAIZE):* Maize monocropping should have a positive influence on the probability that farmers will adopt the no-tillage component. Monocropping is related closely to the production of maize for sale, which in turn is related to cash flow on the farm. If maize is produced chiefly for sale, more maize will be sold at harvest time, and it will be easier for the farmer to purchase inputs with cash. On the other hand, if maize is produced entirely for home consumption, the farmer must obtain cash from other sources to buy inputs. Furthermore, monocropping makes it easier to apply herbicide, as a single crop of maize requires less care compared to the maize-bean intercrop.
- *Nonagricultural business (BUSINESS):* Side businesses (that is, businesses aside from agricultural production) are expected to have a positive influence on the adoption of the no-tillage component. This is related once again to cash flow on the farm, given that someone with a side business is likely to have more cash on hand. The presence of a business is also likely to raise the opportunity cost of family labor.

All of the variables that raise cash flow on the farm can positively influence adoption of the mulch component. As seen earlier, one of the most effective means of conserving crop residues is to enclose the field. Nevertheless, this represents a considerable investment, which might be easier to make if the farmer has more access to cash (for example, through outmigration or grain sales). However, up to the time of this study, few farmers had fenced their fields, so the effect of fencing is unlikely to emerge clearly from the analysis.

Results — Table 17 presents results of the model. Most of the relevant variables for each component of the conservation tillage technology have the expected signs and are statistically significant. Several statistical tests indicate the goodness of fit of the model. However, it is important to point out that very few farmers adopted *only* the mulch component, which weakens this part of the model. On the other hand, it is expected that

Table 17. Factors affecting adoption of conservation tillage in Motozintla, Chiapas (multivariate logistic model, normalized on nonadoption)

	Adoption		
Variable	Mulch only	No-tillage only	Both components
SLOPE	0.0793 (.0276) ***	0.0108 (0.0183)	0.0687 (0.0232) ***
COMLIVE	-0.773 (1.67)	-0.997 (0.961)	-3.62 (1.23) ***
FSIZE	0.627 (0.548)	0.995 (0.388) **	1.48 (0.448) ***
FAMLAB	0.546 (0.530)	0.344 (0.374)	0.885 (0.432) **
DMONMAIZE	1.53 (1.12)	0.0614 (0.812)	1.48 (0.958)
DBUSINESS	-0.183 (1.55)	2.17 (0.889) **	1.11 (1.17)
Constant	-9.56	-3.11	-8.27

Sample size	82		
χ^2 for importance of education	63.5	degrees freedom: 15	prob.:.000
Cases predicted correctly	62%		

Note: Values in parenthesis indicate asymptotic standard errors; ***, **, and * indicate significance at 1%, 5%, and 10%, respectively.

the differences among those who adopted only the no-tillage component and those who adopted both components were principally related to the adoption of the mulch component.

The model presented in Table 17 includes the postulated variables. This model is slightly better than others that did not include farm size, for example, and in its place includes variables closely related to farm size (for example, hiring of day laborers, credit, and extension).

Slope appears to be the variable that best explains the adoption of the mulch component alone. Its coefficient is very significant and of the expected sign. Slope is also significant in explaining total adoption. Aside from slope, communal livestock pressure is also significant in explaining total adoption of the technology (especially the mulch component).

The main variables that explain adoption of only the reduced tillage component include farm size and having a side business. Both variables are significant and have the expected signs. However, only farm size is important in total adoption. Along with the variables that have been mentioned, the availability of family labor — through its effect on the adoption of the reduced tillage component — also helps explain total adoption.

Table 18 presents the probability that a typical farmer will adopt each component alone or together, along with some farmer variations. The probabilities for the typical farmer are based on the average value of the continuous variables and the most common value of the discrete variables. Based on these values, the typical farmer has a greater probability of adopting only the reduced tillage component (which is also the most common group of adopters in the sample, at 37%). A substantial change in the slope of field cultivated by the typical producer has a particularly strong influence on adoption of the mulch component. A farmer who is essentially typical, except for the extreme slope of his field (90%), has a greater likelihood of adopting both components of the technology.

