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An economic Analysis of the *Abonera* Maize Production System in the Atlantic Coast of Honduras

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CIMMYT

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Contents

Abstract

This paper compares the economics of the *abonera* maize production system, in which maize is grown in rotation with a green manure crop (velvetbean, *Mucuna deeringiana),* with traditional bush-fallow cultivation of maize in the Atlantic Coast area of Honduras. A probabilistic cost-benefit analysis of introducing velvetbean into the existing maize cropping pattern is carried out for the field, farm, and regional level. The probabilistic approach allows for a more comprehensive assessment of economic profitability, one which recognizes that farmers are interested in reducing production risk as well as obtaining increases in average net benefits. The analysis reveals that the *abonera* system provides significant returns to land and family labor over the six-year life cycle. The *abonera* is not only more profitable than the bush-fallow system but reduces the variability in economic returns, making second-season maize a less risky production alternative. Although the labor requirement per unit of land is smaller in the *abonera* system than that in the bush-fallow system, the larger area allocated to maize implies a net increase in labor requirements at the farm level. At the regional level, widespread adoption of the *abonera* system appears to have increased the importance of the second season in total maize production. Although a causal link to adoption of the *abonera* system cannot be established conclusively from the data, adoption of the system remains a likely explanation for the changes observed in aggregate maize production in the Atlantic Coast region. Land rental prices for sowing second-season maize also reflect the widespread impact of the *abonera* system.

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Introduction

With the introduction of a legume *(Mucuna deeringiana,* known as velvetbean or mucuna) into the traditional bush-fallow rotation system, a new maize production alternative became available to farmers in Atlántida, Honduras. In the traditional bush-fallow system, which lasts for six years, a farmer cultivates a plot of maize twice a year for two consecutive years and then leaves the plot in fallow for four years. In the *abonera* system, the plot is typically planted to maize once a year during the second cropping season and to velvetbean in the first season, in a continuous maize-velvetbean rotation. The velvetbean plot is referred to as an *abonera* because of its soil improvement characteristics.

Three main beneficial effects can result from incorporating a legume such as velvetbean into a cropping system: soil and water conservation, weed control, and fertilization. Each of these benefits has different consequences for the profitability of the cropping system. Soil conservation effects are related to enhancing the cropping system's long-term productivity or to reducing the cost of maintaining system productivity over time. Water conservation effects are related to short-term increases in the productivity of the cropping system and to a reduction in yield variability. Weed control effects are related to reducing short-term costs of weed control and to the off-farm costs associated with contamination of the environment from herbicides. Finally, fertilization effects are related to short-term reductions in the cost of applying fertilizer.

The beneficial effects of incorporating velvetbean and other green manure cover crops into different cropping systems in Honduras are well recognized (Arellanes 1995, Mausolff and Farber 1995, Sain, Ponce, and Borbón 1994, Triomphe 1996). Wide adoption of the *abonera* system in the Northern Coast of Honduras (Buckles et al. 1992) indicates that for a majority of farmers the system is a profitable alternative for growing maize in the second season. Studies using standard cost-benefits analysis have found the *abonera* system to be more profitable on average than the traditional bush-fallow cropping system (Sain, Ponce, and Borbón 1994).

In this paper, we expand the standard cost-benefit analysis of crop production alternatives to take a more comprehensive look at the costs and benefits of introducing velvetbean into the maize cropping pattern, including the potential for reducing the risk faced by maize farmers. Each alternative is evaluated in terms of its economic returns to land and labor using probabilistic cost-benefit analysis. The analysis is done at the field (plot), farm, and regional levels.

At the field level, the analysis compares the choices that a farmer faces when a new unit of land becomes available for maize production (the allocation of land between maize and other uses is not considered). The farmer can choose to plant maize in the traditional bush-fallow system or in the new continuous *abonera* system.

Next, we examine the consequences at the farm level of choices made at the field level, particularly the effects on land and labor allocation. In the *abonera* system, velvetbean remains in the field during the first cropping season, so maize output is limited to second-season maize each year. In the bush-fallow system, maize is produced in the first and second season during the first two years. If farmers seek to meet some of their household maize consumption needs through their own maize production, the use of the traditional or the *abonera* system implies different restrictions on the allocation of land and labor.

At the regional level, widespread diffusion of the *abonera* system implies a change in the relative contribution of second-season maize to total maize production. Although causality between the adoption of the *abonera* system and the growing share of second-season maize in total production is difficult to establish, the analysis attempts to measure the degree of association between the two events. We also examine the impact of the *abonera* system on the rental market for land to produce maize.

Before we turn to the results of the analysis, a brief description of some of the methods used in probabilistic cost-benefit analysis is useful.

Probabilistic Cost-Benefit Analysis

Cost-benefit analysis is a simple, relatively easy technique for determining the relative profitability of alternative cropping practices. The analysis compares alternative practices with different flows of benefits and costs from year to year. Another advantage of cost-benefit analysis is that it requires less data than other, more comprehensive techniques (Pagiola 1994).

If there are two technological alternatives for maize production, the traditional bush-fallow rotation system and the *abonera* rotation system, then the annual net benefits per unit of land in year t generated by the traditional system (NB_t^t) and the *abonera* (NB_t^a) are defined as the difference between annual gross benefits and annual costs:

[1] $$NB_t^t = p_m * Y^t - C^t$$

[2] $$NB_t^a = p_m * Y^a - C^a$$

where Y^a and Y^t are annual maize yields from the *abonera* and the traditional alternatives, p_m is the price of maize, and C^a and C^t are the annual production costs, excluding land, of both alternatives.

To assess the profitability of the *abonera* system relative to the bush-fallow system, we calculated the net present value (NPV) of the incremental flow of net benefits generated by the alternatives being compared (Steiner 1980). The NPV of the incremental flow of net benefits is given by:

[3] $$NPV_i = \sum_{t=0}^{T} \frac{1}{(1+r)^t} \; [p_m * (Y_t^a - Y_t^t) - (C_t^a - C_t^t)],$$

where r is the rate of discount and T is the time horizon considered in the analysis.

The *abonera* system will be more profitable to the farmer than the bush-fallow system if the NPV is greater than zero. From [3] it can be seen that the relative profitability of the *abonera* system depends on two factors: the discounted value of the flow of the value of annual yield differences, and annual cost differences.

Traditionally, cost-benefit analysis uses average or modal values of the variables to calculate NPV. This approach is deterministic in the sense that no measurement of uncertainty is attached to the resulting net benefits. For example, consider the calculation of the gross benefits for the *abonera* system in a given year. Assume that the average maize price received by farmers (p_m) is \$0.09/kg and the average maize yield using the new technology (Y^a) is 2,000 kg/ha. The deterministic gross benefit (GB^a) is: $GB^a = 0.09 * 2{,}000 = \$180/\text{ha}$. This statement simply says that a farmer using the *abonera* will probably get a gross benefit of \$180/ha.

This statement can be enhanced by performing a sensitivity analysis considering worst- and best-case scenarios as well as the modal case. The hypothetical example provided in Table 1 indicates that the possible values of gross benefits range from a worst-case low of \$144/ha to a best-case high of \$270/ha, with a modal or most common value of \$180/ha. However, while it is more revealing, sensitivity analysis does not indicate the *likelihood* that a farmer will realize high, low, or average gross benefits. Probabilistic cost-benefit analysis attempts to overcome this limitation by considering not only the range of values of the variables but also by attaching to these values a measure of the likelihood of their occurrence (Pouliken 1970, Reutlinger 1971, Anderson and Dillon 1992). This information allows for a more comprehensive assessment of economic profitability, one which recognizes that farmers are interested in reducing production risk as well as obtaining increases in average net benefits (Anderson and Dillon 1992). The impact of each alternative on the variability of the NPV can be compared, thereby providing a measure of the impact of alternatives on the levels of uncertainty or risk faced by farmers. Some or all of the parameters included in this kind of analysis must be treated as random variables from which a cumulative distribution function can be calculated. These functions in turn make it possible to associate probabilities of occurrence to the range of each variable.

Maize yield is a good example of a random variable. Maize produced by farmers under rainfed conditions is subject to a large number of unpredictable events which result in yield variability from year to year and from farmer to farmer. If we assume that this yield variability follows a normal distribution, then maize yield (Y) would be associated with a normal cumulative distribution, represented as $Y \sim N(\mu, \sigma^2)$, where the mean is μ, and the variability around the mean (variance) is σ^2.

Table 1. Hypothetical sensitivity analysis

	Scenarios		
Parameter	**Worst**	**Modal**	**Best**
Maize price (US\$/kg)	0.09	0.09	0.09
Maize yield (kg/ha)	1,600	2,000	3,000
Gross benefits (US\$/ha)	144	180	270

Unlike a deterministic cost-benefit analysis, which produces a single value, the probabilistic approach produces the cumulative distribution function of the NPV of the economic returns from the alternatives. A comparison of these measures makes it possible to assess not only the impact of alternative practices on the average economic returns but also on the risk the farmer faces.

Probabilistic cost-benefit analysis is carried out through Montecarlo simulation. The cumulative distribution function of the NPV is obtained on the basis of a simulated sampling process from the probability distribution of the random variables included in the analysis. Following the example above, the cumulative distribution function of the gross benefits is obtained by sampling the probability distribution of the yield variable and multiplying it by a sampled value from the probability distribution of the price variable. This process is repeated many times to obtain a robust estimate of the cumulative distribution function of the gross benefits.

Model Specifications

To run the simulation model described above, the maize production technology must be specified along with the cumulative distribution function of all random variables and the values of the non-random variables included in the calculation of the NPV, as outlined in [3]. In the analysis, maize yields and prices are treated as random variables and represented by their cumulative distribution functions. For simplicity, technology is considered nonrandom and represented by a set of constant technical coefficients. The time horizon of the analysis and the discount rate, two other variables in the analysis, are also considered nonrandom (Table 2).

To enhance the integrity of the analysis, significant correlations between the random variables were examined. The analysis indicated that maize yields under the alternative cropping systems were strongly correlated, probably as a result of the common climatic conditions affecting the distribution during any given season. Consequently, the correlation coefficient used in the analysis assured that when sampling from the yield distribution, samples for a high yield for the *abonera* system in the second season were matched with a sample from the high tail of the probability distribution of the yield of second-season maize using the bush-fallow system. Given the small size of the second-season maize area relative to the national maize market, it is assumed that there is no correlation between maize price and maize yield.

