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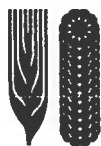
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Farmer Assessment of Velvetbean as a Green Manure in Veracruz, Mexico: Experimentation and Expected Profits

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NRG

Natural Resources Group

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Abstract

This study explores factors associated with farmers' decision to experiment with velvetbean (*Mucuna* spp.), a green manure, as a maize intercrop in three villages of Veracruz, Mexico. To assess whether velvetbean might be adopted on a wide scale in the region, the study also examines variation in farmers' perceptions of profits achieved by using the velvetbean intercrop compared to the farmer's usual practice. A stratified random sample of 92 households was selected from three villages reflecting differing conditions in the study area. All farmers who participated in a velvetbean extension program in the previous year were included; a random sample was drawn of the remaining households in the villages. The analysis reveals that the current practice to which farmers compared the maize/velvetbean intercrop played an important role in the perceived profitability of the new technology. Farmers who used neither herbicides nor fertilizer perceived a much larger positive difference in expected profits than farmers who compared the velvetbean intercrop with maize production using fertilizer or herbicides or both. Farmers with opportunities to earn off-farm income were less likely to experiment with velvetbean. Thus velvetbean may be adoptable on a wide scale by poorer farmers with limited access to chemical inputs and off-farm employment. However, these conclusions should be qualified in several ways. First, this study did not account for the full costs of using modern chemicals. Second, since the study was conducted, falling maize prices, coupled with higher prices for chemical inputs and more restricted availability of credit, may have made the intercrop more attractive to farmers. Third, the study was conducted early in the technology dissemination process, and farmers' judgments are based on only limited experience with velvetbean. Future experimentation with velvetbean may develop a method that increases production and modifies labor needs so that velvetbean, or another green manure, becomes more acceptable to farmers. In addition, the use of a green manure in combination with inorganic fertilizer might prove acceptable to farmers and enhance the sustainability of maize production in ways that the use of chemical fertilizer alone could not do. It would also be useful if future research could assess whether using velvetbean as an intercrop is actually more sustainable than current practices or whether social benefits of wide-scale velvetbean adoption would be greater than social costs.

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Farmer Assessment of Velvetbean as a Green Manure in Veracruz, Mexico: Experimentation and Expected Profits

Meredith J. Soule

Introduction

Over the past several years in both developed and developing countries, interest in using green manures as one element in more sustainable farming systems has increased. Green manures are crops grown specifically to improve the soil. Leguminous plants are often chosen as green manure crops because of their ability to fix nitrogen, control water and wind erosion, and improve the organic matter content of the soil.

The study described in this paper explores factors associated with farmers' decision to experiment with one green manure, velvetbean, as a maize intercrop in southern Veracruz, Mexico.¹ The study also examines the variation in farmers' perceptions of profits achieved by using the velvetbean intercrop compared to the farmer's usual practice. Governments may wish to encourage the adoption of more sustainable farming technologies, such as green manures, because they may provide net social benefits in the form of reduced soil erosion or groundwater contamination. However, farmers will be unlikely to adopt such techniques if they do not perceive them to be privately profitable. By analyzing what type of farmer experiments with velvetbean and — of the farmers who do experiment — which ones perceive the green

manure to be most profitable, this study also provides insights into whether velvetbean might be adopted on a wide scale in the region. Determining whether using velvetbean as an intercrop is actually more sustainable than current practices or whether social benefits of wide-scale velvetbean adoption would be greater than social costs are empirical questions that are beyond the scope of this analysis.

Velvetbean (*Mucuna* spp.), known in the southern Veracruz study area as *picapica mansa*, is a fast-growing legume that probably originated in Asia. It fixes nitrogen and provides abundant biomass, which serves to improve soil structure and helps the soil to retain humidity. In addition, velvetbean is a climbing vine that rapidly covers the ground and thus can help control weeds. Some farmers in Central America have intercropped velvetbean with maize for decades (Buckles et al. 1992), but velvetbean intercropping with maize was first widely introduced to farmers in the Sierra de Santa Marta region of southern Veracruz through an extension campaign in 1992.² The extension program was designed to encourage farmers to experiment with using velvetbean to improve soil fertility and decrease reliance on purchased inputs such as fertilizer and herbicides (Buckles, Arteaga, and Soule 1994).

¹ An intercrop is usually planted close to the planting date of the main crop, here maize. A relay crop is planted much later than the main crop. Given the variability in planting dates among farmers, velvetbean could be considered either an intercrop or a relay crop. To minimize confusion, we refer to it as an intercrop in this study.

² Some farmers in the area had already used velvetbean as a green manure before the extension campaign, but the practice was not common.

The survey was designed to collect information on the costs and yields associated with growing maize using the farmer's current technology and the costs and yields associated with maize intercropped with velvetbean (for the farmers who used velvetbean). Farmers were also questioned extensively about their knowledge of velvetbean. Other data were collected on farm and farmer characteristics, including age, education, family size, family labor employment, farm size, land tenure, credit availability and use, and the use of chemical fertilizers and herbicides.

Land tenure and its impact on farm size differ in the three communities. In Soteapan, 174 farmers hold land in the 3,600 ha *ejido*. The land of an *ejido* is owned by the community of *ejidatarios*, individuals with rights to cultivate *ejido* land. At the time of this study, *ejido* land could not be sold or rented out, but it could be passed on to a single heir. Subsequent land reforms have allowed *ejidatarios* to sell or rent out the land assigned to them by the *ejido*. When this study was conducted, the *ejido* of Soteapan had not been divided up into individual parcels, so each *ejidatario* did not have a particular plot or plots of land assigned to him or her. However, the *ejidatarios* did tend to cultivate the same parcel from one year to the next. An additional 176 farming families lived in the village but had only informal access to land; the *ejido* normally allocated these farmers a piece of land to cultivate. Some of these farmers were children or other relatives of *ejidatarios* (sometimes called *anexantes*) who could eventually inherit a parcel of land; others, who had no present claims to land, were referred to as *avecindados* (Perales 1992).