The table also presents the probabilities of adoption based on other variations in

Table 18. Probabilities of adoption of conservation tillage for different groups of farmers, Motozintla, Chiapas

		Adoption		
Variable	Value	Mulch only	No-tillage only	Both components
Typical farmer	Average or most common value[a]	23 %	61 %	40 %
Δ slope	50%	5 %	55 %	14 %
	90%	57 %	66 %	71 %
Δ communal livestock pressure	Tuixcum	17 %	49 %	11 %
	Carrizal	27 %	67 %	64 %
	fenced	42 %	83 %	98 %
Δ total farm size	1 ha	9 %	21 %	5 %
	5 ha	55 %	94 %	95 %
Δ labor	1 person	8 %	41 %	8 %
	6 people	56 %	79 %	87 %
Δ side business	Yes	20 %	93 %	67 %

[a] A typical farmer has a field with a slope of 71%, communal livestock pressure of 1.13 AU/ha, a total farm size of 2.76 ha, potential family labor of 3.38 persons, does not monocrop maize, and has no business other than farming.

characteristics of the typical farmer. When the level of communal grazing reflects the level inherent in the *ejido* of Tuixcum, the typical farmer is likely to adopt neither component of the technology, whereas the same farmer in Carrizal is likely to adopt only the reduced tillage component. However, if the farmer encloses his field he will probably adopt both components.

Farm size strongly influences the adoption of the reduced tillage component. A typical farmer with only one hectare of land will probably adopt neither technology component, but a farmer with 5 ha is likely to adopt both components. The results for family labor are similar. Having a side business considerably increases the probability that the farmer will adopt only the reduced tillage component.

Farmers' Opinions of Conservation Tillage

Farmers were asked their opinions about various statements reflecting the potential advantageous and disadvantageous effects of the conservation tillage technology (specifically, leaving residues on the field) (summarized in Figures 10 and 11).

The great majority of farmers (93%) thought that conservation tillage practices did not increase soil compaction, probably because compaction is not a serious problem in these unmechanized hillside production systems. Most farmers (85%) also thought that conservation tillage practices did not increase the number of days needed for land preparation and planting. Apparently the presence of the residues does not impede these operations.

According to the majority (93%) of sample farmers, conservation tillage practices do not increase weed problems. This is contrary to what one would expect because a greater incidence of perennial weeds, which are hard to control, would be likely under conservation tillage. However, informal information provided by survey farmers seems to link the presence of some problem weeds (such as *Cynodon dactylon*) to herbicide use.

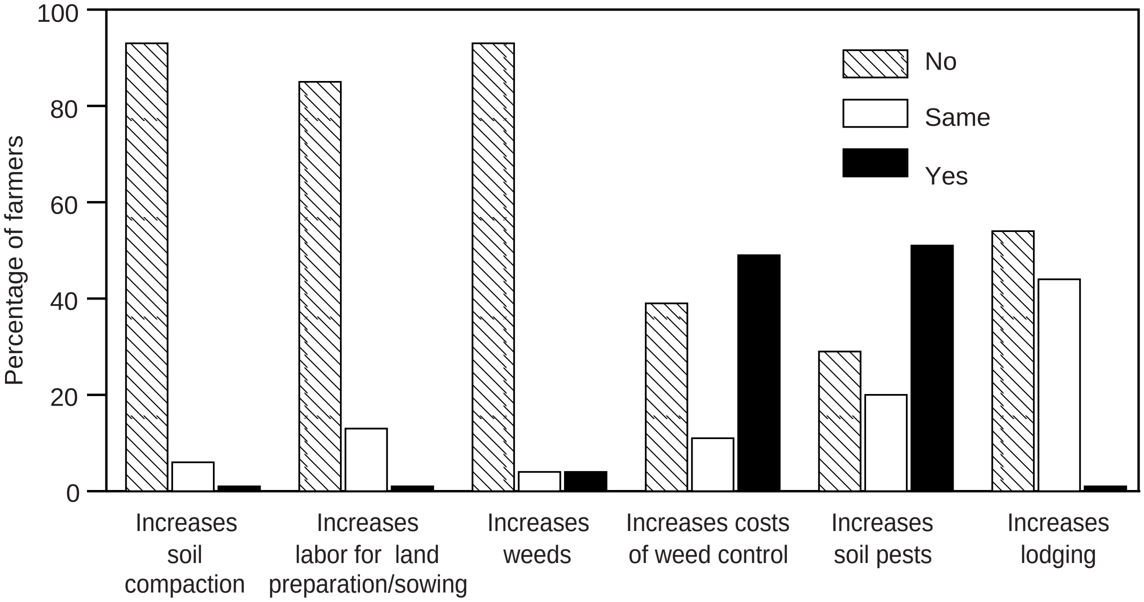

Figure 10. Farmers' opinions of potential disadvantages of conservation tillage, Motozintla, Chiapas.

Opinion was divided with respect to whether conservation tillage increased the cost of weed control. Half of the farmers (49%) though that it did, whereas the remainder thought it did not. Economic data presented earlier indicate that the cost of weed control was in fact reduced. The fact that half of the farmers did not perceive this reduction is probably related to the "visibility" of cash costs for herbicides compared to costs in kind for family labor. Farmers' evaluation also probably did not include the costs/health risks of using herbicides, which are invisible costs.