Maize Production Technology

Maize production technology in the Department of Atlántida is relatively simple and uniform between cropping seasons and systems. There are no important differences in maize production technology between the bush-fallow and *abonera* systems, and seasonal differences are minimal (Buckles et al. 1992). Most farmers prepare land for planting by slashing and burning fallow fields during the first season and by slashing crop residues or the velvetbean that has grown in an *abonera* in the second season (Table 3). Farmers typically use local maize varieties at a planting density of approximately 15 kg/ha of seed. Maize is

Table 2. Characteristics of the variables used in the simulation model to calculate the net present value of net benefits

Variable	Characteristic
Maize yields under different systems	Random
Input and output prices	Random
Technology (technical coefficients)	Nonrandom
Time horizon and rate of discount	Nonrandom

weeded twice, with the first control usually done manually at about 30-35 days after sowing and the second control done with herbicide at 40-45 days after sowing. According to survey and interview data, chemical pest control is infrequent.

Most farmers do not use fertilizer on first-season maize, probably because of the relatively low level of profiïbility of maize production in this season and the high production risk. In-the second season, however, about 44% of farmers surveyed in 1992 applied small amounts of nitrogenous fertilizer (these were typically farmers growing maize in the bush-fallow system). The application of fertilizer in the second season is less risky than in the first season and potentially more profitable. Nevertheless, in the simulation, annual budgets were calculated without fertilizer to avoid raising the costs of the bush-fallow system. This is in keeping with the customary practice in cost-benefit analysis of conservatively judging the alternative practice (in this case, the *abonera* system) under the "worst" possible conditions.

In the first season, farmers double the maize plant before harvest and pick the ears later, once they have dried. The doubling operation is not needed during the second season as the ears dry on the upright plant under the winter sun.

Management of the *abonera* is also relatively simple and uniform. Velvetbean seed is sown manually with a dibble stick when planted for the first time but subsequently reseeds itself with very limited additional labor requirements. Although some manual reseeding may be needed occasionally to maintain even plant stands, and although velvetbean in maize is controlled during the season (as part of the weeding operation), the costs associated with management of velvetbean after the first year are negligible and ignored in the simulation.

The technical coefficients used in calculating annual budgets for the maize production technology described above are considered nonrandom in the simulation. Information on technical coefficients was obtained from informal surveys by the Secretaría de Recursos Naturales (SRN) of Honduras and the International Maize and Wheat Improvement Center (CIMMYT) during 1991 and 1992 (Table 4).

Table 3. Maize production technology in the first and second cropping seasons, Atlantic Coast, Honduras

	Cropping season	
	First	**Second**
Land preparation	Slash and burn (69%)	Slash (94%)
Type of seed	Local (72%)	Local (65%)
Plant density (number seeds/ha)	41,000	44,000
Weed control (number of weedings)	2 (60%)	2 (70%)
Fertilizer application	No (71%)	No (56%)
Doubling maize before harvest	Yes	
Harvest	Manual (100%)	No Manual (100%)

Source: Buckles et al. (1992).
Note: Values in parentheses correspond to percentage of surveyed farmers.

Maize Yields As noted earlier, maize yields are highly unpredictable throughout the Atlantic Coast of Honduras because rainfall varies considerably from year to year and season to season. Over 1962-91, annual rainfall on the Atlantic Coast fluctuated around an average of 3,034 mm/yr. Although the data show a continuous declining trend, years of dry weather and high rainfall alternate in a four- to five-year cyclic pattern over the period. The years 1963, 1970-72, 1975, 1985-86, and 1991 were particularly dry. In contrast, 1967, 1973, 1976, 1979, 1984, and 1988 had unusually high precipitation.

Besides the annual frequency of rainfall, rainfall distribution throughout the year is also an important source of uncertainty for farmers in Atlántida. Annual rainfall distribution is bimodal (Figure 1). Average annual precipitation at Buena Vista, Atlántida is approximately 3,063 mm, with some rain falling virtually every week of the year (Figure 2). The first rains usually begin in June, establishing the first cropping season *(primera).* Rains are light at this

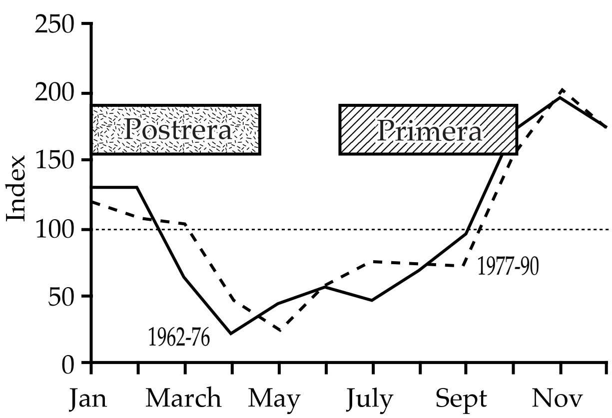

Figure 1. Rainfall and maize cropping seasons, Department of Atlántida, Honduras, 1962-91.

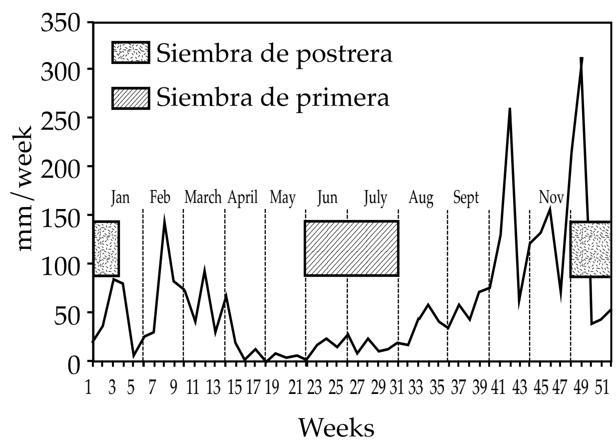

Figure 2. Average weekly rainfall, Finca Buena Vista, Atlántida, Honduras, 1989-91.

Table 4. Technical coefficients for maize in different cropping systems and seasons, Atlantic Coast, Honduras

Description	Unit/ha
Labor for slashing *guamil*	20.0 person-days
Labor for slashing *guatal*	15.0 person-days
Labor for slashing, first-season	12.0 person-days
Labor for slashing *abonera*	10.0 person-days
Maize seed	14.5 kg
Labor for sowing maize Velvetbean seed	5.0 person-days
Labor for sowing velvetbean	14.0 kg 5.0 person-days
Gramoxone chemical weeding	21
Labor for applying Gramoxone	2.5 person-days
Labor for manual weeding of *abonera*	9.0 person-days

Note: A *guatal* is a field left uncultivated to allow natural regrowth for three years or less. A *guamil* is a field left uncultivated to allow natural regrowth for approximately five or more years.

time and quite variable from year to year, creating a production risk for farmers planting first-season crops. Planting may be delayed or repeated because of poor germination. The heaviest and most consistent rainfall on the Atlantic Coast coincides with the last trimester of the year (October-December) and initiates the second cropping season *(postrera).* Rainfall during the later part of the second season is erratic, however, and crops run the risk of drought stress. The rains drop off sharply in April, interrupting most agricultural activities. May is the driest month of the year. This short, sharply demarcated dry period is known as summer *(verano).*

In addition to the risk caused by light or late rains during the first season and drought stress during the second season, rainfall patterns also contribute to the risk of soil erosion resulting from extremely heavy daily cloudbursts at various times of the year (Figure 3). In 1989, some 325 mm of rain fell on October 20, while in 1990 and 1991 several rainfall events exceeded 200 mm/day. Without adequate ground cover, considerable soil loss can occur in a singleday .

Heavy rains during the later part of the first season can also provoke high maize yield losses from ear rot *(maíz muerto,* caused by *Stenocarpella* spp. and other pathogens). The disease is transmitted from crop residues and other pathogen reservoirs to plants weakened by poor nutrition, insect damage, and abiotic stresses. During flowering and grain-filling, maize plants are vulnerable to the rapid spread of *Stenocarpella* spp. through rainfall splash, which may be responsible for the relatively high incidence of ear rot in Atlantic Honduras.

Variability in rainfall is the main source of yield uncertainty, which in turn is the main source of income uncertainty faced by small-scale farmers. Compared to the bush-fallow system,

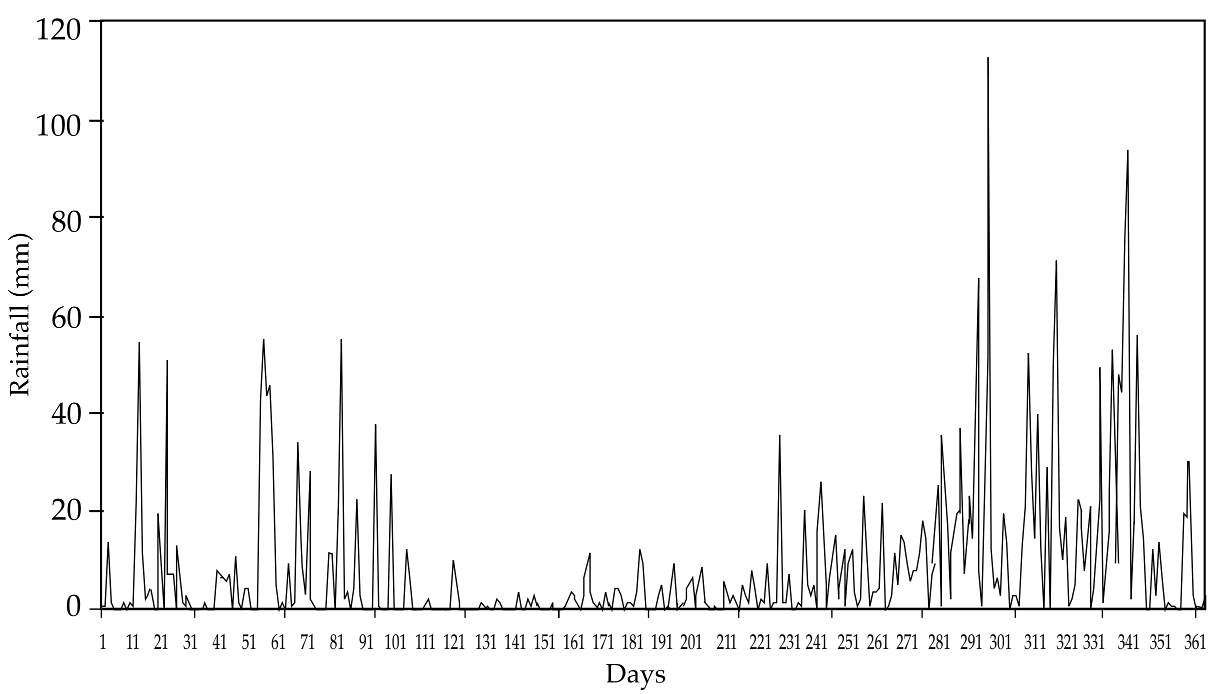

Figure 3. Average daily rainfall, Finca Buena Vista, Atlántida, Honduras, 1989-91.

the *abonera* system has two main effects on the distribution of maize yield: it increases average yields and reduces yield variability. These effects arise mainly from four sources:

1. A residual effect on soil fertility from the nitrogen that velvetbean leaves in the soil. The main impact of this short-term effect is to increase the mean of the yield distribution.
2. Better moisture conservation because of the mulch left in the field. This is also a short-term effect, but its main impact lies in reducing the variability of the yield distribution. Better management of soil moisture reduces maize yield losses from variable rainfall.
3. An improvement in soil quality from a reduction in soil erosion. This factor requires some time to have a significant impact on maize yields. In the long run it is expected that better soil characteristics will increase the mean of the distribution, reducing its variability as well.
4. Better weed control in the crop. As in the previous case, some time must elapse before this factor can have a significant impact on maize yields. Its effects are the result of a reduction in the quantity and a change in the quality of the weed population. In this case, however, a short-term reduction in the costs of weed control may be expected.