The village of Venustiano Carranza was founded in 1965 by mestizo farmers moving in from other parts of the State of Veracruz to

claim land newly opened by the government. This *ejido* was parceled, and each of the 49 *ejidatarios* had approximately 20 ha. The land for each farmer was in a combination of pasture, fallow, crops, and forest. There were 13 non-*ejidatario* (*avecindados* and *anexantes*) farming families, and 19 of the *ejidatarios* did not live in the village. Most of these non-resident *ejidatarios* rented their land out as pasture.

In Santa Rosa, 47 farmers had rights to land in the 900 ha *ejido*. An additional 46 farmers cultivated land informally with permission from the *ejido*. The *ejido* was parceled in 1993, giving *ejidatarios* secure tenure over their parcels for the first time.

Table 1 shows the average farm size for the sample in each village, the average area planted in maize per farm, and the percentage of *ejidatarios*, children of *ejidatarios*, and *avecindados* in the sample in each village. Farmers in Carranza have the largest farms, but farmers in Santa Rosa devote larger areas to maize. Carranza has the highest percentage of *ejidatarios* while Soteapan has the lowest.

Table 1. Land tenure and farm size in the three study villages, Veracruz, Mexico

	Soteapan (n=37)	Venustiano Carranza (n=25)	Santa Rosa (n=30)
	Mean	Mean	Mean
Farm size (ha)	5.2	17.2	9.7
Maize area (ha)	1.3	1.7	2.3
	(%)	(%)	(%)
<i>Ejidatarios</i>	46	68	57
Children of <i>ejidatarios</i>	19	20	27
<i>Avecindados</i>	35	12	17

In the sample, 36% of the farmers had access to credit. Credit is not available to all farmers, and at the time of the survey, credit was organized through two special government programs for marginal agricultural areas. One program, run by the National Indigenous Institute (INI), provided loans to indigenous villages. These loans were provided as in-kind inputs of herbicide, fertilizer, and sometimes improved maize seed. No interest was charged on the loans, and repayment was made to a community fund for local public works. The government replenished the loan fund only if all farmers in the village had repaid their loans.

The Secretary for Social Development (SEDESOL) operated a similar loan program for non-indigenous, marginal farmers. In this case, the loan was in cash of 350 Mexican pesos (MxP 3 = US\$ 1) per hectare of maize, and a farmer could receive a loan for 1-4 ha. Like the INI program, SEDESOL charged no interest, and loans were repaid to a community fund for local public works. For both programs, the *ejido* itself decided whether the non-land-owning *avecindados* and *anexantes* were eligible for the loan. In most instances they were not, leaving the most marginal farmers further marginalized.

The Velvetbean Technology

As noted earlier, declining soil fertility and increased weed infestations in maize fields constrained maize production in the Sierra (Buckles and Erenstein 1996). Two years of farmer participatory research in the area had identified velvetbean as a potential technology for dealing with these problems (Buckles and Perales 1995). In 1992, the Sierra de Santa Marta Project (PSSM), a Mexican non-governmental

organization involved in research and extension projects in the Sierra, launched an extension campaign in conjunction with CIMMYT to inform farmers about velvetbean and to encourage them to experiment with it in their fields (Buckles, Arteaga, and Soule 1994).⁴

To start the campaign, a workshop was organized with farmers from several communities to consider various velvetbean management options and to solicit farmers' assistance in making those options available to other farmers in their communities. Subsequently, general assemblies were organized in more than 20 communities to present a slide show on velvetbean management and discuss the potential of the practice for use in the local agricultural system. Farmers were invited to take 1.5 kg of velvetbean seed if they were interested in trying it out in their own field. This is enough seed to cover one *tarea*, a local unit of land measurement which is 25 m on each side (625 m²). More than 300 farmers requested seed. Ninety-nine of them were later visited by project staff and farmers experienced in the use of velvetbean (Buckles, Arteaga, and Soule 1994).

The presentation to farmers suggested that they experiment with a choice of two velvetbean management strategies: 1) intercropping the velvetbean between maize rows at 30-40 days after planting the maize, with a 1 m distance between velvetbean plants; or, 2) planting the velvetbean in a cleared field before the first rains, leaving 1 m between plants to improve the soil for future maize crops. To facilitate comparisons with farmers' normal practice, farmers were encouraged to plant the *tarea* of velvetbean and maize next to a *tarea* of maize without velvetbean.

⁴ The campaign was repeated in 1993 and 1994 with some modifications.

Farmers who accepted seed agreed to plant it and allow a village-level extension worker to visit their fields and to monitor the development of velvetbean and their maize. Eighty-eight of the 99 farmers monitored actually planted velvetbean in their fields, typically as an intercrop. Forty-two farmers in the survey planted velvetbean as an intercrop in 1992, and only two of those farmers followed the second strategy of planting velvetbean alone in a cleared field or used some other method. Since so few farmers tried velvetbean alone to improve the fallow, only the velvetbean intercrop is analyzed in this study. Forty-two farmers also planted the velvetbean intercrop in 1993, although 11 farmers were planting for the first time while another 11 had dropped the practice. Although it was suggested that farmers should plant the velvetbean intercrop 30-40 days after planting their maize, farmers actually planted it anywhere from 10 to 125 days later.

Expected benefits and costs of the velvetbean intercrop vary between the first and subsequent years of use. In the first year, the improved soil properties are less apparent because the velvetbean mulch from the previous season has not been incorporated. Soil improvements leading to noticeable increases in yield may be expected from the second year (Zea 1992). In addition, the first year of use features the added costs of planting the velvetbean. In later years, some seed may sprout voluntarily, so less seeding is required. Labor input over traditional practices may increase in all years for cutting back the velvetbean vines so that they do not strangle the maize. A decrease in the labor inputs for weeding (caused by velvetbean's ability to smother weeds) is usually noted only in the second and subsequent years. Labor requirements for harvesting maize may

increase in all years for fields intercropped with velvetbean as a result of the abundant growth of the vines, which inhibit movement. Whether velvetbean use increases or decreases total labor input compared with the farmer's usual practice in any one year depends on the planting date of velvetbean, the velvetbean stand establishment, and the farmer's other management practices. In addition, labor requirements are likely to decrease as farmers gain more experience in managing velvetbean.

