Economic evaluation methods for integrated pest management in intercropped maize and sorghum production systems in southern Honduras

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Abstract: Economic evaluation of integrated pest management (IPM) programs on maize and sorghum in southern Honduras can be divided into three components: on-farm evaluation, evaluation of aggregate economic impact, and evaluation of aggregate environmental impact. In order to achieve a better understanding of the Honduran resource-poor farmer crop production system, a combination of these three components should be considered using the appropriate economic evaluation methods. Using the appropriate economic model, a suitable integrated pest management (IPM) technology package can be recommended to fit the actual needs of subsistence farmers in southern Honduras and other areas with similar agroecosystems, such as the Pacific coasts of Nicaragua and El Salvador. Any technology package that improves the economic returns of resource-poor farmers by increasing the expected yields of maize and sorghum through a reduction in the impact of lepidopterous pests constraints on the grain crops is a valuable contribution to regional development. This paper presents a review of methods available for economic analyses of potential IPM programs appropriate for practical utilization in intercropped maize and sorghum production systems in southern Honduras.

Index words: Corn, economic methods, IPM, *Sorghum bicolor*, *Zea mays*.

Resumen: La evaluación económica de los programas de Manejo Integrado de Plagas (MIP) en maíz y sorgo en el sur de Honduras puede dividirse en tres componentes: evaluación en fincas, evaluación del impacto económico agregado y la evaluación del impacto ambiental agregado. Para tener un mejor entendimiento del sistema de producción de cultivos del campesino hondureño de escasos recursos, se debe considerar una combinación de estos tres componentes usando los métodos económicos apropiados. Usando un modelo económico apropiado, se puede recomendar un paquete tecnológico de MIP que se ajuste a las necesidades actuales del campesino de subsistencia en el sur de Honduras y otras áreas con agroecosistemas similares, como las costas del Pacífico de Nicaragua y El Salvador. Cualquier paquete tecnológico que le mejore el retorno económico a los agricultores de escasos recursos, aumentando el rendimiento esperado del maíz y sorgo, reduciendo el impacto de plagas lepidópteras sobre los cultivos, es una contribución valiosa al desarrollo regional. Este reporte presenta una revisión de los métodos disponibles para análisis económicos de programas potenciales de MIP para uso práctico en cultivos de maíz y sorgo en el sur de Honduras.

Palabras clave: Maíz, métodos económicos, MIP, *Sorghum bicolor*, *Zea mays*.

Introduction

Maize, *Zea mays* L., and sorghum, *Sorghum bicolor* (L.) Moench, are the first and third most important basic grains produced in southern Honduras (Portillo *et al.*, 1991). Both crops are mainly produced by resource-poor subsistence farmers under extremely adverse environmental conditions (Trabanino and Pitre 1989). DeWalt and DeWalt (1982) reported that in 1974, 68% of the farms in southern Honduras were less than 5 ha. Sorghum is intercropped with 90% of the maize produced in this area (Portillo 1994). If the maize crop is lost to drought, farmers will use sorghum as a substitute to feed their families and animals (DeWalt and DeWalt 1987).

Insect pests are the major constraint to maize and sorghum production in southern Honduras (DeWalt and DeWalt 1982). Farmers in this region often refer to the complex of caterpillars that attack these crops as "langosta" because of the extensive, locust-like feeding damage to the plants caused by the insects. Pitre (1988) and Portillo *et al.*, (1991) identified the different lepidopteran species in the langosta complex. Maize and sorghum seedling losses may be as high as 27% during the first three weeks of crop growth as a consequence of feeding activity of the langosta species (Portillo *et al.*, 1991), and total crop destruction may occur in untreated fields (Portillo 1994). The cost of additional seed and replanting is considerable and possibly prohibitive for the subsistence farmer (Pitre 1988).

A viable tactic for management of the lepidopterous pests that are constraints to intercropped maize and sorghum development is optimization of the use of insecticide. Insecticide use by farmers in southern Honduras is variable (Portillo *et al.*, 1991). The farmer's decision to spray for insect pests is based on several factors including financial resources, weather and perceived plant damage. Farmers rely on insecticides to protect their crops, and most generally spray twice, but some do not spray at all (Portillo *et al.*, 1991).