To capture the variability of maize yield, the cumulative distribution function for maize yield needs to be estimated. Table 5 shows the summary statistics for maize yield in the first and second seasons reported by farmers for the 1991-92 agricultural year. These data, obtained through a large formal survey, are the most complete and comprehensive source of yield information available from the region.

An empirical cumulative distribution function for maize yield in different seasons and cropping systems was generated from the 1992 survey data (Figure 4). The distributions illustrate the risk reduction effects of the *abonera* system. The cumulative distribution function for second-season maize grown in an *abonera* lies to the right of the other two distributions. Figure 4 shows that the probability of achieving a yield level less than or equal to 1,000 kg/ha is about 70% in the first season, about 62% in the second season without an *abonera*, and as low as 40% for second-season maize grown in an *abonera*. This result illustrates the lower risk of heavy losses in second-season maize production achieved by farmers using the *abonera* system.

Table 5. Maize yield (kg/ha) distribution in different cropping seasons, Department of Atlántida, Honduras, 1992 farmer survey

		Second season	
Parameter	**First season**	**Without *abonera***	**With *abonera***
Mean	851	1,007	1,498
Standard deviation	509	742	954
Coefficient of variation	0.60	0.74	0.64
Minimum	209	201	201
Maximum	2,667	3,978	4,546
Average 25% worst	313	363	486
Count	104	47	63

Source: CIMMYT-SRN farmer survey, Department of Atlántida, Honduras, 1992.

However, a comparison of these data with other yield data from the region suggests that the estimated average yields from the 1992 survey may be considerably below what can be considered normal. Table 6 shows that data for mean maize yields obtained through other sources (surveys or trials) were consistently higher than data gathered through the formal survey. For second-season maize grown in the *abonera* system, for example, the average yield estimated from the four additional data sources was 2,645kg/ha, well above the level reported in the formal survey. The discrepancy in yield estimates between the 1992 survey and other data sources may have occurred because farmers under-report yield (a common limitation in farm surveys) and/or because maize yields were affected by drought in 1991.

Despite being at variance with other data sources, the estimate of yield variability from the 1992 survey seems correct. The coefficient of variation for second-season maize grown in the *abonera* system (0.64) is much smaller than for second-season maize grown without an *abonera* (0.74), a tendency consistent with similar comparisons made in other regions.[1] As might be expected, the coefficient of variation for first-season maize

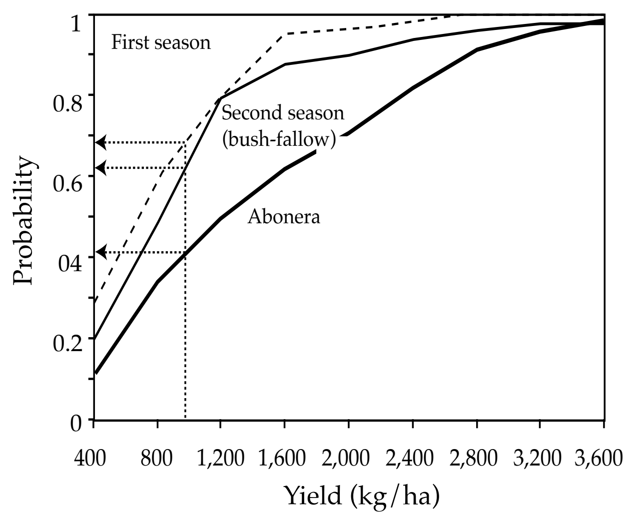

Figure 4. Empirical cumulative distribution function of maize yield in the bush-fallow system (first and second season) and under an *abonera*, Department of Atlántida, Honduras.

Table 6. Average maize yield (kg/ha) by system and season as reported in various surveys and trials, Atlantic Coast, Honduras

	First season			Second season					
				Without *abonera*			With *abonera*		
Source	Mean	s.d.	No. obs.	Mean	s.d.	No. obs.	Mean	s.d.	No. obs.
1985/86 verification trials	1,662	"	8	"	"	"	"	"	"
1989 informal survey				1,472		11	2,638	"	23
1991 informal survey	1,668	"	7	"	"	"	2,638	"	9
1992 informal survey	"	"	"	1,413	"	7	2,340	"	8
1992 formal survey	851	509	90	1,007	742	47	1,498	954	63
1992/93 field sampling	"	"	"	"	"	6	2,835	"	46
Total	"	"	**97**	**"**	**"**	**71**	**"**	**"**	**149**

Source: Licona (1987) for verification trials, 1985/86; Avila Nájera and López (1990) for informal survey, 1989; CIMMYT-SRN for informal surveys, 1991 and 1992; Buckles et al. (1992) for formal survey; and Triomphe (1993) for 1992/93 field sampling.
Note: "s.d."= standard deviation; "no. obs." = number of observations.

[1] Mausolff and Farber (1995) reported on trials in Central Honduras in which the coefficient of variation of maize yield was 0.47 under the *abonera* system and 0.67 without the *abonera.*

(0.60) is smaller than for second-season maize grown in either system, possibly because of the much lower variability of rainfall during the first season.

Building the basic cumulative distribution function. A theoretical distribution was fitted to the data from the 1992 survey. Results showed that the probability distribution which best fit the data was the lognormal distribution function.[2] This function is defined by two parameters: the mean and the standard deviation. The second column of Table 7 shows the values of these parameters before transformation.

Incorporating additional information. To correct for the apparent underestimate of yield levels in the survey, the yield mean of the lognormal distributions was scaled up by a specified factor. The standard deviation was adjusted to preserve the coefficient of variation. The new mean was estimated by calculating the average of the mean yield from all available sources of information.[3]

The third column of Table 7 shows the results of the transformation. According to the new parameter values, planting maize in an *abonera* system almost doubles average yields compared to yields of maize planted in the second season without an *abonera* or yields of first-season maize. This finding is consistent with the common perception of yield differences expressed by farmers, researchers, and extension agents familiar with the technology and with findings of other measured estimates (Avila Nájera and López 1990; Duron 1992; Mausolff and Farber 1995).

Farm Prices

Prices that farmers receive for their products and pay for inputs and services are also subject to considerable variability resulting from market forces (supply and demand) and policies that modify farmers' economic environment. Prices consequently represent an important source of uncertainty for farm household income.

Table 7. Transformed mean yield and standard deviation for maize grown in different seasons and cropping systems, Atlantic Coast, Honduras

	Parameters of the lognormal probability distribution: mean μ (kg/ha) and standard deviation σ (kg/ha)	
Variable	**Before transformation**	**After transformation**
Yield, first-season maize	μ = 851; σ = 509	μ = 1,394; σ = 834
Yield, second-season maize without *abonera*	μ = 1,007; σ = 742	μ = 1,413; σ = 1,041
Yield, second-season maize with *abonera*	μ = 1,498; σ = 954	μ = 2,387; σ = 1,520

2 The lognormal distribution is commonly used to represent random variables that are the product of a large number of other, unknown variables. Like the normal distribution, it is characterized by two parameters, the mean and the standard deviation, but unlike the normal distribution only positive numbers are allowed in its domain.

3 Several weighting procedures using the number of observations as a base to build the weights were attempted without satisfactory results. The main reason for this is the uneven structure in the number of observations for each system in the different data sources. For example, the weight for the 1992 survey varies from 42% in the case of maize grown with an *abonera* to a high 94% for first-season maize.

To analyze the past performance of farm-level prices for maize and the main production inputs, nominal prices (in Honduran lempiras) were deflated by the Consumer Price Index (base = 1985) and converted to US dollars at the official exchange rate. As can be seen in Table 8, real prices of maize, inputs, and services have declined steadily over 1980-91, with a sharp decline in 1990 and 1991. This long-term downward trend is the result of the structural adjustment programs implemented in Honduras (Diaz Arrivillaga y Cruz Díaz 1992).

Another important characteristic of maize prices in Honduras is that they fluctuate over the year. Some 80% of national annual maize production is produced in the first season, with the result that maize prices are lowest during the three months when the harvest occurs (October- December). By January, the national maize supply begins to diminish and maize prices rise until second-season maize is harvested (March-April). As the supply of second-season maize flows into the market, prices drop again, but maize prices still remain above the annual average because the total volume is relatively low. In June prices start to rise once more, and the seasonal price cycle starts over (Figure 5). The amplitude of the seasonal price fluctuation between the second-season harvest (+5%) and the first-season harvest (-15%) is high, providing farmers with a strong incentive to plant second-season maize.[4]

Maize prices at the farm gate were calculated by adjusting annual farm prices by the seasonal indices of +5% for second-season maize and -15% for first-season maize (Table 8). Field prices were estimated by adjusting the farm gate price to reflect the costs of harvest and transport. These amounted to 25% of the farm gate price in the first season, 20% in the second season for maize grown with the *abonera* system, and 15% for maize grown in the second season without the *abonera* system. The differences in these figures reflect differences in the cost of labor to double the maize in the first season and to harvest ears with velvetbean in the field.

Maize seed prices for local varieties were estimated using opportunity costs (that is, second-season farm gate prices were used as the price of seed for first-season maize and vice versa).

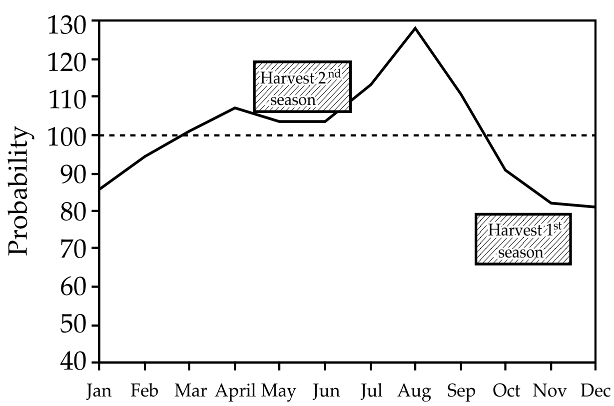

Figure 5. Seasonal pattern of maize wholesale prices, Honduras, 1970-91.