On average, farmers in the survey found that the velvetbean intercrop required a higher total labor input per hectare than maize without velvetbean in both the first and second years of use, although farmers tended to use more family labor and considerably less hired labor on their maize field with velvetbean. For the velvetbean users, labor per hectare for maize intercropped with velvetbean averaged 79 days, whereas the labor input per hectare for the farmer's usual practice averaged 65 days. Farmers who planted the velvetbean intercrop for two years in a row in the same plot averaged 74 days of labor per hectare in the second year.

As mentioned previously, the main benefits of using velvetbean pertain to its effect on soil properties (and thus yield) and weed control. The increased labor requirements for managing velvetbean are a significant cost for many farmers. Previous research in the area had identified several other disadvantages of velvetbean that might affect a farmer's decision to use it. These included increased risk of fire from the dry biomass, increased incidence of rats and snakes, and the loss of area normally allocated to beans by velvetbean. To understand the importance of the various advantages and disadvantages to farmers, all farmers, including non-users of velvetbean, were asked to rank the various

advantages and disadvantages, which were pictured on a series of cards.⁵ Table 2 shows the frequency with which farmers pointed to the various advantages and disadvantages.

The most commonly noted advantage of velvetbean was improved soil fertility, followed by moisture conservation and then weed control. Thus, from their initial exposure to velvetbean and the extension presentations, farmers understood that velvetbean could assist them by improving the soil's fertility and its ability to hold moisture. They also believed that velvetbean could help to control the weeds in their fields.

On the other hand, 40 farmers identified the increased incidence of snakes and rats in fields with velvetbean as a major disadvantage. Some farmers reported that rats climbed up the vines of the velvetbean intercrop to eat the maize as it ripens in the field (Buckles and Perales 1995). Although some farmers believed that

velvetbean would help them to control weeds (and thus possibly reduce labor requirements), others believed that velvetbean would increase the labor input in the maize field. Only 11 farmers saw the competition of velvetbean for space with beans as a constraint to velvetbean use.

It is important to emphasize that farmers' assessments of velvetbean were based on only one year of experience with the crop. It is likely that their assessments of the advantages and disadvantage of velvetbean will change as they use velvetbean in their own environment.

The Survey Data and Empirical Model

The Data

Farmers presented with the technique of planting velvetbean between their rows of maize must assess the usefulness of the technique on their own farms and decide how much of their maize area to plant using their current production methods and how much to plant using the velvetbean intercrop. In the early phases of learning about the new technique, some farmers will experiment by planting a small area with the maize/ velvetbean intercrop to determine the usefulness of the technique on their own farm, while others will plant none at all. Assuming that one measure of the usefulness of the new technology is its profitability, we expect the assessment of the profitability of the new technology to vary across farmers, and across time for each farmer, because of differences in the information each farmer has about the technique in each year and differences in the production environment of each farmer.

Table 2. Farmer-identified advantages and disadvantages of velvetbean in the study villages, Veracruz, Mexico

	Most important advantage	Second important advantage
Improves soil fertility	28	21
Conserves moisture	17	8
Controls weeds	16	14
Softens soil	11	10
Improves dry season	6	7
Erosion control	3	9
	Most important disadvantage	Second important disadvantage
Rats and snakes	40	11
More labor	18	9
No beans	10	1
Fire risk	7	12
No disadvantage	6	0

⁵ This system was adopted from work by Daniel Buckles, at that time an anthropologist with the CIMMYT Economics Program. See Buckles et al. (1992).

This study analyzes the factors associated with the decision to experiment with velvetbean. It also examines variation in farmers' subjective assessments of the average profitability of the maize/velvetbean intercrop compared to their subjective assessment of the average profitability of their usual maize cultivation practice.⁶ The farmer's subjective assessment of stochastic yields and thus profits reflects uncertainty about the outcome of the agricultural production season, caused by weather, prices, pests, the level of experience with the technology used, the riskiness of the technology, and other variables beyond the farmer's control. It is expected that the subjective assessment will change from year to year as the information available to the farmer, prices, and other conditions of the farming environment change. This uncertainty about maize yields and thus profits in any year for both practices is reflected in probability distributions of yields and profits. In other words, the farmer may attach a very low probability to a very high or a very low yield and higher probabilities to yields and profits between the two extremes.⁷

Although the subjective assessment will change from year to year as farmers gain more experience with the velvetbean intercrop, only one year of data was available for this study. The data are for 1993, when farmers who used the velvetbean intercrop in 1992 were asked about their expectations of the profitability of the maize/velvetbean intercrop and their usual practice in 1993. In 1993, farmers already

had one year of experience with velvetbean and could expect to achieve some of the benefits that are not available until the second year of use, such as improved soil fertility and weed control.

Farmers' subjective assessments of profits were derived from their subjective assessments of the yield distribution of the maize crop in plots with and without velvetbean. A triangular distribution was used to elicit the probability distribution of yields (Anderson, Dillon, and Hardaker 1977).⁸ Thus farmers were asked to give the lowest probable maize yield, the highest probable yield, and the most likely yield for each technique on their farm. Each yield point was multiplied by the village-specific output price for maize to arrive at a triangular distribution for gross profits. Total costs (herbicide, fertilizer, hired labor, seed, and transport of harvest) were then subtracted from each point in the distribution to arrive at the distribution of net profits for each technique. The mean and variance of profits per hectare were then calculated from the triangular distribution of net profits.

Input and output prices varied in the three villages, largely because of differences in access to roads and markets. Table 3 presents the most commonly used farm inputs (herbicide, fertilizer, and hired labor) and their prices at the time of the study in the three villages as well as the average output price for maize in each village. Santa Rosa is on a main

⁶ "Subjective assessments" or "subjective probabilities" are commonly employed terms in probability and statistics. They mean that the assessments are the farmer's and imply nothing about the goodness or correctness of those assessments.

