FIRST DRAFT

ECONOMIC CONSIDERATIONS IN CHEMICAL TILLAGE AND WEED CONTROL FOR MAIZE*

L.W. Harrington**
J.C. Martínez**

1.0 Introduction

The use of herbicides in maize cultivation is a topic of increasing interest throughout the developing world, including Central America. In Africa, IITA (International Institute of Tropical Agriculture) has conducted research that compares zero tillage with tractor tillage in maize cultivation, and has concluded that zero tillage increases yields (IITA, 1978). In Mexico, CIMMYT (Centro Internacional de Mejoramiento de Maíz y Trigo) has likewise shown interest in research on herbicides for maize. For example, CIMMYT's Maize Training Program has trained many developing country agronomists in procedures for on-farm research - including herbicide use. CIMMYT on-farm training experiments indicate that proper herbicide use increases maize yields over those obtained with manual tillage and weed control in Veracruz, Mexico (Soza et al, 1978). Research on herbicide use in maize production is not limited to the IARC's (International Agricultural Research Centers). Many national programs are actively engaged in such research.

In Central America, many advocates of herbicide use on maize may be found. Ortiz (1980), for example, considers zero tillage in maize sufficiently attractive that it should be extended to Panamanian farmers. Zaffaroni et al (1979) found that zero tillage with chemical weed control resulted in maize yields superior to those obtained with three different check treatments. Villena and Soza (1980) find that zero tillage appears to give excellent economic returns to farmers in several Central American countries.

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** The authors are economists at the Centro Internacional de Mejoramiento de Maíz y Trigo. The views presented here do not necessarily represent those of CIMMYT.

Herbicide use on maize, then, is of great potential importance to Central American farmers. The very importance of the subject, however, implies that it merits detailed study by researchers, including economists. Economists must proceed beyond the relatively "naive" economic analysis that is often conducted on herbicides; they must address some of the complications associated with the introduction of herbicides and include them in more comprehensive analyses.

The purpose of this paper is to present some of the economic consequences of herbicide use in maize cultivation. Empahsis will be placed on those consequences that are frequently overlooked. Where possible, illustrations will be provided from the N. Veracruz area of Mexico.

The paper will conclude with a list of conditions that favor the use of herbicides on maize. No judgement will be made in the paper regarding the propriety of herbicide use on maize in Central America, as such a judgement is best made in light of local conditions.

2.0 Costs and Returns to Herbicide Use - A Simple Analysis

Frequently, recommendations for use of chemical tillage and/or chemical weed control are made on the basis of yield comparisons or, at best, relatively simple economic analysis. Agronomic experiments are used to measure the increase in maize yield obtained when one shifts from a conventional tillage and weed control treatment to one base on herbicides. Following procedures developed by Perrin et al (1976), the value of this yield change is usually termed "gross benefits". Gross benefits are reduced by labor costs and input costs. In the case of conventional control, the cost of tractor hire or manual hoeing (or both) are subtracted. As wage rates or tractor hire prices rise, manual control becomes less attractive. In the case of zero tillage with chemical weed control, herbicide costs together with application costs are taken into account. These "costs that vary due to treatment differences" are subtracted from gross benefits to estimate "net benefits". It is common to find that "net benefits" are higher and "costs that vary" are lower for herbicide use than for conventional tillage and weed control.

Table 1 illustrates the above for N. Veracruz, Mexico. On-farm experiments found that zero tillage with chemical weed control increased maize yields by around 500 kg/ha over treatments representing "conventional tillage and weed control"[1/]. Labor requirements fell from 30 to 7 man-days/ha, as measured by farm surveys. The savings of labor cost more than outweighed the new herbicide cost. In effect, yield and revenue seem to have increased while costs appear to have simultaneously been reduced. Herbicides offer an "absolute superiority" over manual weed control.