Opinion was also divided with respect to whether conservation tillage practices increased soil diseases. More than half (51%) of farmers thought that they did; one-third (29%) thought that they did not; the remainder thought that they made no difference. With mulch, limited tillage, and no more burning of residues, a greater incidence of soil diseases might be expected. However, disease pressure apparently continues to be low and is less of a problem than the strong, crop-damaging winds. The wind problem and resulting lodging of maize plants do not seem to be worse under conservation tillage. Nearly all farmers claimed either that the problem had not increased or that it had stayed the same.

With regard to the advantages of conservation tillage, farmers unanimously said that conservation tillage reduced soil erosion. Their response is probably related to the fact that the reduction in soil erosion is highly visible when mulch is used on steeply sloping fields. Greater amounts of mulch than those presently used by farmers in the study area could reduce erosion even more.

The great majority of producers (92%) observed that conservation tillage practices helped the soil retain more moisture. Like the reduction in soil erosion, this effect is also highly visible. Many farmers have observed that the soil under the mulch is generally damper than exposed soil.

Most farmers (84%) thought that conservation tillage practices increased soil fertility. The source of this perception is probably farmers'

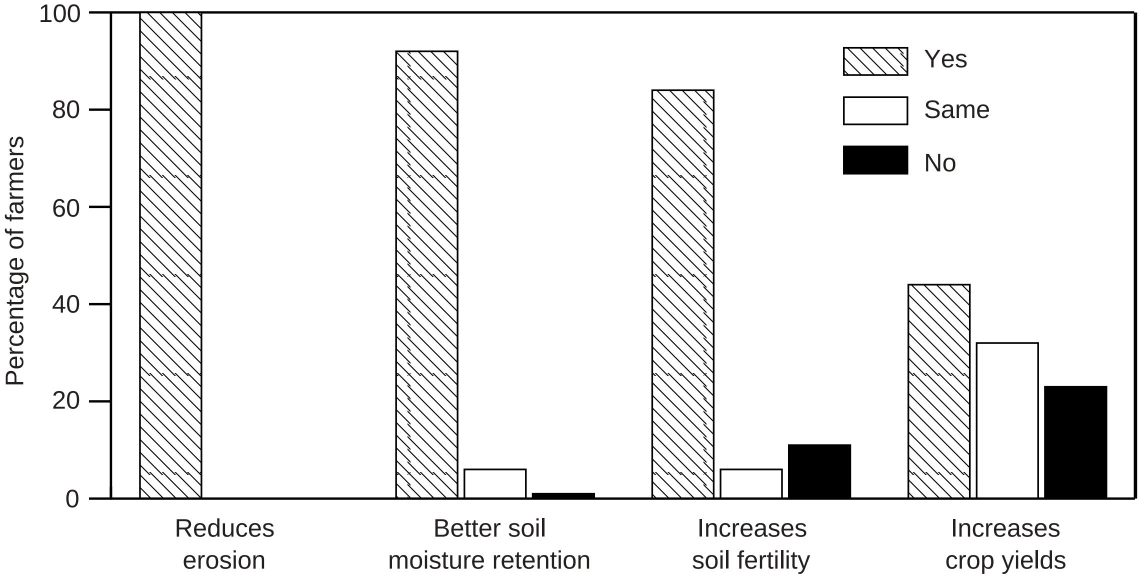

Figure 11. Farmers' opinions of the potential advantages of conservation tillage, Motozintla, Chiapas.

awareness that crop residues turn into soil. It is important to recall that the residues have a high C:N ratio and that their effect as an organic fertilizer is limited in terms of a greater availability of nutrients in the short run. Their effect on soil fertility is related more to the dynamics of organic matter and can be considered a long-term effect.

Opinion is divided over whether conservation tillage practices increase maize yields. Less than half of the farmers surveyed (44%) thought that they did, one-fourth (23%) thought that they did not, and one-third (32%) thought that yields remained unchanged. This agrees with observed maize yields; in the 1993 summer cycle, there were no significant differences among groups of adopters. However, there is a difference in relation to the adoption of the mulch component. Those who adopted the mulch component, alone or together with the tillage component, had more favorable opinions about whether conservation tillage increased yields (for example, 55% of adopters thought that yield improved, versus only 38% of nonadopters).

Summary and Conclusions

The adoption of conservation tillage practices in the unmechanized hillside production systems in the Motozintla area appears relatively promising. Farmers no longer burn crop residues, and 66% of the survey farmers have adopted the reduced tillage component as well. However, only 38% of farmers leave enough residue on their fields to produce an effective mulch. Thus only 29% of the farmers surveyed can be considered true adopters of conservation tillage.