Price uncertainty is introduced into the simulation by assuming that prices follow a uniform cumulative distribution function, with the maximum and minimum prices chosen from maximum and minimum values achieved during 1987-91.[5] All prices in that range have the same probability of coming out in the simulation. This assumption is consistent with the price band scheme adopted by Honduras to stabilize internal prices for agricultural products. Under this scheme, the government establishes maximum and minimum prices (band) for

4 An additional advantage of the second season is that the harvest occurs during a relatively dry period, which improves the phytosanitary condition of maize relative to maize harvested during the first season.

5 We selected 1985 as the initial year because this is when structural adjustment began in Honduras.

the product of interest based on past variation in international prices. Supply and demand (trade) determine the internal price for the product within the band while the government keeps prices within the band limits by regulating the import and export markets. Prices are linked for the simulation to draw the same price for the same season. Table 9 summarizes the probability distributions of the prices used in the simulation.

Another output of the bush-fallow system that needs to be priced for the simulation is the firewood produced during the fallow period. After four years of fallow, a significant amount of firewood can be collected and sold on the market, although access to firewood markets varies considerably within the region depending on proximity to major urban centers. In our analysis, the level of production is assumed to be 200 cargas over the four-year fallow. The average price for firewood in 1992 (based on an informal survey) was used as a nonrandom variable, since the lack of systematic data precluded the estimation of a probability distribution for this variable. Finally, the discount rate was assumed to be 10% per year, in keeping with the average real rate of interest in Honduras during 1985-91.

Table 8. Real prices of maize, main input (Gramoxone), and labor, Department of Atlántida, Honduras

			Maize price		
Year	Gramoxone (US$/1)	Labor (US$/day)	Annual (US$/kg)	First season (US$/kg)	Second season (US$/kg)
1980	7.56	3.90	0.18	0.15	0.19
1981	10.27	3.67	0.16	0.13	0.16
1982	9.80	3.09	0.17	0.14	0.18
1983	8.61	2.93	0.17	0.14	0.17
1984	7.79	2.67	0.14	0.12	0.15
1985	7.13	2.50	0.16	0.14	0.17
1986	6.85	2.76	0.17	0.14	0.17
1987	6.19	2.62	0.17	0.14	0.17
1988	5.92	3.20	0.16	0.13	0.17
1989	7.33	1.99	0.16	0.13	0.17
1990	4.24	0.78	0.08	0.07	0.08
1991	4.06	0.52	0.14	0.12	0.15

Note: First-season and second-season prices calculated by weighting annual maize prices by a seasonal index of -15% and +5%, respectively.

Table 9. Probability distribution for maize yields and prices used in the simulation

Variable (unit)	Probability distribution (parameters)
First-season maize (US$/kg)	Uniform (0.07, 0.14)
Second-season maize (US$/kg)	Uniform (0.08, 0.17)
Gramoxone (US$/1)	Uniform (4.06, 7.33)
Labor (wage) (US$/person-day)	Uniform (0.52, 3.20)

Note: For the uniform distribution the parameters are the minimum and maximum values.

[6] A *carga* is a local unit of measure equivalent to approximately 50 units of firewood.

Implications at the Field Level

Before we present the results of the simulation analysis, a few observations are in order.

The unit of analysis is a single, indivisible plot of land to be cropped with maize. We assume that a single plot is available (it is assumed to be an extra or marginal unit), and that it is allocated to maize (which is assumed to be the most profitable alternative). Under these circumstances, the options opened to the farmer are either to cultivate the plot under the bush-fallow system or the *abonera* system.

The period of comparison is six years, the typical life-cycle of the bush-fallow system. As described earlier, in the bush-fallow system a farmer will typically produce first-season maize and second-season maize for two consecutive years. Afterwards, the plot will remain fallow for four years before being cleared and cultivated again. The entire six-year cycle results in a land use intensity of 33%.

In contrast, if the farmer chooses the *abonera* system for producing maize, the plot is typically cropped once a year in a continuous rotation of maize with velvetbean. If we assume that the period of comparison is the six-year life-cycle of the bush-fallow system, then the land-use intensity of the *abonera* system is 50%.

For the analysis we assume that the *abonera* system begins to have a positive impact on maize yield in the second year after velvetbean is introduced~ and that yields remain constant over subsequent years. In the first year, velvetbean is sown at maize flowering. The velvetbean does not compete greatly with the maize and consequently has no significant detrimental impact on maize yields. Maize yields increase gradually during subsequent years, but for simplicity and with a view to judging the *abonera* system conservatively, the simulation assumes that yields remain constant over the six-year cycle.

Annual budgets for the six-year period are listed in Appendix A. In putting together the budgets for the alternative systems, only short-term impacts were taken into account. Given data constraints, all long-term benefits and costs associated with soil improvements and off-farm effects linked with the change from bush-fallow to the *abonera* system are ignored.

Returns to Land

The assumptions about costs and benefits outlined above and the annual budgets listed in Appendix A allow us to examine the flow of annual net benefits evaluated at the mean values of the random variables (maize yields and prices). Table 10 shows the flow of annual net benefits from the two systems under examination. Figure 6 shows the incremental flow.

At this level of analysis, the comparison of the *abonera* with the bush-fallow system seems clear. Land intensification seems to offer a clear economic advantage for the *abonera* system compared with the traditional bush-fallow system. The first two years of the cycle can be

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7 Although maize yields rise during the first year after velvetbean is introduced, the full impact is attained in the second year after introduction.

considered an investment in establishing the *abonera.* After the third year, the *abonera* system provides a clear economic advantage over the bush-fallow system.

The last four rows of Table 10 show the net present value (NPV) of the annuals flows of net benefits of both systems and of the incremental flow calculated for a range of discount rates. These figures show the relative profitability of the systems evaluated at the mean values of all the variables (deterministic cost-benefit analysis). For all the discount rates used in the calculation, the NPV for the *abonera* is larger than that of the bush-fallow system. However, the difference diminishes as the discount rate increases, because the benefits from investing in the *abonera* system are realized after the third year and the costs are recovered in the first two years. Farmers whose circumstances lead them to discount the future heavily (those who rent land are an extreme example) will perceive smaller benefits from investing in the *abonera* compared to farmers with lower discount rates. Figure 7 shows the decline in the advantage of the *abonera* system as the discount rate increases. As a matter of fact, at a discount rate of 174% both systems are, on average, economically similar from the farmer's point of view.

This deterministic analysis of costs and benefits from both systems shows that on average the *abonera* system is economically superior to the bush-fallow system. However, the analysis says nothing about the impact of the *abonera* system on the

Table 10. Annual flows of average net benefits from the abonera and bush-fallow systems, and net present value calculated at different discount rates, Department of Atlántida, Honduras

	Annual flow of net benefits by cropping system (US$/ha)	
Year	***Abonera* (a)**	**Bush-fallow (b)**
1	97.87	119.92
2	89.30	135.54
3	192.79	0.00
4	192.79	0.00
5	192.79	0.00
6	192.79	137.87
NPV (10%)	734.60	328.75
NPV (30%)	487.80	261.32
NPV (100%)	232.87	192.00
NPV (150%)	183.66	175.55

Note: Values in parentheses are discount rates used in calculating the NPV.

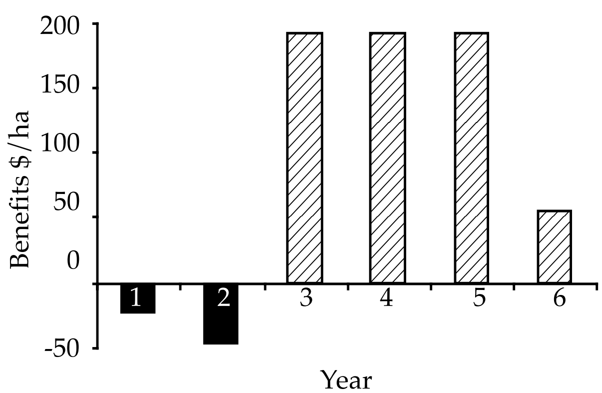

Figure 6. Incremental flow of annual net benefits between the abonera and the bush-fallow system, Department of Atlántida, Honduras.

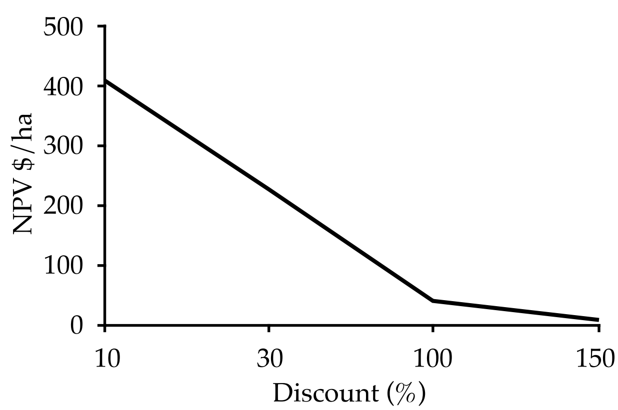

Figure 7. Net present value of the incremental flow of net benefits as a function of the discount rate.

probability distribution of the net benefits. It is clear from our previous discussion of maize yields that this is an important aspect of the *abonera* system which should be analyzed.

Probabilistic cost-benefit analysis estimates the parameters that characterize the probability distribution of the NPV of the incremental flow of net benefits between the *abonera* and the bush-fallow system. Table 11 summarizes three of these parameters: the mean value, the standard deviation, and the probability that the NPV of the incremental flow of net benefits is above zero (that is, the probability that the *abonera* system will be more profitable than the bush-fallow system).[8] These parameters were estimated for different discount rates (with a fixed planning horizon of six years) and for different planning horizons (with a fixed discount rate of 30%).

When the farmer's planning horizon spans the six years of the bush-fallow cycle, the *abonera* system has a more than 80% probability of rendering an NPV of net benefits larger than that of the bush-fallow system. Even with discount rates as large as 100%, this probability is greater than 60%. Profitability is far more constrained by the length of the farmer's planning horizon than by the discount rate. If farmers look only one or two years ahead in their decision making, then the *abonera* system is not an option for them. In the best of cases, the probability that they will profit from the choice is only slightly greater than 10%. But if farmers look ahead three or more years when planning land use, the *abonera* system is the best choice for maize production on the additional plot.

Another way to view the impact of the *abonera* system is to compare the cumulative distribution functions for the incremental NPV between both systems. Figure 8 shows the cumulative distribution function of the NPV of net benefits for a six-year planing horizon and two discount rates. At a low discount rate (10%), there is a 17% probability of obtaining

Table 11. Selected parameters of the distribution of the net present value of the flow of incremental net benefits per unit of land (hectare) for different discount rates and planning horizons, Department of Atlántida, Honduras

Discount rate (%)	Mean (US$/ha)	s.d. (US$/ha)	P(NPV>0) (%)	Planning horizon (years)	Mean (US$/ha)	s.d. (US$/ha)	P(NPV>0) (%)
10	409	515	83	1	-22	8	0
30	**229**	**300**	**82**	2	-58	62	13
50	137	195	79	3	57	118	70
70	85	137	75	4	146	193	82
90	53	103	70	5	213	253	86
110	32	80	66	**6**	**229**	**300**	**82**

Note: "s.d." = standard deviation.