3.0 Complications in the Economic Analysis of Herbicide Use - Private Effects

The simple analysis presented above suffers from a defect: Many of the assumptions upon which it is based may be invalid when small farmers compose the target population. Assumptions to be discussed include the following: The probability of obtaining the predicted yield increase, the value or "shadow price" of family labor, the presence of cash flow problems and the role of risk in influencing farmers' decisions, and the effect on intercropping practices and crop rotations. These are termed "private effects" because the individual farmer incurs all costs and benefits to be discussed. "Social effects", or costs and benefits that accrue to diverse social groups, will be discussed in a succeeding section.

3.1 Yield Increases

Farmers may be expected to obtain substantial maize yield increases due to herbicide use only if two conditions are both met: Use of herbicides leads to a reduction in the competition by weeds for moisture and nutrients, and farmers demonstrate management skill in herbicide use.[2/]

1/ This is subjectively inferred from the results of several kinds of experiments. In five experiments using tractor tillage, chemical weed control showed no average yield increase over manual control. In four experiments using zero tillage, chemical weed control led to an average yield increase over manual control of about 500 kg/ha. Finally, in six nitrogen by weed control experiments using conventional tillage, chemical weed control led to an average yield increase of about 500 kg/ha over manual control at zero levels of N. Farmers in N. Veracruz do not fertilize maize.

2/ Some yield increase may at times occur without reduction in weed competition, due to better moisture, retention, etc. Many of the ideas contained in this section were just suggested by CIMMYT agronomists.

TABLE 1: Simple Economic Analysis of Alternative Tillage/Weed Control Treatments for Maize.[1/]

Variable	Farmer[2/] Practice	Zero Tillage[3/] / Chemical Weed Control
Yield (kg/ha)[4/]	3,000	3,500
Gross Benefits[5/] (pesos/ha)	6,300	7,350
Labor Input (man-days/ha)	30	7
Labor Cost[6/] (pesos/ha)	1,500	350
Herbicide Cost[7/] (pesos/ha)	0	925
Sprayer Rental (pesos/ha)	0	25
Varying Costs (pesos/ha)	1,500	1,300
Net Benefits (pesos/ha)	4,800	6,050

1/ 1979 data from on-farm experiments and farm surveys in N. Veracruz, Mexico.

2/ Land preparation and two weedings with hoe.

3/ Machete chopping followed by 2.5 lt/ha Gramoxone and 2 kg/ha Gesaprim 50. This levels are below those recommended by the manual acturer, but nonetheless give good control in on-farm experiments.

4/ In partial budgeting, the nominal yield levels are of little importance. Yield differences, however, is of crucial importance. Nonetheless, the nominal yields shown are similar to those obtained in on-farm experiments.

5/ Field price of maize (before harvest, transport and shelling) = 2.10 pesos/ha. (1 US dollar = 22.5 pesos)

6/ Market wage = 50 pesos/day.

7/ Gramoxone = 250 pesos/lt; Gesaprim 50 = 150 pesos/kg.

Some research exists to the effect that chemical tillage or weed control may not always increase maize yields over those obtained with manual control. Miller and Burrill (1978) report that "yields are statistically identical for well-executed manual and chemical weed control methods" for Central El Salvador and Northeast Brazil. However, some farmers, ofthen those with larger farms, find it difficult to conduct a "well-executed manaul control". In N. Veracruz, for example, farmers provide effective weed control for that part of their field first to be weeded. The maize on that part of the field weeded last, however, suffers from weed competition. As intensity of manual weed control increases, this source of yield loss tends to decline in importance and the yield advantage of herbicide use is correspondingly reduced.

While it is difficult for some farmers to perform timely manual weed control, it may be even more difficult for them to properly execute chemical weed control. Herbicides may be termed "management-intensive", that is, their use requires farmers to correctly make many technical decisions. Such decisions include the following:

1) Given the weed population, which herbicide or combination of herbicides should be used?
2) How much herbicide should be used? In how much water should it be mixed? How much spreader sticker?
3) When should herbicides be applied, with reference to plant growth stage and/or soil moisture conditions?
4) How may even coverage be obtained? (This requires decisions on sprayer pressure to maintain droplet size, choice of nozzle, use of guide-strings, etc.).