To benefit from conservation tillage, farmers must adopt both components of the technology: limited tillage and the use of mulch. The results obtained by the different groups of farmers provide evidence of this. Farmers who adopted both components of conservation tillage in the maize-bean intercropping system that predominates in the study area obtained more favorable yields and farm budgets. For various economic indicators, adopters of both components surpass both nonadopters and partial adopters of the technology. The value added by adopters of both components surpassed that of other groups of adopters by approximately 11-16%, reaching Mx$ 1,770/ha for the 1993 summer cycle. This implies a net benefit of Mx$ 470/ha for these farmers. Production costs are relatively high for all producers, reaching Mx$ 0.60 per kilogram of maize for adopters of both components. This implies that the profit of the maize-bean intercrop principally derives from the bean intercrop. Returns from maize cropping are probably low because maize is mainly produced for home consumption and only the surplus is sold. Finally, labor productivity reached Mx$ 16/day for adopters of both components. All of these indicators were less attractive for the other groups of adopters. The clear advantages of adopting both components only disappear when higher interest rates are assumed.

It is important to emphasize that the 1993 summer season was apparently a good year for producing maize and beans. In normal years, and especially in poor ones, the economic indicators are much less favorable for all farmers. However, there are indications that adopters of the mulch component are less exposed to production risks and that they could benefit from a favorable yield response to levels of mulch higher than the conventional threshold level of 2 t/ha.

The adoption of conservation tillage practices in the study zone particularly influenced weed control and residue management practices. Adoption of the reduced tillage component implied a greater use of herbicides and generated a slight reduction in production costs. Adoption of the mulch component is more complex. The farmer must make a substantial investment to protect the crop residues, and this investment is recovered only through the yield increases obtained when the farmer adopts both components of the technology.

There have been no great qualitative or quantitative changes in other production practices used in maize-bean intercropping. Farmers still use local varieties, use reduced tillage for land preparation, apply mostly nitrogenous fertilizer, and generally use no pest and disease control measures. Wind continues to be one of the principal natural problems affecting the system, partly because fields are located on slopes that are quite exposed to the elements.

This study demonstrates that patterns of adoption were different for the different components of conservation tillage technology. Compared to the adoption of herbicides, adoption of the practice of conserving rather than burning crop residues took longer, although the adoption process began earlier. A local law prohibiting burning encouraged adoption of residue conservation in the study area; by the time a similar law was promulgated at the state level, it produced few changes in the study area. The study also shows that the adoption of the no-burning practice is a necessary but not sufficient condition for adoption of the mulch component. Burning is only one of the factors influencing the availability of residues for mulch.

The study reviewed various farmer characteristics that explained the differential adoption of the two conservation tillage components and used a multivariate logistic model to analyze how the set of variables affected adoption of the different technology components. Adoption of the mulch component can largely be explained by the slope of the field, which determines the access of livestock to the field in the dry season. In turn, adoption of the no-tillage component can be explained by the availability of cash (which is related to ownership of a side business) and farm size. There are various possible explanations for the relation between adoption of the no-tillage component and farm size, such as the amount of labor required for maize-bean intercropping and the amount of income (being able to sell a greater share of the maize production, for example).

The adoption of conservation tillage is the result of the simultaneous adoption of both components of the technology. For this reason, factors that help explain the adoption of one component also help explain adoption of the entire technology. However, aside from the variables we have already mentioned, communal livestock pressure had a significant effect on total adoption (in relation to the mulch component), as did the availability of family labor. Labor availability is closely related to seasonal outmigration by some member of the family, which in turn facilitates adoption of the reduced tillage component.

Forage demand from the farmer’s own livestock does not seem to limit adoption of the mulch component. However, livestock belonging to other people can limit the possibility that there will be sufficient residue left on the field to form an effective mulch. This considerably increases the cost of adoption because crop residues must be protected in some way. Enclosing the field seems to be the most economically attractive means, aside from being the most effective, of achieving this goal. However, the resources needed to fence a field can be a limitation, given the size of the investment required. The state law limiting the cutting of trees does not help in this respect.

The current study summarizes some of the factors that help explain the diffusion of conservation tillage practices on the hillside farms of Motozintla. It is important to emphasize that one of the factors that stimulated adoption was the state agricultural policy, particularly the policy of the development district. There is no doubt that the promotion and distribution of incentives, in combination with the local law against burning, facilitated the adoption of these practices. However, results of the present study show once again that these efforts are much more effective when they fit with actual production systems and farmers' priorities. The new technologies proposed, such as conservation tillage, are viable only if they bring benefits to the producer without an excessive increase in costs. To determine those costs, it is essential to account for the true opportunity costs confronted by these producers with their limited resources.