[8] Simulation analysis was performed using @Risk software by Palisade Co. The model ran 2,000 iterations before convergence was achieved. Convergence of the simulation is evaluated by the amount of change in three statistics: the average percentage change in the percentile values, the mean value, and the standard deviation. When the percentage change in these statistics is less than an established threshold value, convergence is achieved. In this work the threshold value was set at 1.5%.

an incremental NPV less than or equal to zero (in other words, a 17% probability that the NPV of the *abonera* will be less or equal than that of the traditional system). At higher discount rates, for example 90%, this probability increases to 30% (these values can also be obtained from the fourth and eighth columns of Table 11).

In summary, the investment nature of the *abonera* system becomes clear when we consider that, as the farmer's planning horizon increases from two to six years, the differences between the two distributions increases, and the *abonera* system becomes an increasingly attractive alternative use of land. This is reflected in the increasing probability that the NPV of the incremental flow will be larger than zero. Similarly, as the discount rate becomes larger, i.e., as farmers' discounting of future benefits increases, there is a greater probability that the NPV of the incremental flow of net benefits will decrease.

Returns to Labor

The previous section examined net benefits per unit of land. However, it is also important for farm households to evaluate how alternative practices affect net returns to family labor.

Information from the 1992 survey reveals that half of the farmers surveyed hire labor, mainly for land preparation and planting. For this analysis, we assume that 50% of these activities are done by hired labor and 50% by family labor, with the remaining agricultural activities performed exclusively by family labor.

Table 12 presents the annual flow of family labor for the bush-fallow and the *abonera* systems (in person-days/ha) as well as the flow of annual net benefits for each system in terms of returns per person-day per unit of land.

A comparison of family labor requirements in both systems reveals that although growing second-season maize in the *abonera* system requires less labor than growing maize in the bush-fallow system, when the entire rotation is considered, the *abonera* system actually is more labor-intensive than the bush-fallow system. Because of the intensification in land use,

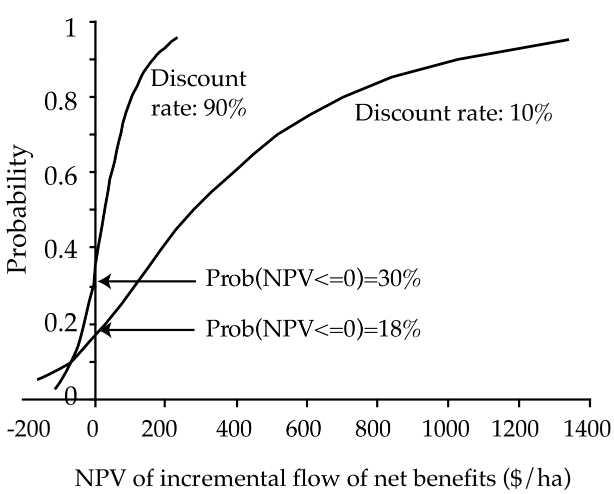

Figure 8. Cumulative density function of the incremental net present value.

Table 12. Annual family labor requirement and results of the simulation of net present value of net returns to family labor in the *abonera* and bush-fallow systems, Department of Atlántida, Honduras

	Person-days/ha		Annual net benefits (US$/person-day/ha)	
Year	***Abonera***	**Bush-fallow**	**Abonera**	**Bush-fallow**
1	54.5	49.5	3.75	4.38
2	19	45.5	6.65	4.93
3	19	0	12.10	0.00
4	19	0	12.10	0.00
5	19	0	12.10	0.00
6	19	27	12.10	7.06
Total	149.5	122	"	"

the *abonera* system increases the total amount of family labor by 27.5 person-days/ha (a 23% increase) or 4.6 person-days/ha/yr.

Figure 9 presents the incremental flow of annual net benefits. The flow of net benefits shows a pattern very similar to that exhibited by the net benefits per unit of land (Figure 6) and serves to emphasize the economic advantages of the *abonera* system even more. As with the analysis of returns to land, when only one year is considered, the bush-fallow system is more attractive than the *abonera* system, because the return to family labor is smaller under the *abonera* system. This pattern is reversed during the second and subsequent years, even assuming that velvetbean has no impact on maize yields in the second year. These results emphasize the cost-saving potential of the *abonera* technology.

Similar to the case of the returns to land, when the entire six-year cycle is considered, the NPV of the incremental flow of net benefits is positive for the range of discount rates (10-110%).

Sensitivity Analysis

The cost-benefit analysis of returns to land and family labor demonstrates that the *abonera* system is more profitable than the bush-fallow system when the analysis is carried out at the field or plot level. This economic advantage is undoubtedly an important reason why the *abonera* system spread quickly throughout the Department of Atlántida. Sustained use of the system or its diffusion into other regions would require, however, that the factors influencing this economic advantage remain approximately the same.

Table 13 shows that yield gains and price differences are the main factors associated with the differences between the flow of net benefits for the *abonera* and bush-fallow systems, under different discount rates. The data reveal the sensitivity of the cost-benefit analysis to changes in these factors. For example, independently of the discount rate, the maize yield obtained in the *abonera* system is clearly the most important factor. The positive correlation coefficient associated with this variable is very strong.

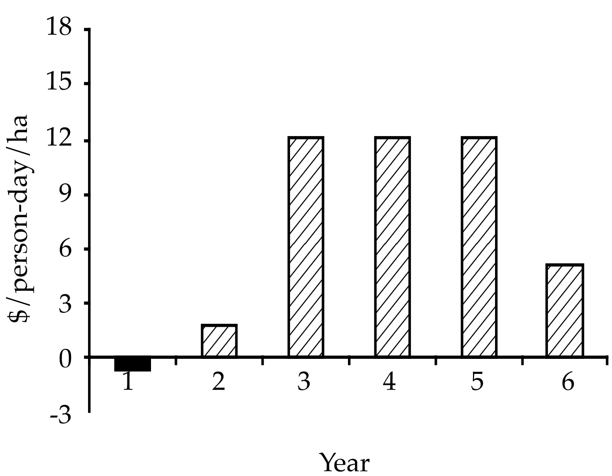

Figure 9. Annual flow of increment net benefits per person-day per hectare of family labor, Department of Atlántida, Honduras.

In summary, for a single unit of land (at the margin), the *abonera* system is a much more intense use of land than the bush-fallow system over the six-year life cycle. As a result of this land intensification, the *abonera* provides larger economic returns per unit of land than the bush-fallow system after two years (in year three of the cycle). In contrast, when we consider returns per unit of family labor, returns to the *abonera* system are larger after the first year (year two of the cycle). Since it was assumed that there is no effect onmaize yield in the first year after the velvetbean is planted, this result emphasizes the *abonera* system's potential for saving laborcosts.

Table 13. Sensitivity analysis of the simulation of the net present value of the incremental flow of net benefits per unit of land, Department of Atlántida, Honduras

	Rank correlation for different discount rates					
Variable	**10**	**30**	**50**	**70**	**90**	**110**
Yield, second-season maize in *abonera*	0.91	0.89	0.87	0.84	0.86	0.84
Yield, first-season maize					-0.36	-0.42
Maize price, second-season	0.35	0.34	0.33	-0.32	0.25	0.24
Maize price, first-season	-0.14	-0.18	-0.26	0.32	-0.11	-0.13

Two elements associated with the relative profitability of the *abonera* system are the farmer's planning horizon and discount rates. Factors that conditions these two elements will influence whether farmers find it economically convenient to adopt the system. Another element which should be taken into account is the opportunity cost of land. Although the *abonera* system is more profitable than the alternative of growing maize under the bush-fallow system, alternative land uses could provide better economic returns than the *abonera* system. The opportunity cost of the land can be defined as the returns to land in the best alternative use. If the return per unit of land in the *abonera* system is less than the opportunity cost of land, then it would make more sense to allocate the land to the better alternative use. The opportunity cost of a given unit of land depends, among other factors, on the amount and quality of the land endowment available to the farmer.

Implications at the Farm Level

Land Allocation

Decisions In the previous section we examined the relative profitability of the *abonera* system when a single plot of land is considered. Here, we extend the analysis to the farm level to determine how the *abonera* system fits into the maize cropping system and to assess the consequences of its introduction.

Figure 10 depicts three of the options that have become available to farmers since the *abonera* system was introduced (in the figure, dashed rectangles represent a single plot of land). First, farmers may decide to continue using the bush-fallow system to grow maize (case A in the figure). Second, farmers may decide to add the *abonera* system to the bush-fallow cropping pattern (case B). Third, farmers may decide to employ two distinct, exclusive cropping patterns: a modified bush-fallow system to grow first-season maize and the *abonera* system to grow second-season maize (case C).

The survey data show that almost equal numbers of farmers pursue each strategy. One-third of the farmers surveyed continued to manage all of their maize in the bush-fallow system. Another third used both cropping systems simultaneously within the same farm and within the same season. For these farmers, adoption of the *abonera* did not replace the bush-fallow system but rather added to it. Finally, one-third of the farmers grew all of their second-season maize in *aboneras* and all of their first-season maize in fields cleared from bush fallow.

First-season fields were either left fallow during the second season or planted to other annual crops such as beans and cassava.

The land use allocations outlined above have significant implications for the number of maize plots cultivated and the land area dedicated to second-season maize. Farmers who adopt the *abonera* system (B and C in Figure 10) typically plant two plots of maize in the second season, while farmers without *aboneras* (A in the figure) crop only one. The increase in the number of plots will be reflected in an increase in the area cropped with maize in second season for both groups.

Table 14 shows the consequences of these adoption decisions for land allocation when the six-year cycle of the rotation system is considered. In the table, a "plot" is a physical parcel of land and a "land unit" incorporates the time dimension. For example, the first and third rows of the table indicate that a farmer who does not use the *abonera* system will use three physical parcels of land to grow six land units in the six-year period, because the farmer shifts to a new plot every two years. The introduction of the *abonera* system requires an additional plot (a 33% increase), which is cropped with maize once a year for the entire six-year cycle. This adds one additional land unit.

By the end of the six years, farmers who did not adopt the *abonera* will have planted 12 units of land to maize, for a total of 12 ha, using three plots. The gain in land intensification resulting from the adoption of the *abonera* as a second maize plot (case B) is clear: by the end of the cycle, the farmer will have planted 19 units of land, totaling 31 ha of maize, using four plots. The farmer will have increased the area planted to maize by 158% (17% in the first season and 300% in the second season) by increasing the number of maize units by 58% with an increase of only 33% in the number of plots used.