⁷ Assuming yields and profits are normally distributed, the distribution is described completely by the mean and variance.

⁸ Several techniques have been proposed and used for eliciting subjective probability distributions (e.g., Francisco and Anderson 1972; O'Mara 1983). However, the triangular distribution is probably the easiest to administer with farmers who have little formal education.

road and thus has the lowest prices for maize and fertilizer but a higher price for the daily agricultural wage, since there are more alternative income-earning opportunities. Venustiano Carranza is the most remote village (road access is poor) and thus has the highest price for maize. Soteapan falls between the other two villages in access to markets and thus prices.

Table 3. Input and output prices (in Mexican pesos) in the three study villages, Veracruz, Mexico

	Soteapan	Venustiano Carranza	Santa Rosa
Herbicide (MxP/l)	22	23	23
Fertilizer (MxP/kg)	0.72	0.72	0.67
Hired labor (MxP/day)	10	15	15
Maize (MxP/kg)	0.8	0.9	0.7

Note: MxP 3 = US\$ 1.

Data on total input costs and mean yields and profits per hectare, calculated from the triangular distribution of the 1993 subjective assessments of yields, are presented in Table 4. Sample averages are presented for the entire sample and for the sub-samples of 1992 users and non-users of the velvetbean intercrop. The average subjective mean and standard deviation of net profits for both technologies (maize grown using the farmer's usual practice and maize grown with the velvetbean intercrop) are calculated from the triangular distribution when family labor is not subtracted as a cost. Expected profits for 1993 are the mean of the subjective probability distribution of profits. Returns to family labor per hectare are calculated by dividing expected profits by number of family labor days per hectare for each farmer. The mean for the sample is found by averaging across farmers. Expected profits per hectare in 1993 and returns to family

Table 4. Expected per hectare profits of maize (in Mexican pesos) with and without the velvetbean intercrop (value of family labor not subtracted as a cost)

Variable	Whole sample (n=92) (mean)	1992 users of velvetbean (n=42) (mean)	1992 non-users of velvetbean (n=50) (mean)
Farmer's usual practice			
Expected profit (MxP/ha)	876	912	847
Standard deviation of profit (MxP)	211	207	214
Expected maize yield (kg/ha)	1,556	1,622	1,501
Herbicide (MxP/ha)	105	89	118
Fertilizer (MxP/ha)	44	40	47
Hired labor (days/ha)	11	13	10
Family labor (days/ha)	54	53	54
Returns to family labor (MxP/ha)	22.3	24.2	20.7
Maize/velvetbean intercrop			
Expected profit (MxP/ha)	..	1,253	..
Standard deviation of profit (MxP)	..	230	..
Expected maize yield (kg/ha)	..	1,814	..
Herbicide (MxP/ha)	..	43	..
Fertilizer (MxP/ha)	..	18	..
Hired labor (days/ha)	..	8	..
Family labor (days/ha)	..	72	..
Returns to family labor (MxP/ha)	..	23.5	..

Note: MxP 3 = US\$ 1.

labor for the farmer's usual maize-growing practice were higher for the 1992 users of velvetbean than for the non-users, although the difference is not statistically significant at the 0.05 level. Expected returns per hectare were much higher for the fields with the velvetbean intercrop than for fields without velvetbean because expected yields were higher while herbicide and fertilizer use were lower. However, the family labor input was also much higher, so on average, returns to family labor in the plot with velvetbean are lower than in the plot without velvetbean.

Table 5 reports expected profits when family labor costs are subtracted valuing family labor at the market wage. On average, expected profits are higher with the velvetbean intercrop. However, at the farm level, the farmer is more interested in comparing expected profits from his own assessment of the two technologies than in average expected profits of the whole sample. The last row of Table 5 shows that the sample average of the difference between expected profits of the maize/velvetbean intercrop and expected profits from the farmer's usual practice for the 42 velvetbean users is MxP 110/ha. Figure 1 presents the distribution of the difference in expected profits across the 42 farmers.

The bars in the histogram of Figure 1 represent all cases that fall between the number directly under the bar and the number below. For example, in 7 cases the difference in expected profits fell between -100 and 0. Thus 24 farmers expect the maize/velvetbean intercrop to be, on average, more profitable than their usual practice, while 18 farmers expect their usual practice to be more profitable.

Since one of the main ways that the usual maize-growing practice varies across farmers is through farmers' varying use of fertilizer

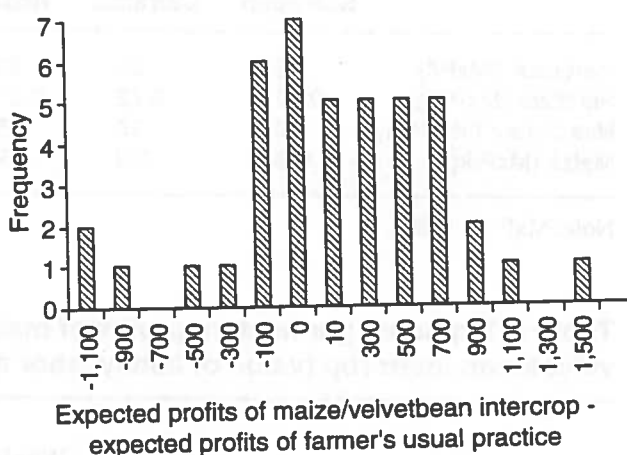


Figure 1. Distribution of the difference in expected profits in the velvetbean study, Veracruz, Mexico.

Table 5. Expected per hectare profits (in Mexican pesos) of maize with and without the velvetbean intercrop (value of family labor subtracted as a cost)

Variable	1992 users Whole sample (n=92) (mean)	1992 non-users of velvetbean (n=42) (mean)	of velvetbean (n=50) (mean)
Farmer's usual practice			
Expected profit (MxP/ha)	179	201	160
Standard deviation of profit	212	207	216
Maize/velvetbean intercrop			
Expected profit (MxP/ha)	..	311	..
Standard deviation of profit	..	230	..
Difference in expected profits	..	110	..