The fact that the components promoted in the study area fit well with current production systems raises a question about the nature of adoption (Tripp, pers. comm.). Adoption of the practices that were promoted in the study area supposedly reflects a new understanding on the part of farmers and its subsequent application. However, some of the technology adoption observed in the study area is related to changes in production practices that originated in another way. The adoption of herbicides may have occurred even without an extension program, simply because farmers needed to free up labor to perform more remunerative work outside of the study zone. The adoption of mulch on steeply sloping fields seems to be related mainly to the practice of free grazing and to farmers' decision to stop burning crop residues. This more or less spontaneous adoption process differs from the adoption decision of farmers who purposely fenced their fields to conserve crop residues.

Regardless of the process by which farmers came to adopt the technology, the proposed changes were relatively easy to adopt. Most practices, such as sowing *cajeteada,* did not need to be adapted for farmers to start using the components of conservation tillage technology. Nor did adoption of the mulch component generate conflicting demands for use of the residues, whereas it did offer the potential for increasing yields and reducing production risks. In fact, the results suggest a positive relationship between yield and the amount of mulch left on the field — even higher than the threshold of 2 t/ha proposed. The data also indicate that it was the relatively better-off farmers and commercial farmers who adopted the components that were promoted.

The study illustrates that the law against burning truly helped promote the residue conservation practice, chiefly because the law was applied at the local level. Clearly laws related to the management of natural resources will succeed only if they are actually enforced. On the other hand, massive government campaigns that promote soil conservation practices are only successful if there is sufficient follow-up and if the practices suit the needs of farmers.

The use of conservation tillage practices in the Motozintla area shows what can happen when farmers with few resources adopt several external inputs (fertilizers and herbicides) but fail to adopt improved varieties at the same time. Because farmers still use local varieties, the productivity of the system has remained relatively low despite the use of conservation tillage practices, and potential cash flow problems remain. However, the production potential in the area is high, and it can be realized more adequately through the introduction of improved varieties adapted to the zone. In addition to improving the productivity of the system, the use of improved varieties could also have the positive effect of increasing the availability of residues for forage or mulch.

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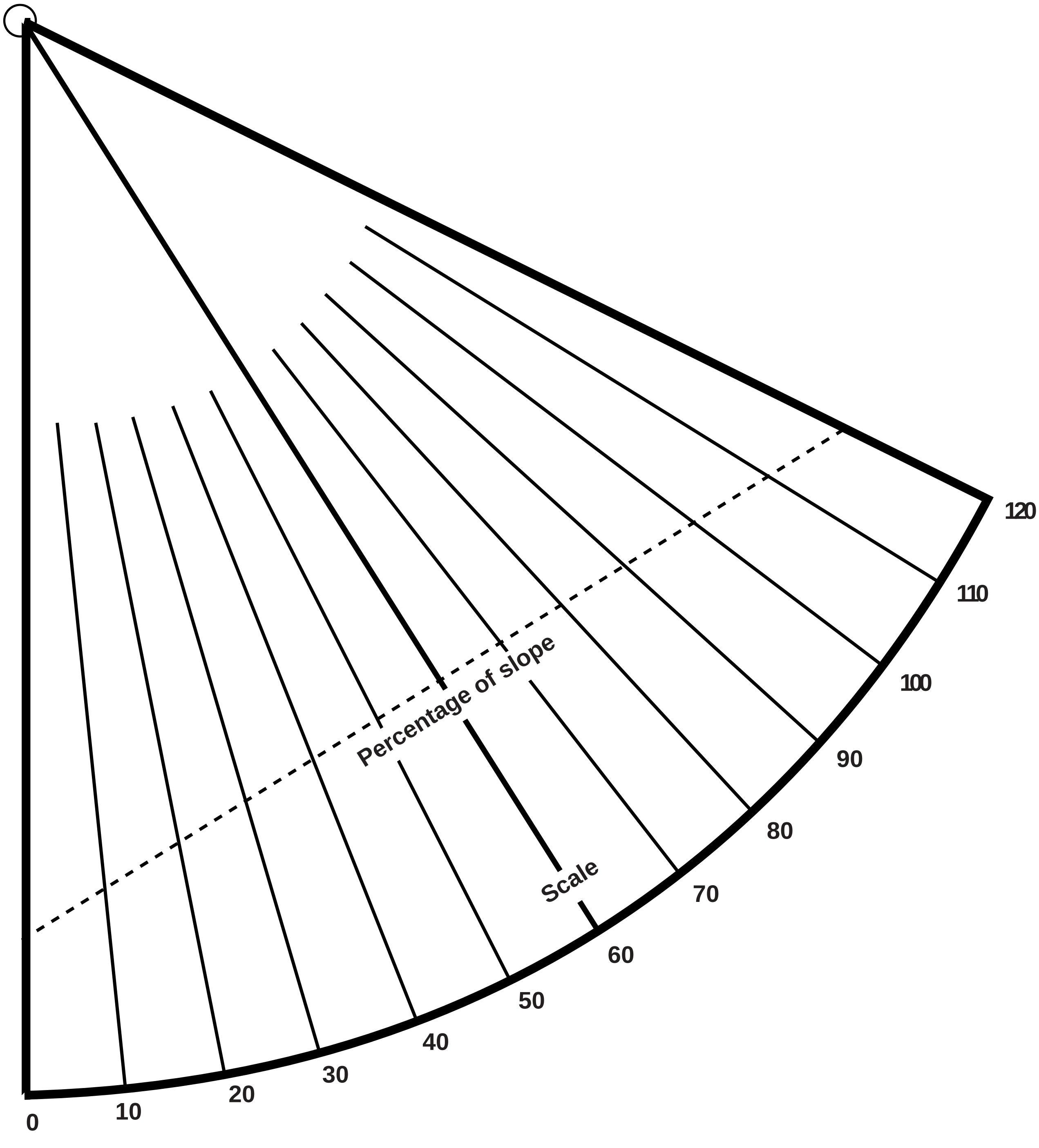
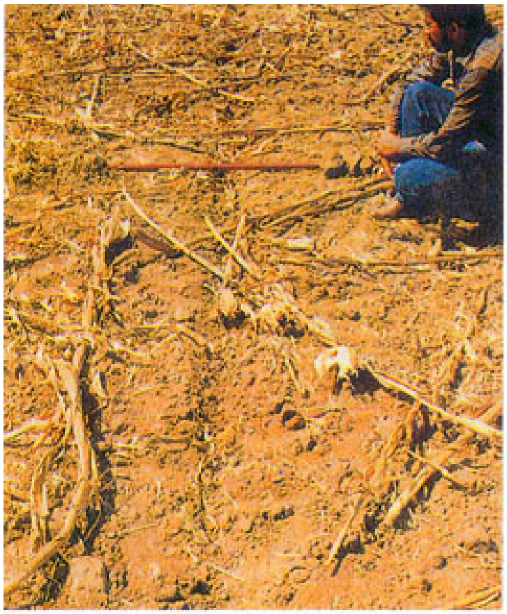
Appendix A. Visual Aids Used in the Farmer Survey