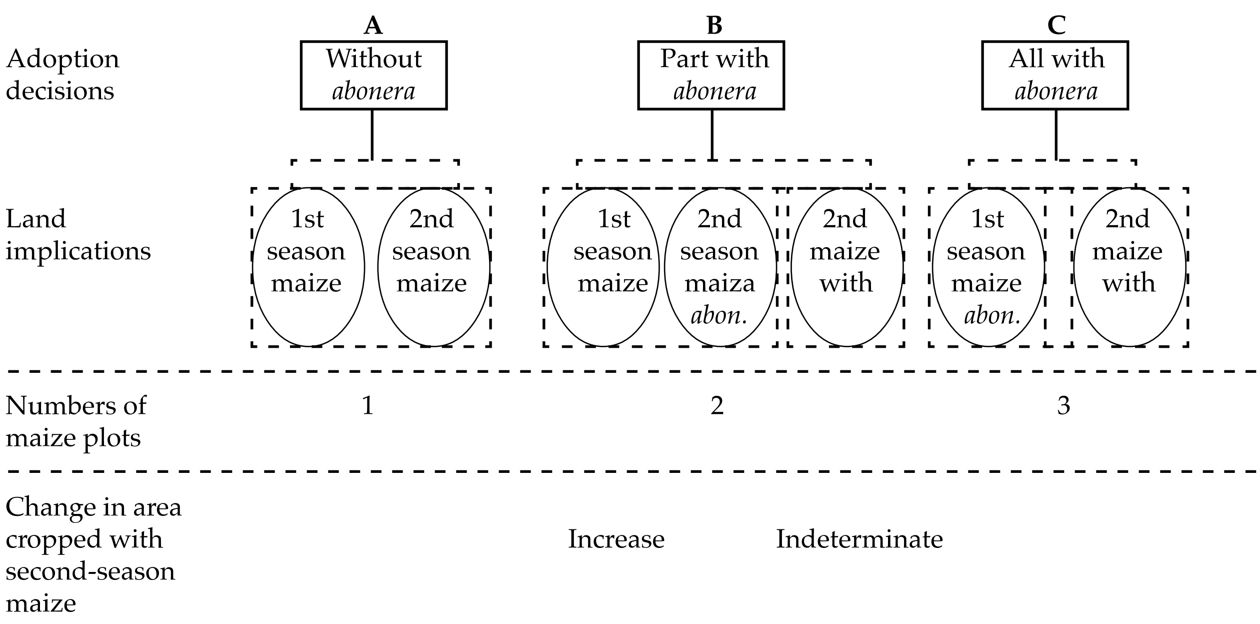

Figure 10. Adoption decisions and land allocation, Atlantic Coast, Honduras.

In case C, the farmer chooses to grow all second-season maize in an *abonera* and to fallow the plot used to grow first-season maize. After six years, the farmer will have planted 13 units of land to maize, a gain of 8%, for a total of 19 ha of maize, which represents an increase of 58% (17% in the first season and 100% in the second season), again with a 33% increase in the number of plots.

Adopters of the *abonera* system also gain greater flexibility in the use of the plot where they plant first-season maize. Farmers have the option of using the plot to grow second-season maize (B in Figure 10), a different second-season crop such as beans, or simply to leave the plot fallow (C in Figure 10).

In summary, adoption of the *abonera* system increases the maize area of the farm, particularly second-season maize area. However, the *abonera* does not substitute for the traditional bush-fallow system but complements it. If no distinction between partial or total adoption is made, then adopters on average grow more maize in the second season than nonadopters. Adopters plant an average of 1.9 ha of maize in the second season, while nonadopters plant only 1.2 ha (Table 15). Table 15 also shows that adoption of the *abonera* system has no significant impact on the number of plots or the area planted to maize in the first season. Both groups tend to plant only one plot of approximately the same size.

Labor Use

The introduction of the *abonera* into the farming system of Atlantic Honduras has modified not only the allocation of land but also the allocation of labor resources within the farming system. The increase in area planted to second-season maize implies additional labor requirements, which must be met either by family or hired labor. In this section we examine the implications of the adoption of the *abonera* system for labor use by comparing monthly

Table 14. Land intensification as a result of adoption of the abonera system in the six-year rotation cycle, Department of Atlántida, Honduras

	Adoption decisions in relation to second-season maize		
	Without *abonera* (A)	**Part with *abonera* (B)**	**All with *abonera* (C)**
Number of plots used	3	4	4
Increase in relation to nonadopters (%)	"	**33**	**33**
Number of first-season maize land units	6	7	7
Size of each land unit (ha)	1	1	1
Total area first-season maize (ha)	6	7	7
Increase in relation to nonadopters (%)	"	**17**	**17**
Number of second-season maize land units	6	12	6
Size of each land unit (ha)	1	2	2
Total area second-season maize (ha)	6	24	12
Increase in relation to nonadopters (%)	"	**300**	**100**
Total land units cropped	12	19	13
Increase in relation to nonadopters (%)	"	**58**	**8**
Total area cropped (ha)	12	31	19
Increase in relation to nonadopters (%)	"	**158**	**58**

labor requirements in the bush-fallow and *abonera* systems. Comparisons are made at the field and farm levels.

A monthly calendar of common activities performed by farmers in producing first- and second-season maize and the labor requirements per unit of land are presented in Table 16. Growing first-season maize requires 60 person-days/ha, whereas second-season maize in the bush-fallow system requires 47.5 person-days/ha. If second-season maize is grown in an established *abonera*, the amount of labor required falls to 44.5 person-days/ha, an 8% reduction compared to the labor requirements for second-season maize grown in the bush-fallow system. The reduction in labor requirements is even greater (40%) when we compare labor requirements for producing second-season maize in an *abonera* with requirements for producing first-season maize in a field that must be cleared of the fallow vegetation that has accumulated over four years.

Table 15. Maize area of farmers who own land, Atlantic Coast, Honduras, 1991

	Second season		**First season**	
	Farmers with *abonera*	**Farmers without *abonera***	**Farmers with *abonera***	**Farmers without *abonera***
Mean	1.91	1.24	1.63	1.18
Mode	2	1	2	1
Standard deviation	1.35	0.97	1.6	0.98
Difference	0.67**		0.45	

Note: ** = different from zero at 95% probability (t-test).

Table 16. Calendar of activities and labor requirements per unit of land for maize production in different seasons and systems, Department of Atlán(ida, Honduras

Activity	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
First season												
Slash and burn					20							
Sowing						5						
First weeding							12.5					
Second weeding								2.5				
Doublin maize									5			
Harvesting maize											20	
Second season												
Slash ush-fallow												12
Slash *abonera*)												10
Sowing (bush-f allow)	5											
Sowing (*abonera*)	5											
First weeding (bush-fallow)		11										
First weeding (*abonera*)		9										
Second weeding (bush-fallow)			2.5									
Second weeding (*abonera*)			2.5									
Sowing velvetbean												
Harvesting (bush-fallow)				17								
Harvesting (*abonera*)				18								

Table 17 presents the monthly labor requirements for maize production at the farm level, estimated for the three groups of farmers outlined above: nonadopters (group A), farmers who use both systems to grow second-season maize (group B), and farmers who grow all their second-season maize in an *abonera* (group C). To calculate the labor requirements it is assumed that nonadopters grow one hectare of first- and second-season maize. The partial adopters (group B) grow one hectare of first-season maize, one hectare of second-season maize in an *abonera*, and have one hectare in bush-fallow. Total adopters (group C) also grow one hectare of first-season maize and have two hectares of second-season maize in an *abonera*. Labor requirements are calculated by multiplying the labor requirements per unit of land by the area planted to maize in the first and second seasons.

Compared to nonadopters, for partial adopters the annual labor requirement increases by 39%; it increases to 37% for total adopters. This increment is the result of the larger area that is planted to maize in the second season following the decision to adopt the *abonera* system. Note the minimal difference in labor requirements between partial and total adopters of the *abonera* system.

At the farm level, the *abonera* system plays a dual role with respect to labor use. First, the labor savings per unit of land allow farmers to increase the area planted to maize in the second season with a less-than-proportional increase in labor use. As a result, adoption of the *abonera* system increases the total amount of labor used at the farm level. This effect could have potentially beneficial consequences at the regional level by opening new employment opportunities (see the discussion in the next section).

Table 17. Monthly labor requirements at the farm level for maize in different cropping systems, Department of Atlántida, Honduras

	Labor requirements (person-days) by second-season adoption decision		
Month	**Without *abonera* (A)**	**Part in *abonera* (B)**	**All in *abonera* (C)**
May	20	20	20
June	5	5	5
July	12.5	12.5	12.5
August	2.5	2.5	2.5
September	5	5	5
October	0	0	0
November	20	20	20
December	12	22	20
January	5	10	10
February	11	20	18
March	2.5	5	5
April	17	35	36
Total	**112.5**	**157**	**154**

Implications at the Regional Level

Adoption of the *abonera* system has had an impact on the area allocated to second-season maize, on annual net benefits accruing to farmers, and on aggregate labor demand. Here we examine the regional implications of these changes for the Department of Atlántida, where adoption of the *abonera* system seems to be concentrated. This level of aggregation makes it possible to use regional statistics published at the department level. Interviews suggest that some adoption of the *abonera* system has also occurred in neighboring departments, where biophysical and socioeconomic conditions resemble those in the study area. Results of the regional analysis are probably thus conservative estimates of the full impact of the *abonera* system on the economy of the Atlantic Coast of Honduras.

Previous sections of this paper have emphasized that two important effects of the adoption of the *abonera* system at the plot and farm level are an increase in maize productivity per unit of land and an increase in the area planted to maize in the second season. Extensive adoption of the *abonera* system at the department level implies that these farm-level effects will be reflected in a relative increase in area planted to second-season maize and an increase in second-season maize production relative to areas where the *abonera* system has not been adopted.

To estimate the pattern of adoption over time in the Department of Atlántida, a logistic function was fitted to the 1992 survey data (Table 18). The logistic equation has the form (CIMMYT 1993) :

[4] $Y = K / (1+e^{-a\ -\ b^{*}t})$

where K is the adoption ceiling, t is time in years, and a and b are unknown parameters to be estimated. An adoption ceiling of 70% was assumed, given that land ownership seems to be an important factor influencing adoption of the *abonera* system and that about 75% of farmers in the region are landowners. The equation was estimated using ordinary least squares by transforming the equation using the defined value of K (70%). The estimated equation is:

[5] $Y^{*}_{t} = -6.63 + 0.437\ t$
(-17.8)*** (18.7)***
$R^2 = 0.98$ (n=15)

where Y^{*}_{t} is the transformed variable, $1n(Y^{*}_{t} / K - Y_{t})$, which allows linearization of the equation, values between parentheses are t-statistics, and *** indicates that the associated coefficient is significantly different from zero at 99% probability.

Figure 11 shows the observed and the estimated adoption pattern. The *abonera* system was first introduced to the region by migrant farmers in the early 1970s and expanded from farmer to farmer throughout most communities. Dissemination was slow until the beginning of the 1980s (Buckles et al. 1992), but by 1992, 65-70% of the hillside maize farmers in the Department of Atlántida used the *abonera* system to produce second-season maize.