Note: MxP 3 = US\$ 1.

and/or herbicide, it is revealing to look at expected profits under both technologies for farmers who used fertilizer (with or without herbicide), farmers who used herbicide (but not fertilizer), and farmers who used neither input. For this definition of expected profits, all costs, including family labor costs, have been subtracted. The results of this categorization are presented in Table 6.

The difference in results when the farmers are classified according to their use of modern inputs is striking. Farmers who used herbicide but no fertilizer expected that practice, on average, to be more profitable than the velvetbean intercrop. Farmers who used fertilizer still expected the velvetbean intercrop to be more profitable. Although the sample size is small for farmers who use neither herbicides nor fertilizer, those farmers expected much higher profits from maize with a velvetbean intercrop than without velvetbean. Given the small sample sizes and the large variances, a simple test of the hypothesis of equality of means cannot be rejected for any of the three groups. Nevertheless, this classification shows the importance of weed control and access to herbicides in the determination of profits. It suggests that farmers who cannot afford

herbicides may stand to gain the most from adopting a velvetbean intercrop. These results will be discussed more fully as part of the statistical analysis below.

It may be noted that at times expected profits are negative. Since family labor valued at the market wage has been subtracted as a cost, negative profits suggest that some farmers are not earning the market wage for their family labor. Negative profits for some farmers in a village study of Soteapan are also reported in Perales (1992).

The Empirical Model

Of the 92 farmers in the sample, 42 had experimented with the velvetbean intercrop in 1992. For the 50 farmers who did not experiment, no data were available on their expectations of the profitability of the maize/velvetbean intercrop for the next year, 1993. Thus, the 42 farmers who experimented with velvetbean in 1992, for whom there are data on 1993 expected profits, form a non-random sample, which poses a sample selection problem.

If a least-squares regression were applied to this non-random sample of expected profits for 42 farmers, the model would produce biased estimates of the coefficients (Heckman 1979). To

Table 6. Expected profits per hectare (in Mexican pesos) by use of fertilizer and herbicide

		Used fertilizer	Used herbicide	Used neither
Farmer's usual practice				
Expected profits per hectare	Mean (Sample size)	216 (55)	261 (25)	-165 (12)
Maize/velvetbean intercrop				
Expected profits per hectare	Mean (Sample size)	359 (25)	-3 (11)	691 (6)
Difference in expected profits per hectare				
	Mean (Sample size)	140 (25)	-180 (11)	522 (6)

Note: MxP 3 = US\$ 1.

produce unbiased estimates, a two-equation model is estimated. The first equation is based on a binary dependent variable, whether the farmer experimented with velvetbean or not in 1992. This binary or probit model estimates the probability of experimentation with velvetbean in 1992 and is represented by the equation:⁹

$$(1) \quad Z_i = W_i\gamma + u_i,$$

where Z_i takes on a value of 1 for farmers who used velvetbean in 1992 and 0 if they did not, and W_i is a vector of exogenous variables expected to affect the choice to experiment with velvetbean.

The second equation is a regression explaining the difference in expected 1993 profits for farmers who used velvetbean in 1992, and is given by (Greene 1993):

$$(2) \quad Y_i = X_i\beta + \varepsilon_i,$$

where Y_i is observed only when $Z_i=1$. Y_i is defined as the difference in expected profits from the two technologies, and X_i is a vector of variables that have an impact on the expected profitability of velvetbean intercropped with maize relative to the usual maize-growing practice for each farmer. An extra variable calculated from the probit model, the inverse Mill's ratio, is also included in X_i to control for the sample selection bias.¹⁰

The two equations taken together assist us in understanding what type of farmer initially experimented with velvetbean, and, for those farmers who did, what factors are associated with higher profitability expectations for the maize/velvetbean intercrop.

Assuming the error terms u_i and ε_i have a bivariate normal distribution, the Heckman two-step estimation procedure is applied to control for sample-selection bias. The econometric package LIMDEP (Greene 1991) was used for the estimations reported below.¹¹

Explanatory Variables and Descriptive Statistics

Descriptive statistics for variables used in the analysis are presented in Table 7 for the whole sample, for farmers who used velvetbean in 1992, and for farmers who did not use velvetbean in 1992. Choice of explanatory variables in the two equation system is guided by economic theory and past work on adoption (since little previous work has been done on factors affecting experimentation).¹² It is expected that large farms and secure tenure will be positively associated with the decision to experiment with the maize/velvetbean intercrop, since large farms will need to dedicate a smaller proportion of total land area to the new technique, and farmers with secure tenure will be improving their own land. Average farm size in the sample is 9.9 ha, although it ranges from 0.25 to 80.25

⁹ A tobit model could be used with a dependent variable of land area under the new technology. However, most (69%) of the farmers who planted velvetbean in 1992 planted 1/16 ha, so there is little variation in the land area and thus little is gained from using the tobit instead of the probit specification.

¹⁰ The inverse Mill's ratio, λ , is calculated using the probit estimates for γ ($\lambda = \phi(\gamma'W) / \Phi(\gamma'W)$), where ϕ and Φ are the normal density function and cumulative density function, respectively.

¹¹ A more complete analysis is presented in Soule (1994).

¹² Many studies were consulted in developing these hypotheses, including Ervin and Ervin (1982); Featherstone and Goodwin (1993); Feder, Just, and Zilberman (1985); Feder and Onchan (1987); Lee and Stewart (1983); Norris and Batie (1987); Rahm and Huffman (1984); Saliba and Bromley (1984); and Smale, Heisey, and Leathers (1995).

ha. *Ejidatarios* have the most secure tenure of the three classes of farm tenure and make up 55% of the sample.¹³

A farmer who has been cultivating the same maize plot for many years may also be more likely to try velvetbean to improve that plot. Survey farmers had cultivated their maize plots for an average of almost nine years

without letting the soil rest. Velvetbean users tended to use the maize/velvetbean intercrop on fields that had been continuously cultivated (for at least one season per year) for an average of 11 years. This suggests that velvetbean users may have been choosing more degraded fields for the velvetbean intercrop than for growing maize with their usual practice.