Diagram with degrees of incline to estimate slope (CIMMYT, unpublished material)



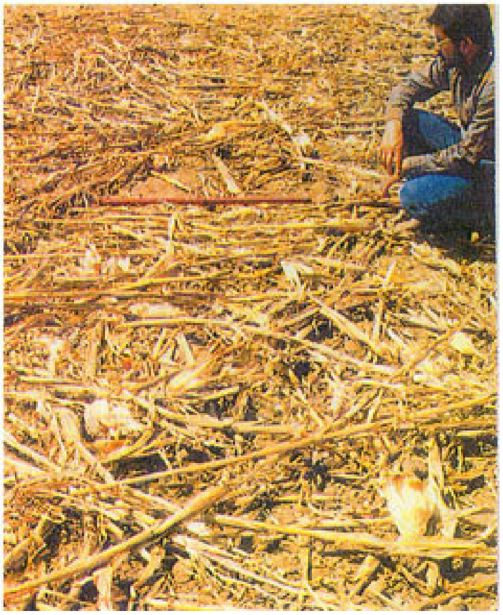
Level of residue coverage:
The photos represent an area of approximately 2 m x 2 m, with dry stover distributed uniformly on the soil surface. The amount in each photo represents the higher limit of the range for each level.



Level 1
0-0.5 t/ha
Approximate coverage (10-20%)

Level 2
1-2 t/ha
Approximate coverage (20-30%)