Table 18. Observed and estimated diffusion pattern of the *abonera* system in the Department of Atlántida, Honduras

	Percentage of sampled farmers	
Year	**Observed**	**Estimated**
1971	2	0.1
1972	"	0.2
1973	"	0.3
1974	"	0.5
1975	"	0.8
1976	"	1.2
1977	4.3	1.9
1978	"	2.9
1979	"	4.4
1980	4.5	6.6
1981	6.9	9.7
1982	15	14.0
1983	17.9	19.5
1984	25	26.2
1985	29.2	33.6
1986	37	41.2
1987	44.9	48.2
1988	52.7	54.2
1989	61.1	58.9
1990	65.6	62.4
1991	65.3	64.9
1992	66.4	66.6
1993	"	"
1994	"	"
1995	"	"

Note: .. = not available.

One way to test for aggregate impact is to compare the rates of growth in maize area and production in the Department of Atlántida with rates for other departments where diffusion of the *abonera* system has not occurred. Unfortunately, data disaggregated by cropping season are available only for the Atlantic Coast Region, which encompasses two other departments besides Atlántida. However, these data show that the contribution of second-season maize to total production in the Atlantic Coast Region grew at a rate of 1.4%/yr during 1975/76-1994/95 (Table 19). This implies that production of second-season maize grew at a higher rate than first-season maize, which is consistent with expectations based on observations at the farm level. Figure 12 shows the second-season maize area relative to total maize area in the Atlantic Coast Region. To illustrate the underlying trend more clearly, the figure also shows the

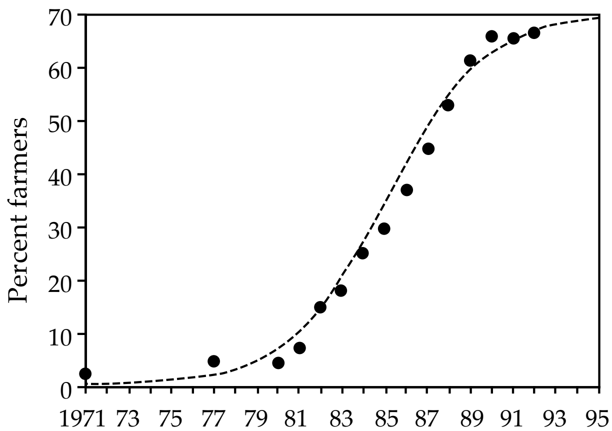

Figure 11. Observed and estimated diffusion pattern of the *abonera* system, Department of Atlántida, Honduras.

Table 19. Area and production of maize grown in the first season and second season, Atlantic Coast, Honduras, 1975/76-1994/95

	Area			Production		
Crop year	First season (ha)	Second season (ha)	Share of second season (%)	First season (t)	Second season (t)	Share of second season (%)
1975/76	12,644	7,053	35.8	26,588	14,159	34.7
1976/77	13,672	8,570	38.5	25,299	18,711	42.5
1977/78	14,722	10,088	40.7	24,010	23,262	49.2
1978/79	18,008	10,404	36.6	31,408	15,593	33.2
1979/80	11,708	8,161	41.1	9,868	9,468	49.0
1980/81	25,855	13,831	34.9	41,232	23,071	35.9
1981/82	26,167	20,631	44.1	53,446	30,493	36.3
1982/83	15,812	14,966	48.6	19,695	21,529	52.2
1983/84	20,615	9,646	31.9	36,843	20,892	36.2
1984/85	30,687	6,588	17.7	56,019	13,231	19.1
1985/86	9,921	13,271	57.2	27,205	26,876	49.7
1986/87	9,483	13,271	58.3	19,156	26,876	58.4
1987/88	20,629	15,879	43.5	47,377	28,970	37.9
1988/89	21,078	11,670	35.6	34,327	22,516	39.6
1989/90	12,329	12,159	49.7	21,143	23,427	52.6
1990/91	11,641	16,233	58.2	25,245	29,659	54.0
1991/92	14,035	12,810	47.7	22,403	21,837	49 4
1992/93	18,459	13,699	42.6	45,280	26,471	36.9
1993/94	17,899	12,019	40.2	28,445	15,651	35.5
1994/95	13,188	12,040	47.7	19,582	19,232	49.5

Source: SRN, *Compendios Estadísticas Agropecuario,* 1984, 1991,1994, and 1995.

three-year moving average in a solid line. During most of the 1970s and early 1980s, second-season maize accounted for less than 40% of the area planted to maize in the region. In the early 1980s there is a clear trend of increasing second-season maize area, and by the end of the period the second season has become the most important season for maize production.

It is difficult to prove causality between the adoption pattern and the contribution of second-season maize to total maize production in the Atlantic Coast Region, because the influence of exogenous factors cannot be ruled out. The available data do allow us to test for an association between growth in the relative importance of second-season maize and diffusion of the *abonera* system. Time-series data on the share of area planted to second-season maize (A_t) are regressed on the percentage of farmers who adopted the *abonera* rotation system (A_{bt}) and on the ratio of the second-season maize price to the first-season maize price, with a lag of one year (Pm_{t-1}).

Results confirm the association between both series:

[6] $$A_t = 0\ 33 + \underset{(3.6^{***})}{0.18\ A_{bt}} + \underset{(0.60)}{0.03\ Pm_{t-1}}$$

Durbin-Watson: 1.56; R^2 =0.52; n =15

where values between parentheses indicate t-values and *** indicates that the associated coefficient is significantly different from zero at 99% probability. The value of the Durbin-Watson test does not reject the null hypothesis that the disturbances are not autocorrelated.

The impact of the expansion of the *abonera* system during the same period on the relative importance of the second season as a supplier of maize is reflected in the highly significant coefficient associated with the variable. An increase of 10% in the number of farmers adopting the *abonera* system in the Department of Atlántida is associated with an increase of almost 2% in the relative importance of the second season in supplying maize to the Atlantic Coast Region.

Figure 12. Importance of second-season maize area in relation to total maize area, Atlantic Coast, Honduras, 1976-94.

Although the action of other factors affecting the allocation of land between seasons by farmers cannot be ruled out, other studies in the area reveal no technological or economic innovation that would have been capable of producing such a dramatic shift in land allocation between the two cropping seasons. A comparative analysis of maize production technology from 1982/83 to 1992/93 has shown that, aside from the introduction of the *abonera* system, no changes in the way maize is produced in the area can explain the shift (Sain and Matute 1992).

Land Rental Markets

The sale or purchase price of agricultural land is influenced by the land's ability to produce economic rents over the long term and by other factors, such as the degree of urbanization, accessibility (distance to roads), and macroeconomic variables such as the inflation rate.

In contrast, rental markets for agricultural land depend more on short-term land productivity and less on exogenous factors. For example, a farmer wishing to rent a plot for a single year or a single cropping season will pay more attention to factors related to land fertility than to other factors.

Farmers' awareness that the *abonera* system provides better economic returns to land is reflected in land rental prices in the Department of Atlántida. Rental prices for sowing second-season maize vary by land use (Table 20). There is no difference in rental prices for *abonera*s of different ages, but there is a significant difference in the rental price for land in the *abonera* rotation and land that has been in fallow or under pasture.

The rental price of $30.00/ha for land under the *abonera* system is $12.00 higher than the average rental value reported for the land used in guatal, guamil, and pasture, which averaged $18.00/ha. (A guatal is a field left uncultivated to allow natural regrowth for three years or less; a guamil is a field left uncultivated to allow natural regrowth for approximately five or more years.) If there were perfect information and no transaction costs, this $12.00/ha difference would represent the expected value of the gain that farmers perceived from sowing maize in a plot of land under the *abonera* system rather than sowing maize in a plot under the bush-fallow system. This value, however, is lower than the approximate difference in the average net benefits from sowing maize in an established *abonera* rather than in the bush-fallow system (first and second season). The discrepancy may be partially attributed to profits accrued to the renter farmer and to distortions in the land rental market. Among the most important distortions are farmers' lack of information about the real gain in land productivity, the impact of alternative land uses, and changes in agricultural policies. For example, the land market in the area has been distorted as a result of extensive land purchases by international enterprises for pineapple production.

Table 20. Land rental prices by land use, Atlantic Coast, Honduras, 1991

	Land rental price by land use (US$/ha)				
	Abonera				
	(< 3 yr)	**(> 3 yr)**	***Guatal***	***Guamil***	**Pasture**
Mean	29.1	30.2	18.1	19.4	16.7
Median	27.0	27.0	16.2	16.2	14.8
Mode	27.0	27.0	13.5	13.5	17.0
Standard deviation	7.1	7.0	9.3	9.0	8.4
Minimum	10.8	16.2	5.4	5.4	5.4
Maximum	43.1	43.1	43.1	43.1	27.0
Number of observations	23	23	23	22	10

Furthermore, maize pricing and credit policies have discouraged maize production in the area and promoted a shift of land to alternative uses. This trend may be reversed if the current rise in international maize prices persists.

Summary and Conclusions

This economic analysis of the *abonera* system has emphasized two important aspects of the system. First, establishing an *abonera* is an investment activity. The farmer must invest in the system at a net cost in the first two years. Second, once established, the *abonera* rotation is a very profitable investment with significant returns to land and family labor over the six-year life-cycle. The *abonera* is not only more profitable than the bush-fallow system with respect to the mean of the distribution but also reduces the variability in economic returns, making second-season maize a less risky production alternative.

The reduction in risk in second-season maize production results from the effect of velvetbean on the yield of second-season maize. The probability of achieving a second-season maize yield less than or equal to 1,000 kg/ha drops from 65% if maize is grown in the bush-fallow system to 40% if maize is grown in an *abonera*. This represents a significant short-term effect on production risk.

These two features of the *abonera* system, higher average yield and lower risk, make it the economically logical choice for growing second-season maize for farmers who have a planning horizon of more than one year.

While the *abonera* system is a profitable use of land and is capable of intensifying land use over time, adoption of the *abonera* system imposes additional constraints at the farm level on the allocation of land and labor. As a result, more complex cropping systems have emerged in the region. Some farmers have chosen to manage all of their second-season maize under the *abonera* system, while others prefer to combine the *abonera* system with the less profitable traditional bush-fallow system. This preference may be the result of consumption considerations within the household. The net effect on the farming system of adopting the *abonera* system is an increase in the number of plots dedicated to maize production and in the total area planted to second-season maize. Although the labor requirement per unit of land is smaller in the *abonera* system than in the bush-fallow system, the larger area allocated to maize implies a net increase in labor requirements at the farm level.