Table 7. Summary statistics for the sample of farmers in the velvetbean study, Veracruz, Mexico

Variable	Whole sample (n=92)	1992 users of velvetbean (n=42)	1992 non-users of velvetbean (n=50)
	Mean	Mean	Mean
Difference in expected profits	..	110	..
Farm size (ha)	9.9	9.09	10.6
Years same maize plot cropped since original clearing	8.9	11.4	6.9
Family size	5.6	5.4	5.9
Years of schooling	2.4	2.1	2.6
Age	40.5	42.5	38.8
Number of <i>tareas</i> of velvetbean planted, 1992	0.8	1.8	0.0
Numbers of fields of velvetbean observed	3.9	5.7	2.4
	Percentage	Percentage	Percentage
Binary (0-1) variable:			
Planted velvetbean in 1992	46	100	0
<i>Ejidatario</i>	55	57	53
Child of an <i>ejidatario</i>	22	26	19
<i>Avecindado</i>	23	17	28
Religion (Catholic) ^a	87	95	79
Household head worked off-farm in previous year	50	40	58
Credit constrained	61	62	60
Two or more years of school	53	43	61
Used fertilizer in 1992	60	60	60
Used herbicide but not fertilizer in 1992	27	26	28
Used neither fertilizer nor herbicide in 1992	13	14	12
Participated in the extension campaign in 1992	41	86	4
Venustiano Carranza village dummy variable	27	24	30
Santa Rosa village dummy variable	33	38	28
Soteapan village dummy variable	40	38	42

Note: One *tarea* is a local unit of land measurement which is 25 m on each side (625 m²).

^a Available for only 90 farmers.

¹³ In this study *ejidatarios* have the most secure tenure, children of *ejidatarios* currently have no land of their own but may hope to inherit the land they are working, and *avecindados* work land granted to them on a year-by-year basis and thus have the least secure tenure.

Religion may also be important in explaining experimentation with the maize/velvetbean intercrop, because Catholics and Protestants often socialize separately. In one of the three villages, the intercropping technique was promoted through a Catholic community activist. Eighty-seven percent of the farmers in the sample are Catholic.

Whether the household head worked off of the farm in the previous year is a variable that indicates whether the farmer had alternative income-earning opportunities. It is expected that farmers with other work opportunities, and thus less time to work on their own farms, will be less likely to use velvetbean. Fifty percent of the sample farmers worked off of the farm in the previous year. Also, it is hypothesized that larger families might have more labor available and thus those households will be more likely to use the velvetbean intercrop. The typical farm household in the survey had 5.6 members.

A farmer was classified as credit constrained if he did not receive any credit but wanted it, or received some credit but wanted more. A farmer who is not credit constrained will probably be more likely to purchase chemical fertilizer and herbicide rather than use velvetbean, if the farmer finds returns to the chemical inputs to be high. Sixty-one percent of farmers reported themselves to be credit constrained.

Age and education were included in the regression since older, more experienced, and more educated farmers have often been found to be early adopters of new technologies. Village dummy variables were included to control for village-level effects.

A variety of factors will affect the variation in the difference in expected profits (the second equation estimated in the two-step procedure). Farmers who cultivate older fields are expected to perceive the velvetbean intercrop to be relatively more profitable since their fields may be more degraded. If a farmer used fertilizer or herbicides (or both) in the previous year, it is expected that the farmer would find that technology to be more profitable compared to a velvetbean intercrop with maize.¹⁴ Sixty percent of the farmers used fertilizer (with or without herbicide) in 1992, while 27% used herbicide but not fertilizer. Only 13% used neither. Similarly, farmers who are credit constrained typically use fewer purchased inputs and thus might find the velvetbean intercrop to be relatively more profitable compared to their current practice.

Three variables were included as measures of the level of knowledge of the velvetbean intercrop: (1) number of *tareas* planted with the maize/velvetbean intercrop in 1992; (2) whether the farmer participated in the extension program in 1992; and (3) the number of other fields with the maize/velvetbean intercrop that the farmer had observed on other farms. It is expected that more knowledgeable farmers will consistently perceive the maize/velvetbean intercrop to be either more or less profitable compared to current practices, depending on whether their experiences were negative or positive. Farmers who used velvetbean in 1992 planted an average of 1.8 *tareas*, and velvetbean users observed velvetbean on other fields an average of 5.7 times. Non-users were less aware of velvetbean on other fields and only observed it an average of 2.4 times.

¹⁴ Use of purchased inputs for the previous year rather than the current year were used to avoid the modeling problems associated with simultaneous decisions.

Again, village dummy variables were included to control for village-level effects. Out of the sample of 92 farmers, 90 observations were available for the analysis, since the religion variable had two missing values.

Empirical Results

The first equation of the regression model examines the factors associated with experimentation with the maize/velvetbean intercrop in 1992. Results are reported in the top half of Table 8. Farming households where the head of household did some off-farm work were less likely to experiment with velvetbean than households where the head did not do any off-farm work. It is likely that farmers with off-farm labor and income opportunities have a higher opportunity cost of labor than farmers who do not work off-farm and will thus be less interested in a technique that could increase labor and management time. Contrary to indications concerning education in other adoption studies (Ervin and Ervin 1982), the more educated farmers were less likely to try the velvetbean intercrop. One explanation for less education being associated with velvetbean use may be that the velvetbean technology is easy to understand and implement; there are no labels to read, nor are there strict application schedules to follow. Catholics were more likely to experiment with velvetbean than Protestants, probably because the technique was promoted partially through Catholic activists. Farmers in the village of Santa Rosa were also more likely to experiment with velvetbean than farmers in the other two villages in the sample.