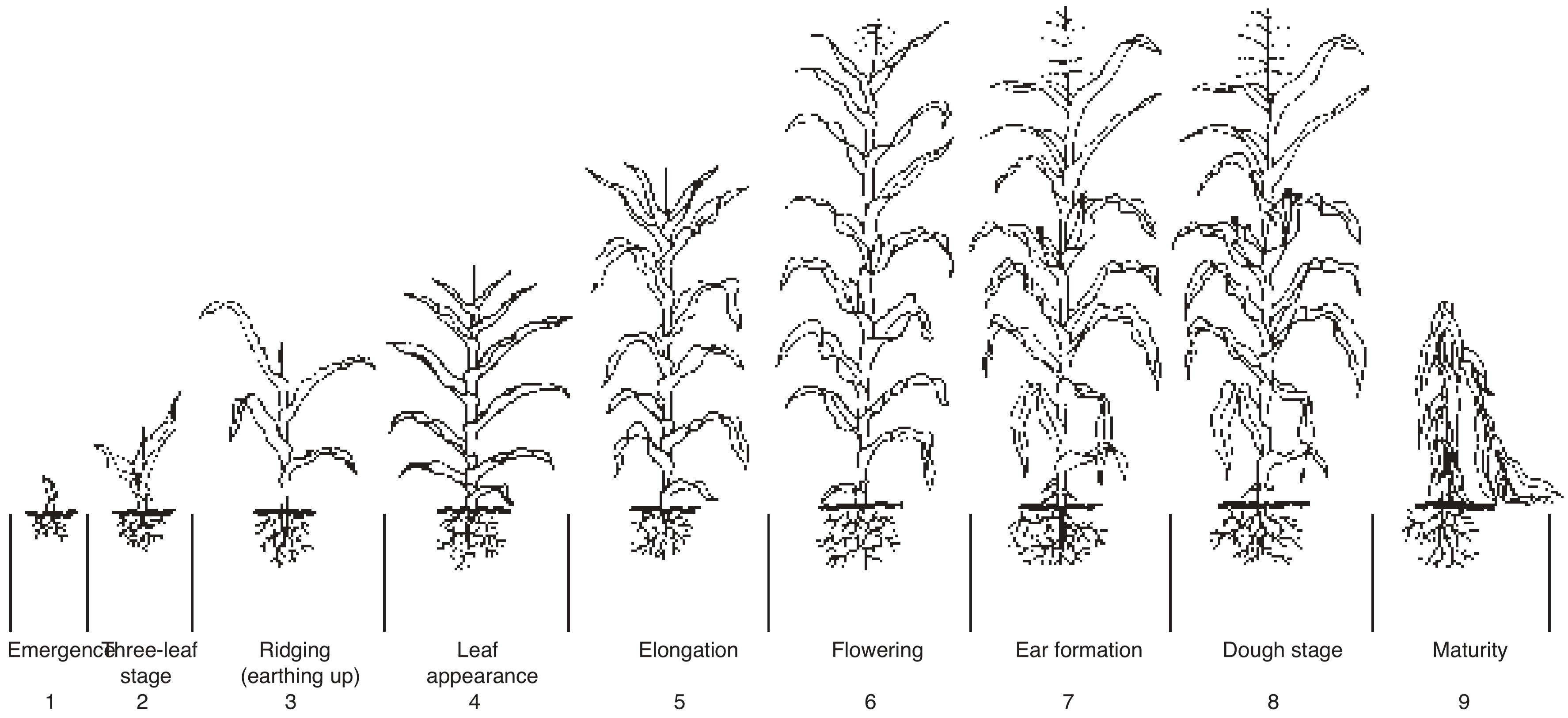
Level 3
2-3 t/ha
Approximate coverage (30-60%)



Level 4
4-5 t/ha
Approximate coverage (>60%)

Source: Tripp and Baretto (1993) and unpublished training documents, CIMMYT.

Stages of development of the maize plant (CIMMYT, unpublished material)



Appendix B. Field Prices and Local Units of Measure

Table B1. Field prices, Motozintla, Chiapas

Type	Unit	Farm cost	Specification
Labor			
Any task	day day	8 10	Food included. Food not included.
Harvest	*costal*	1.5-3	Includes transport.
Animal transport	*carga*	5	
Seed			Local price for seed of local varieties.
Maize	kg	1	
Beans	kg	4	
Fertilizer			Commercial price plus transport. Transport price calculated as Mx$ 3/*bulto* (50 kg).[a]
Ammonium sulfate (21-0-0 NPK)	50 kg	28	Includes transport.
Urea (46-0-0 NPK)	50 kg	38	Includes transport.
Triple 17 (17-17-17 NPK)	50 kg	48	Includes transport.
Diammonium phosphate (18-46-0)	50 kg	45	Includes transport.
Chemicals			Commercial price plus transport. Transport price calculated at Mx$ 1.0/l.[b]
Gramoxone	1	21	
Azinotox		22.5	
Products			Cost of transport per *costal* of grain is calculated to equal that of a *costal* of fertilizer (see above).
Yellow maize	kg	0.60	Commercial price (Mx$ 0.63/kg), minus the cost of shelling, minus the cost of transport. Shelling cost is based on 200 kg/day (Mx$ 0.05/kg). Transport cost calculated as the difference between the amount of maize sold and the amount retained for consumption on the farm, multiplied by Mx$ 0.06/kg.
Beans	kg	1.62	Commercial price (Mx$ 1.60/kg) minus the cost of transport. Transport cost calculated as the difference between the amount of beans sold and the amount retained for consumption on the farm, multiplied by Mx$ 0.60/kg.