In N. Veracruz, for example, one farmer attempted chemical tillage and weed control with paraquat and atrazine on a field with many woody weeds; he harvested little maize. Another farmer applied atrazine to his maize field after planting. The soil was too dry for the atrazine to control weed emergence, however, and he was forced to perform manual control anyway. The assumption that most farmers will correctly use herbicides is not likely to hold in the short run. This reduces the yield advantage of herbicides to levels below those observed in on-farm experiments. Furthermore, farmers

often attempt to compensate for their lack of expertise by increasing the herbicide dose, a practice which increases the cost of herbicide use and affects its profitability.

In the long run, it is possible that experience will enable farmers to overcome these problems. However, herbicide adoption decisions are often made by farmers on the basis of one or two cycles' experience - probably insufficient for them to learn the technical "tricks" of profitable herbicide use.

In summary, if farmers already conduct intensive and timely weed control and/or they have insufficient expertise in herbicide use, maize yield increases due to a switch to herbicide use will probably be small.

3.2 The Cost of Family Labor

In the simple economic analysis of herbicide use shown in Table 1, all labor was assumed paid the current market wage for hired labor. However, the market wage is not necessarily a good estimate of the true value or "shadow price" of family labor.

Following the reasoning of Gittinger (1972), if labor is short and a fairly active labor market exists, the market wage provides a good estimate of the family labor shadow price. If labor is in surplus (the addition of more labor leads to little increase in output) and imperfections exists in the labor market (minimum wage laws, a substantial cost of job search) then the shadow price of family labor may be considerably below the market wage. Such is often the case in heavily-populated areas were small farmers rely on family labor for carrying out farm chores. Shadow wages are especially low during "slack seasons".

When shadow prices are used for family labor in the economic analysis of herbicide use, manual control may become less expensive than the herbicide treatment. In Table 2, for example, family labor is assumed to provide all weeding labor requirements. The shadow price of family labor is esti-

TABLE 2: Economic Analysis of Alternative Tillage/Weed Control Treatments for Maize (Shadow Wages)[1/]

Variable	Farmer[2/] Practice	Zero Tillage[3/] / Chemical Weed Control
Yield (kg/ha)[4/]	3,000	3,500
Gross Benefits[5/] (pesos/ha)	6,300	7,350
Hired Labor (man-days/ha)	0	0
Family Labor (man-days/ha)	30	7
Labor Cost[6/] (pesos/ha)	1,050	245
Herbicide Cost[7/] (pesos/ha)	0	925
Sprayer Rental (pesos/ha)	0	25
Varying Costs (pesos/ha)	1,050	1,195
Net Benefits (pesos/ha)	5,250	6,155
Rate of Return = 624%		

1/ 1979 data from on-farm experiments and farm surveys in N. Veracruz, Mexico.

2/ Land preparation and two weedings with hoe.

3/ Machete chopping followed by 2.5 lt/ha. Gramoxone and 2 kg/ha Gesaprim 50.

4/ See footnote 4, Table 1, for explanation.

5/ Field price of maize (before harvest, transport and shelling) = 2.10 pesos/kg. (1 US dollar = 22.5 pesos)

6/ Market wage = 50 pesos/day; shadow price of family labor = 35 pesos/day.

7/ Gramoxone = 250 pesos/lt; Gesaprim 50 = 150 pesos/kg.

mated at 35 pesos per day.[3/] The farmer practice becomes less expensive than zero tillage with chemical weed control. Nonetheless, herbicide use still offers attractive returns.

3.3 Cash Flow and Risk

Small farmers may find the use of herbicides on maize to be unwise if it creates cash flow difficulties and/or if it increases their probable loss in case of crop failure. If purchased herbicides are substituted for family labor, cash needs at planting may be dramatically increased. The farmer may have to use the formal (or informal) credit market to obtain the necessary funds, with all the complications this entails. Table 2 illustrates cash costs for the "farmer practice" and "zero tillage with chemical weed control" for N. Veracruz. Cash outlay per hectare is increase from zero to 925 pesos.