Tenancy and farm size, variables commonly cited as important factors explaining adoption of soil improvements (Lee and Stewart 1983; Feder and Onchan 1987), were not found to be important in explaining the decision to

experiment with velvetbean. It had been hypothesized that poor soil quality, measured by an increasing number of years since the same plot had first been cultivated, would have a positive impact on the decision to use velvetbean, but the data did not bear this out. Family size, age of the head of household, and whether or not the farmer was credit constrained were not important factors in explaining the decision to experiment with velvetbean.

The most important factors explaining the difference in expected profits (expected profits from one hectare of maize with the maize/velvetbean intercrop, less expected profits from one hectare of maize grown with the farmer's usual practice) are the two dummy variables measuring the use of modern inputs: use of fertilizer (with or without herbicide) and use of herbicide (without fertilizer). The coefficient on the dummy variable may be interpreted as the extent to which profits differ for a farmer in the category compared with the base (Kennedy 1992). Compared with a farmer who did not use fertilizer or herbicides, the average farmer who used fertilizer perceived the difference in expected profits to be MxP 517/ha lower. Likewise, the average farmer who used herbicide but not fertilizer found the difference in expected profits to be MxP 837/ha lower than the average farmer who did not use chemical inputs. In other words, farmers who used neither herbicides nor fertilizer found the velvetbean intercrop much more profitable compared with their usual practice of no modern inputs than did farmers who were using the chemical inputs.

It was expected that the fields that had been cultivated the longest would be the most degraded and thus would profit the most from the velvetbean intercrop. However, the sign on the number of years since the farmer had been

cultivating the same plot was significant but negative rather than positive. One explanation is that the fertility-enhancing benefits of velvetbean may be slower to appear on more degraded fields.

The number of fields that a farmer had observed with a velvetbean intercrop is a variable measuring the farmer's information about the profitability of the velvetbean intercrop. The positive sign on this variable

Table 8. Results of the econometric analysis, velvetbean study, Veracruz, Mexico

Factors explaining probability of experimentation in 1992		
Independent variable	Coefficient	t-ratio
Farm size (logged) ^a	-0.0184	-0.099
Tenancy1 (1= <i>ejidatario</i> , 0=other)	0.0873	0.179
Tenancy2 (1=child of <i>ejidatario</i> , 0=other)	0.6394	1.363
Tenancy3 (1= <i>avecindado</i> , 0=other), omitted case
Years same maize plot cropped since original clearing	0.0059	0.370
Religion dummy variable (1=Catholic, 0=other)	1.2493**	2.292
Household head worked off-farm in previous year (1=yes, 0=no)	-0.6156*	-1.674
Family size	0.0340	0.493
Credit constrained (1=yes, 0=no)	0.0782	0.238
Education dummy variable (1=2 or more years of school, 0=0-1 year of school)	-0.8982**	-2.545
Age of head of household	0.0059	0.373
Venustiano Carranza village dummy (1=V.Carranza, 0=other)	0.16014	0.362
Santa Rosa village dummy (1=Santa Rosa, 0=other)	0.8741**	2.025
Soteapan village dummy (1=Soteapan, 0=other), omitted case
Constant	-1.3604	-1.185
Number of observations	90	
Maddala R-squared	0.22	
Percentage of right predictions	72%	
Factors explaining the difference in expected profits for experimenters		
Independent variable	Coefficient	t-ratio
Years same maize plot cropped since original clearing	-13.332**	-2.133
Credit constrained (1=yes, 0=no)	157.32	1.063
Used fertilizer in 1992 (1=yes, 0=no)	-516.98**	-2.538
Used herbicide but not fertilizer in 1992 (1=yes, 0=no)	-837.16**	-3.749
Number of <i>tareas</i> of velvetbean planted in 1992	-58.136	-1.428
Participated in the extension campaign in 1992 (1=yes, 0=no)	-20.367	-0.081
Number of fields of velvetbean observed	21.333**	2.501
Venustiano Carranza village dummy (1=V.Carranza, 0=other)	-258.27	-1.276
Santa Rosa village dummy (1=Santa Rosa, 0=other)	-203.07	-1.089
Soteapan village dummy (1=Soteapan, 0=other), omitted case
Constant	891.6**	2.107
Selectivity parameter	-89.980	-0.407
Number of observations	42	
R-squared	0.41	

Note: * = significant at 10% level; ** = significant at 5% level.

Note: One *tarea* is a local unit of land measurement which is 25 m on each side (625 m²).

^a Farm size is logged because it is expected that the relationship is non-linear.

suggests that farmers who tried velvetbean in 1992 did not have uniformly favorable experiences, but farmers who supplemented their own experimentation with observations of other fields were more favorably impressed by the technology.

Finally, the selectivity parameter, λ , is not significant in the second equation. This means that the profit equation for velvetbean experimenters is probably not different from the unobserved profit equation of farmers who did not experiment with the maize/velvetbean intercrop in 1992.

Policy Implications and Further Research

Policy Implications

This study was conducted very early in the technology dissemination process, and the judgments of farmers involved are based on only a limited experience with velvetbean. Their expectations of the yield and profit impacts of velvetbean are likely to change over time as they gain more experience with velvetbean. However, a few broad conclusions or implications can be drawn from this study and may assist policy makers in modifying the velvetbean technology and in designing other new technologies for the area.

The usual maize-growing practice to which the farmer is comparing the maize/velvetbean intercrop plays an important role in the perceived profitability of the new technology. Farmers who used neither herbicides nor fertilizer found the velvetbean intercrop to be much more profitable compared to their old technology of no modern inputs than farmers who were already using chemical herbicides and

fertilizer. However, these perceptions could change as farmers become more familiar with the technology and experiment with it in new ways (see the discussion in the next section).

The results also indicate that as the value of the household's labor on- or off-farm increased, farmers appeared to find the velvetbean intercrop less profitable or appealing and did not use it. Since herbicide and fertilizer are both inputs that increase labor productivity, farmers who used those inputs found velvetbean less profitable. Farmers who worked off-farm were less likely to use velvetbean because of the crop's increased labor and management requirements. Thus velvetbean may be adoptable on a wide scale by poorer farmers, but it is less likely that farmers with high off-farm wages or on-farm labor productivity will adopt the velvetbean intercrop, even with more education and information.