Note: Local units: *almud* = 7-8 kg maize; *cuerda* = area 20 m x 20 m = 0.04 ha; *costal* = 75 kg of maize ears = 50 kg maize grain; and a *carga* = 2 *costales.*

[a] Transport price calculated as cost of transporting fertilizer from input supply center to the *ejido* (Mx$ 2.5/*bulto*), plus the cost of transport for the farmer (Mx$ 0.5/*bulto*, assuming a round trip at Mx$ 5.0 to buy 10 *bultos*).

[b] Transport price calculated as the cost of transport for the farmer (Mx$ 1.0/l, assuming a round trip at Mx$ 5.0 to buy 5 l).

Appendix C. Sensitivity Analysis of Farm Budgets

Table C1. Sensitivity analysis of farm budgets, hillside maize-bean intercropping system, Motozintla, Chiapas

	Units	Nonadopter	Mulch only	No-tillage only	Both components
Sensitivity to cost of capital					
Capital: 1%/mo.					
Total gross benefit	Mx$/ha	1,953	1,941	1,971	2,210
Total inputs	Mx$/ha	327	338	411	408
Total labor	Mx$/ha	933	934	777	796
Total variable costs	Mx$/ha	1,260	1,272	1,188	1,204
Total fixed costs	Mx$/ha	299	426	299	426
Return					
Value added	Mx$/ha	1,626	1,603	1,559	1,802
Net benefit	Mx$/ha	394	243	484	579
Costs per kg maize	Mx$/kg	0.587	0.628	0.573	0.559
Labor productivity	kg maize/day	28.0	28.5	32.8	36.1
Return per day	Mx$/day	14.2	12.6	16.2	17.3
Capital: 5%/mo.					
Total gross benefit	Mx$/ha	1,953	1,941	1,971	2,210
Total inputs	Mx$/ha	389	402	489	486
Total labor	Mx$/ha	933	934	777	796
Total variable costs	Mx$/ha	1,322	1,336	1,266	1,282
Total fixed costs	Mx$/ha	354	651	354	651
Return					
Value added	Mx$/ha	1,564	1,539	1,481	1,724
Net benefit	Mx$/ha	277	(47)	350	277
Costs per kg maize	Mx$/kg	0.632	0.737	0.625	0.664
Labor productivity	kg maize/day	28.0	28.5	32.8	36.1
Return per day	Mx$/day	13.0	9.5	14.5	13.5
Sensitivity to yield					
Yield: good year					
Total gross benefit	Mx$/ha	2,251	2,364	2,279	2,760
Total inputs	Mx$/ha	351	362	441	437
Total labor	Mx$/ha	933	934	777	796
Total variable costs	Mx$/ha	1,284	1,296	1,218	1,233
Total fixed costs	Mx$/ha	319	511	319	511
Return					
Value added	Mx$/ha	1,901	2,002	1,838	2,323
Net benefit	Mx$/ha	649	558	742	1,016
Costs per kg maize	Mx$/kg	0.542	0.546	0.512	0.469
Labor productivity	kg maize/day	31.2	34.9	38.0	46.0
Return per day	Mx$/day	17.0	16.0	19.5	22.8
Yield: normal year					
Total gross benefit	Mx$/ha	1,609	1,668	1,562	1,968
Total inputs	Mx$/ha	351	362	441	437
Total labor	Mx$/ha	933	934	777	796
Total variable costs	Mx$/ha	1,284	1,296	1,218	1,233
Total fixed costs	Mx$/ha	319	511	319	511
Return					
Value added	Mx$/ha	1,258	1,306	1,121	1,531
Net benefit	Mx$/ha	6	(138)	25	224
Costs per kg maize	Mx$/kg	0.743	0.751	0.733	0.658
Labor productivity	kg maize/day	22.7	25.4	26.5	32.8
Return per day	Mx$/day	10.1	8.5	10.3	12.8
Yield: poor year					
Total gross benefit	Mx$/ha	1,008	1,005	1,011	1,266
Total inputs	Mx$/ha	351	362	441	437
Total labor	Mx$/ha	933	934	777	796
Total variable costs	Mx$/ha	1,284	1,296	1,218	1,233
Total fixed costs	Mx$/ha	319	511	319	511
Return					
Value added	Mx$/ha	658	643	571	829
Net benefit	Mx$/ha	(594)	(802)	(526)	(478)
Costs per kg maize	Mx$/kg	1.126	1.156	1.094	1.004
Labor productivity	kg maize/day	15.0	16.5	17.8	21.5
Return per day	Mx$/day	3.6	1.4	3.2	4.0

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