At the regional level, widespread adoption of the *abonera* system appears to have induced a dramatic change in the relative importance of the second season in total maize production. Although a causal link to adoption of the *abonera* system cannot be established conclusively from the data, adoption of the system remains a likely explanation for the changes in maize production in the Atlantic Coast region of Honduras. Land rental prices for sowing second-season maize also reflect the widespread impact of the system, showing that farmers recognize the differential benefits that can be obtained from growing maize in the *abonera* system rather than in the bush-fallow system.

Although the cost-benefit analysis shows that the *abonera* system is a more profitable and less risky alternative for growing second-season maize than the bush-fallow system, it says nothing about the profitability of growing maize in relation to alternative uses of land. Changes in relative prices or the introduction of new crops may lead farmers to reallocate land from maize to alternative uses. In this situation, the *abonera* could be a victim of its own success. Although maize in the *abonera* system is more profitable than maize in the bush-fallow system, the farmer may still choose to replace the *abonera* to capture the benefits of improved land quality.

References

Anderson, J.R., and J. L. Dillon. 1992. Risk analysis in dryland farming systems. *Farm Systems Management Series*. No 2. Rome, Italy: Food and Agriculture Organization.

Arellanes, P.G. 1995. Factors influencing the adoption of hillside agriculture technologies in Honduras. MS thesis. Ithaca, New York: Cornell University.

Avila Nájera, R., and J.A. López. 1990. Sondeo preliminar en la asociación maíz frijol de abono (*Mucuna spp.*) en el Litoral Atlántico de Honduras. Paper prepared for the 36th meeting of the PCCMCA, San Salvador, El Salvador, 26-30 March.

Buckles D., I. Ponce, G. Sain, and G. Medina. 1992. *Tierra cobarde se vuelve valiente: Uso y dípisión del frijol de abono* (*Mucuna deeringiana*) *en las laderas del Litoral Atlántico de Honduras*. Mexico, D.F.: CIMMYT.

Diaz Arrivillaga, E., and D. Cruz Diaz. 1992. Ajuste estructural, términos de intercambio internos y la pequeña producción de granos básicos: el caso de Honduras. Paper prepared for the seminar, Impacto del Ajuste Estructural en los Sistemas de Producción de Granos Básicos en Centroamérica, San José, Costa Rica, 20 March.

Duron, E. (ed.). 1992. Avances sobre investigación de abonos verdes en el Litoral Atlántico de Honduras. In: *Programa Regional de Maíz (PRM), Proyectos Colaborativos en Agronomía, Desarrollo y Mejoramiento de Germoplasma en Maíz*. Guatemala City, Guatemala: CIMMYT-PRM.

Licona, E. 1987. Informe anual de los resultadoes de los experimentos en investigación en fincas de agricultores en el área de Jutiapa, 1985-86. Jutiapa, Honduras: Secretaría de Recursos Naturales (SRN). Mimeo.

Mausolff, C., and S. Farber. 1995. An economic analysis of ecological agricultural technologies among peasant farmers in Honduras. *Ecological Economics* 12: 237-248.

Pagiola, S. 1994. Cost-benefit analysis of soil conservation. In E. Lutz, S. Pagiola, and C. Reiche (eds.), *Economic and Institutional Analyses of Soil Conservation Projects in Central America and the Caribbean*. World Bank Enviroment Paper Number 8. Washington, D.C.: World Bank.

Palisade Co. 1994. @ *Risk*. Risk analysis and simulation add-in for Microsoft Excel or Lotus 1-2-3. Release 3.0 User Guide.

Pouliken, L Y. 1970. *Risk Analysis in Project Appraisal*. World Bank Staff Occasional Paper No 11. Baltimore, Maryland: Johns Hopkins.

Reutlinger, S. 1971. *Techniques for Project Appraisal under Uncertainty*. World Bank Staff Occasional Paper No. 10. Baltimore, Maryland: Johns Hopkins.

Sain, G., and R. Matute. 1992. Cambio tecnológico e investigación en fincas en el departamento de Atlántida, Honduras. In J. Bolaños,. G. Sain, R. Urbina, and H. Barreto (eds.), *Síntesis de Resultados Experimentales del PRM 1992*. Guatemala City, Guatemala: CIMMYT-PRM, Guatemala. Pp. 198-211. Sain, G., I. Ponce, and E. Borbón. 1994. Profitability of the *abonera* system practiced by farmers on the Atlantic Coast of Honduras. In D. Thurston, M. Smith, G. Abawi, and S. Kearl (eds.), *Slash/Mulch: How Farmers Use It and What Researchers Know about It*. Ithaca, New York: Cornell International Institute for Food, Agriculture, and Development (CIIFAD), Cornell University.

SRN (Secretaría de Recursos Naturales), Honduras. Various years. *Compendios Estadísticas Agropecuario*. Tegucigalpa, Honduras: SRN, Unidad de Planificación Sectorial Agrícola, Departamento de Información Agrícola.

Steiner, H.M. 1980. *Public and Private Investment: Socioeconomic Analysis*. New York, New York: John Wiley.

Triomphe, B. 1993. Frijol de abono: una clave para que la agricultura de laderas sea sostenible. Paper presented to the I Congreso Universitario Agroecologico: Desarrollo Rural Integrado en Zonas de Alto Riesgo y la Conservación de Recursos, 29-September - 1 October, La Ceiba, Honduras.

Triomphe, B. 1996. Seasonal Nitrogen Dynamics and Long-Term Changes in Soil Properties under the Mucuna/Maize Cropping System on the Hillsides of Northem Honduras. Ph.D. dissertation. Ithaca, New York: Cornell University.

Appendix A

Annual Budgets for Maize Production in the *Abonera* and Traditional Bush-Fallow Systems

Table A1. Annual budgets for maize production in the *abonera* and traditional bush-fallow systems, using mean values of the random variables (maize yield and input-output prices)

	Costs and benefits by system(US$/ha)	
FIRST YEAR: ESTABLISHMENT	***Abonera***	**Bush-fallow**
FIRST SEASON		
Land preparation		
1- Slash and burn	37.20	37.20
Planting maize		
2- Seed	1.81	1.81
3- Labor	9.30	9.30
Weed control		
4- First manual weeding	23.25	23.25
5- Gramoxone (2nd chemical)	7.12	7.12
6- Labor to apply herbicide	4.65	4.65
TOTAL COSTS (excluding land and capital)	87.50	87.50
COST OF CAPITAL	4.17	4.17
TOTAL COSTS (excluding land)	**86.04**	**86.04**
MAIZE YIELD	1,394	1,394
Maize field price	0.08	0.08
GROSS BENEFITS	117.10	117.10
NET BENEFITS FIRST SEASON	**29.60**	**29.60**
SECOND SEASON		
Land preparation		
1- Cut	22.32	22.32
Planting maize		
2- Seed	1.52	1.52
3- Labor	9.30	9.30
Weed control		
4- First manual weeding	20.46	20.46
5- Gramoxone (2nd chemical)	7.12	7.12
6- Labor to apply herbicide	4.65	4.65
Planting velvetbean		
7- Velvetbean seed	3.31	
8- Labor to plant velvetbean	9.11	
TOTAL COSTS (excluding land and capital)	77.98	65.37
COST OF CAPITAL	3.90	3.27
TOTAL COSTS (excluding land)	**81.88**	**68.64**
MAIZE YIELD	1,413	1,413
Maize field price	0.11	0.11
GROSS BENEFITS(1)	150.13	158.96
NET BENEFITS SECOND SEASON	**68.25**	**90.32**
TOTAL NET BENEFITS	**97.85**	**119.92**

(1) The difference in gross benefits is the result of different maize field prices.

(Cont.).

	Costs and benefits (US$/ha)	
SECOND YEAR	***Abonera***	**Bush-fallow**
FIRST SEASON		
Land preparation		
1- Slash and burn		22.32
Planting maize		
2- Seed		1.81
3- Labor		9.30
Weed control		
4- First manual weeding		23.25
5- Gramoxone (2nd chemical)		7.12
6- Labor to apply herbicide		4.65
TOTAL COSTS (excluding land and capital)	0.00	68.45
COST OF CAPITAL	0.00	3.42
TOTAL COSTS (excluding land)	0.00	71.87
MAIZE YIELD		1,394
Maize field price		0.08
GROSS BENEFITS	0.00	117.10
NET BENEFITS FIRST SEASON	**0.00**	**45.22**
SECOND SEASON		
Land preparation		
1- Slash	18.60	22.32
Planting maize		
2- Seed	1.52	1.52
3- Labor	9.30	9.30
Weed control		
4- First manual weeding	16.74	20.46
5- Gramoxone (2nd chemical)	7.12	7.12
6- Labor to apply herbicide	4.65	4.65
TOTAL COSTS (excluding land and capital)	57.93	65.37
COST OF CAPITAL	2.90	3.27
TOTAL COSTS (excluding land)	60.83	**68.64**
MAIZE YIELD	1,413	1,413
Maize field price	0.11	0.11
GROSS BENEFITS (1)	150.13	158.96
NET BENEFITS SECOND SEASON	**89.30**	**90.32**
TOTAL NET BENEFITS	**89.30**	**135.54**

(1) The difference in gross benefits is the result of different maize field prices.

(Cont.).

	Costs and benefits (US$/ha)	
THIRD to FIFTH YEAR	*Abonera*	**Bush-fallow**
SECOND SEASON		
Land preparation		
1- Slash	18.60	
Planting maize		
2- Seed	1.52	
3- Labor	9.30	
Weed control		
4- First manual weeding	16.74	
5- Gramoxone (2nd chemical)	7.12	
6- Labor to apply herbicide	4.65	
TOTAL COSTS (excluding land and capital)	57.93	
COST OF CAPITAL	2.90	
TOTAL COSTS (excluding land)	60.83	
MAIZE YIELD	2,387.00	
Maize field price	0.11	
GROSS BENEFITS	253.62	
NET BENEFITS SECOND SEASON	**192.79**	**0.00**
ANNUAL NET BENEFITS	**192.79**	**0.00**

SIXTH YEAR	*Abonera*	**Bush-fallow**
SECOND SEASON		
Land preparation		
1- Slash	18.60	
Planting maize		
2- Seed	1.52	
3- Labor	9.30	
Weed control		
4- First manual weeding	16.74	
5- Gramoxone (2nd chemical)	7.12	
6- Labor to apply herbicide	4.65	
Harvest wood		100.44
TOTAL COSTS (excluding land and capital)	57.93	100.44
COST OF CAPITAL	2.90	5.02
TOTAL COSTS (excluding land)	60.83	105.46
MAIZE YIELD	2,387.00	
Maize field price	0.11	
WOOD YIELD		200.00
Wood price		1.22
GROSS BENEFITS	253.62	243.33
NET BENEFITS SECOND SEASON	**192.79**	**137.87**
ANNUAL NET BENEFITS	**192.79**	**137.87**

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Understanding Global Trends in the Use of Wheat Genetic Diversity and International Flows of Wheat Genetic Resources