Closely related to this is the question of risk. In the event of a crop failure, the farmer will lose much of the cash he inverted in the crop. Small farmers, for whom a switch to herbicides usually implies an increased cash expense, find that their expected loss in case of unfavorable weather increases correspondingly. Many agronomists argue, however, that herbicides reduce the probability of crop failure due to drought and allow timely weed control under conditions of excess moisture. This tends to reduce risk. Thus, the frequency of unfavorable weather and the capacity of herbicides to lessen its effects, become important.

Of course, not all farmer rely on family labor for tillage and weed control. If herbicides substitute for hired labor or cost on hired services, the cash outlay by farmers may be reduced, with a corresponding decline in risk.

3/ Shadow wages may be estimated by determining the "opportunity cost" of family labor - that is, what it is worth in its best alternative use. This may be the value of its use in the production of an alternative crops or its value in off-farm employment, less job search costs. In actual fact, an active and unhampered labor market exists in N. Veracruz, along with a shortage of labor during the maize weeding season, so the value of family labor is close to 50 pesos/day. The example given is offered only as an illustration.

3.4 Cropping Patterns

Not all farmers grow their maize in pure stands. Some farmers intercrop or rotate their maize with such other annual crops as beans, broadbeans squash, or peppers. Many of these crops may be damaged by residues or herbicides recommended for maize cultivation. Many Veracruz farmers, for example, plant maize in June and beans in September among the maize plants. The two crops are harvested together in November - December. Little evidence yet exists to indicate whether or not atrazine residuals will affect this bean crop. If however, it is found that the use of herbicides on maize excludes the relay crop of beans, the foregone profit from beans must be counted as a cost of switching to herbicides in maize cultivation.

4.0 Social Costs and Benefits in the Economic Analysis of Herbicide Use

The above section presented some complications in the economic analysis of herbicide use from the point of view of the individual farmer. Another set of complications exists from the viewpoint of society. These include policy-induced price distortions, effects on employment and effects on the cost of food for consumers.

4.1 Price Distortions

One frequently finds policy-induced distortions in the prices of inputs used in weeding on tillage. Herbicides and tractor here are subsidized in many countries. Miller and Burrill (1978) report the presence of a 40% payroll tax on labor, making labor artificially more expensive. To examine the efficiency of input use from "society's" point of view one must adjust for these subsidies and taxes.

In Mexico, for example, the (unsubsidized) market price for Gesarpim 50 is 230 pesos/ka. Farmers in N. Veracruz obtain it from a government outlet for only 150 pesos/kg. From society's viewpoint, however, 230 "pesos worth" of resources have been used. The full cost of 230 pesos/kg. should be used in any economic analysis aimed at determining whetehr herbicides are "proftable" for society as a whole. As Table 3 shows the rate of return to herbicide use drops, but is still acceptable when unsubsidized prices are used.

TABLE 3: Economic Analysis of Alternative Tillage/Weed Control Treatments for Maize (Sahdow Wages and Unsubsidized Input Costs)[1/]

Variable	Farmer[2/] Practice	Zero Tillage[3/] / Chemical Weed Control
Yield[4/] (kg/ha)	3,000	3,500
Gross Benefits (pesos/ha)	6,300	7,350
Labor Cost[6/] (pesos/ha)	1,050	245
Herbicide Cost[7/] (pesos/ha)	0	1,085
Sprayer Rental (pesos/ha)	0	25
Varying Costs (pesos/ha)	1,050	1,355
Net Benefits (pesos/ha)	5,250	5,995
Rate of Return = 244%		

1/ 1979 data from on-farm experiments and farm surveys in N. Veracruz, Mexico.

2/ Land preparation and two weedings with hoe.

3/ Machete chopping followed by 2.5 lt/ha. Gramoxone and 2 kg/ha Gesaprim 50.