These results underline the importance of discriminating among different types of farmers and the different practices they use when proposing, developing, and evaluating new technologies. In its current form, the maize/velvetbean technology appears to be most suitable for the poorest farmers who have the least access to credit and cash for purchased inputs. Policy makers should consider whether they wish to encourage development of technologies suitable mainly for the poorest, most marginal farmers or if they would rather implement policies to make credit and modern inputs available to those farmers. There is also considerable scope to develop a modified version of the maize/velvetbean technology, in which the green manure is a complement rather than a substitute for chemical inputs. Such a technology could prove more appropriate for a wider range of farmers in the study area.

Extension Policy

The findings presented earlier also have implications for extension policy and farmer learning. In this analysis, more observations of other farmers' fields planted with velvetbean led to a more favorable evaluation of the technology. However, more observations could have also led to a less favorable evaluation. Either way, the additional observations helped the farmer to arrive more quickly at a stable evaluation, positive or negative, of the technology. In addition, farmers who observed the technology only on their own field may have been unduly influenced by an outlier if they had either very good or very bad results with the maize/velvetbean intercrop. The increased sample size available for inference when farmers observe a technology on other fields counteracts the effect of only one observation driving the evaluation. There is great value to facilitating discussions among farmers and visits to other farmers' fields to evaluate the technology under different circumstances and management techniques.

Finally, this study of the promotion of a new and potentially more sustainable technology has implications for how extension programs are evaluated. The success of extension programs is commonly measured by the rate of adoption of a new technology or increases in production brought about by the new technology (Birkhaeuser, Evenson, and Feder 1991). For the velvetbean technology, as for many sustainable technologies, we do not necessarily expect large increases in output but rather a more stable, sustainable output over an extended period. In addition, an extension program may be very successful in its goal of providing information to farmers so that they can make the best decision in their own circumstances, but the program may still produce low rates of adoption if the technology turns out to be most appropriate for an

ecological niche or only one segment of farmers. We might expect low adoption rates more frequently with technologies that have had little experiment station testing or are best suited to specific niches, compared to expected adoption rates for technologies that are more profitable over a wide area and thus adopted by many farmers. Thus, it may be more appropriate to measure the impact of extension on farmer knowledge or on some measure of sustainability rather than only on yields or adoption rates.

Social Cost-Benefit Analysis and Further Research

An important next step is to measure the impact of the extension program and the velvetbean technology on some measure of sustainability. Unfortunately, such an analysis was beyond the scope of this study. To consider the question, first a measure of sustainability would need to be defined. Common measures are rates of soil loss or changes in soil nutrients, but such studies are rarely conducted on farmers' fields because they are costly. In addition, we need to consider the sustainability of the current practices as well as the sustainability of the new technology. Since farming practices vary widely across farmers, we would want to consider more than one current practice. It may turn out that one of the practices currently used by farmers is not less sustainable than the new technology being proposed. We simply do not have the data to know.

To perform a social cost-benefit analysis, we would also need information on externalities. If the new technology is not increasing profits for farmers, does it have socially desirable externalities such as a decreased loss of topsoil or less chemical run-off into drinking water supplies? What is the value of these externalities to society at large?

Another question raised is the relative importance of sustainability in the maize production system. Is a hectare of rainforest converted to pasture a greater threat to sustainability than a hectare of maize grown with limited use of herbicides and fertilizer (the current practice of most farmers)? This is an important question in the Sierra de Santa Marta, given that in some villages, such as Venustiano Carranza, a much greater area is given over to pasturing cattle than to maize production (400 ha in pasture compared to 50 ha in maize in 1993), and the destruction of the rainforest for pasture continues.

Conclusion

Although poorer farmers might adopt velvetbean on a wide scale, from these initial results it seems less likely that farmers who currently grow maize successfully with fertilizer and herbicides, or farmers who have off-farm work opportunities, will adopt the maize/velvetbean intercrop. However, these conclusions must be qualified in several ways. First, this study has not accounted for the full costs of using modern chemicals, such as the incidence of poisonings from incorrectly used herbicides (Buckles and Erenstein 1996) and the risks of chemical run-off into drinking water supplies. Second, the Mexican economy has changed dramatically since this study was conducted in 1993. A lower maize price, coupled with higher prices for chemical inputs and the more restricted availability of credit, may make the velvetbean intercrop more attractive to farmers. Finally, farming is a dynamic enterprise. Farmer experimentation with the technology has just begun, and future experimentation may lead to a method that increases production and modifies labor needs so that velvetbean, or another green manure, becomes more acceptable to farmers.

This research raises still another policy issue. Although velvetbean appears to be an appropriate technology, especially for the poorest farmers, perhaps other technologies could help these farmers even more. It appears that farmers who can afford herbicides and fertilizer achieve large gains in productivity by using these inputs. Poorer farmers cannot afford them and often do not have access to the credit programs through which the better-off farmers can purchase inputs. In the short term, it may be more useful to make currently available productivity-enhancing inputs available to the poorest farmers rather than to design new technologies that are more profitable than traditional practices but still do not approach the profitability of modern inputs. However, in the long term, it may prove worthwhile to investigate options for modifying the velvetbean technology and/or incorporating other green manures into the maize cropping system. In addition, the use of a green manure in combination with inorganic fertilizer, judiciously applied, might prove acceptable to farmers and enhance the sustainability of maize production in ways that the use of chemical fertilizer alone could not do. Future research should also assess whether using velvetbean as an intercrop is actually more sustainable than current practices or whether social benefits of wide-scale velvetbean adoption would be greater than social costs. Without a more comprehensive understanding of the sustainability issues affecting maize production systems in the study area and in similar sites, policy makers will be hard pressed to make well-informed decisions about technological options that are profitable for poor farmers, advantageous to their communities, and beneficial to the environment.

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