4/ See footnote 4, Table 1, for explanation.

5/ Field price of maize (before harvest, transport and shelling) = 2.10 pesos/kg. (1 US dollar = 22.5 pesos)

6/ Market wage = 50 pesos/day; shadow price of family labor = 35 pesos/day.

7/ Gramoxone = 250 pesos/lt; Gesaprim 50 = 230 pesos/kg.

4.2 Employment Effects

A commonly mentioned and potentially serious effect of herbicide use is growth in rural unemployment. While it may be profitable for farmers to adopt herbicides, workers whose income is obtained by doing farm work for others may lose their livelihood. This will also tend to worsen any current problems of rural-urban migration.

4.3 Effects on Consumer Prices

For countries that are self-sufficient in maize, the effect of either a yield increase or a decrease in production cost should lead to increased total production of maize and, assuming reasonably efficient and free markets, a decrease in the real price of maize to consumers (i.e., price adjusted for inflation). For maize-importing countries, the possibility of a reduction in maize prices for consumers is much less likely. A reduction in imports would likely receive higher priority by policy-markers.

5.0 A Summary of the Effects of Herbicide Adotpion

A series of factors complicating the economic analysis of herbicide use on maize have been presented one by one. It has been seen that the following conditions favor the adotpion of chemical tillage and/or weed control by farmers:

1) High market wage rates or high tractor hire prices.
2) Shadow price of family labor equals market wage (labor scarcity during weeding season).
3) Large yield losses to weeds caused by low-intensity of manual control and/or climatic factors.
4) Farmer expertise in herbicide use (or an effective extension system whereby farmers may quickly learn herbicide use for their own farming conditions).
5) Herbicides substitute for hired labor or tractor hire, reducing cash requirements and risk to farmer (but possibly creating serious social problems of rural unemployment).

6) Subsidization of herbicide prices (facilitating farmer adoption but requiring further analysis with unsubsidized prices to see if herbicide use is wise from the social viewpoint).

7) Herbicides do not require costly changes in crop rotations or intercropping practices.

Herbicide use offers great potential for Central American maize farmers. However, the correct determination of the profitability of herbicides to farmers (and the wisdom of herbicide use from the viewpoint of society) requires more than experimental data on yield differences coupled with estimates of reduction in labor requirements. Despite yield increases and decreased labor inputs, it is possible for herbicides to be unprofitable.

Table 4 demonstrates such a hypothetical case where conditions do not favor herbicides. Labor is inexpensive, but the shadow wage is nonetheless below the market wage. Herbicides substitute for family labor, so cash requirements rise sharply. Farmers see only a small yield increase when they use herbicides because their manual control is intensive and because they find herbicides so complicated that they increase the herbicide dose to obtain adequate control. Herbicides are not subsidized, so farmers pay the full cost. Manual control is more profitable despite the fact that herbicide use increases yields and decreases labor requirements.

TABLE 4: Economic Analysis of Alternative Tillage/Weed Control Strategies (hypothetical data)

Variable	Farmer[1/] Practice	Zero Tillage[2/] / Chemical Weed Control
Yield (kg/ha)	3,200	3,300
Gross Benefits[3/] (pesos/ha)	6,720	6,930
Family Labor Input (man-days/ha)	30	7
Labor Cost[4/] (pesos/ha)	1,050	245
Herbicide Cost[5/] (pesos/ha)	0	1,565
Sprayer Rental (pesos/ha)	0	25
Costs that Vary (pesos/ha)	1,050	1,835
Net Benefits (pesos/ha)	5,670	5,095

1/ Land preparation and two early weedings with hoe.

2/ Machete chopping followed by 3.5 lt/ha Gramoxone and 3 kg/ha Gesaprim 50.

3/ Field price of maize = 2.10 pesos/kg.
(1 US dollar = 22.5 pesos)

4/ Shadow price of family labor = 35 pesos/day.

5/ Gramoxone = 250 pesos/lt; Gesaprim 50 = 230 pesos/kg.

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