Generally, farmers may have enough economic resources to purchase fertilizers or pesticides, but traditionally they rely on biological and cultural methods of crop protection. As a result, the crops receive little or no fertilizer, insecticide, herbicide or fungicide. Thus, the farmer's approach results in limited maize and sorghum yield.

In order to improve yield potential in the maize-sorghum intercropped system in southern Honduras, it is important to apply the information available regarding the integration of cultural, biological, and chemical methods of pest control. This knowledge could lead to actions in decision-making with emphasis on pest control, commonly known as integrated pest management (IPM). Integrated pest management strategies attempt to integrate all biological and economic components into a coordinated system that takes full advantage of as much information as possible (Cochran 1985).

Unfortunately, little IPM research has been done in maize-sorghum production systems in Honduras, even though the positive effects of individual components of pest control programs (improved crop variety, seed treatment, planting date, weed management, fertilization and insecticide application) have been extensively described by several authors (Pitre 1988, Trabanino and Pitre 1989, Portillo *et al.*, 1991, Vergara *et al.*, 2002). In order to improve pest control for resource-poor farmers in Honduras through the development of a multi-tactical IPM program, on-farm programs must be evaluated. If farmers respond logically to market economics, they will adopt an IPM program that increases yields and produces a surplus that can be sold, thus increasing their yearly cash flow.

The information obtained from studies of the agronomic practices that influence yield within IPM programs must be given economic evaluation. Several methods can be used for economic evaluation of IPM programs. Seldom are the methods direct substitutes for one another. Some methods are also complementary (e.g., budgeting is a precursor of mathematical programming or economic surplus analysis).

This paper reviews some of the methods available for economic on-farm analysis, methods for analysis of aggregate economic impact, and methods for analysis of environmental impact of IPM programs in southern Honduras. Experimental observations from a 1996 on-farm study (Vergara *et al.*, in press) were used as the basis for this discussion.

On-farm Analysis of IPM Programs

Economic analyses of on-farm IPM programs focus on choice among different alternatives of pest control in order to optimize the use of pest management practices (Tramel 1957). Because IPM programs are combinations of several tactics of pest control, the economic analysis should be capable of determining which of the combinations produce optimal welfare for the farmer (Leftwich 1979). Most of these analyses consider increased net economic returns to be the major objective of the farmer, but in the case of resource-poor subsistence farmers in Honduras, risk reduction and security of food production are also major considerations.

The most widely used method for on-farm evaluation of IPM programs is budgeting analysis (Norton and Mullen 1994). There are two types of budgets: total farm budget and partial farm budget. The total farm budget is a listing of all estimated income and expenses associated with farm management to obtain an estimate of its profitability (Makeham and Malcolm 1986). The use of a total farm budget for IPM evaluation involves developing per planted area crop budgets including input quantities and costs, output quantities and prices, and net returns for non-IPM production practices and IPM production practices. Input costs are broken down into variable and fixed costs (Norton and Mullen 1994). Seitz et al. (1994) define variable costs as the costs that vary with the level of production of the farm, applicable to both the short and long run (e.g., variable costs of maize production include fertilizer, planting, harvesting, and drying costs), while fixed costs are the costs that do not vary with production levels (e.g., land and machinery payments). There are no fixed costs in the long run because all inputs are variable. Finally, variable costs can be broken down into pest management and non-pest management costs. One problem of using total farm budgets is that differences in management among farmers may lead to erroneous interpretations of the positive (or negative) impact of IPM programs. It also complicates the classification of farmers into users and non-users of IPM programs because the degree of adoption of IPM tactics may vary considerably. On the other hand, partial farm budgets differ from total farm budgets in that several farms may be involved in the change in practices at the same time. Also, only benefit and cost of items expected to change significantly are considered. If there are no changes in crop area planted, then partial budgets can provide a quick and effective analysis of the effects of IPM per acre on profit.

When total and partial farm budgets are used to compare yields, costs, or profits of alternate IPM practices, then calculation of t-statistics and analysis of variance are important tools to define the differences among practices (Anderson *et al.*, 1977). Another useful statistical method that can be applied in specific cases such as measurement of yield under different pesticide treatments is the z-test (Parvin *et al.*, 1993). When farmer characteristics (such as education, age, risk perception) vary from farm to farm, they can be compared using a chi-squared test (Parvin *et al.*, 1993). A further step in the statistical analysis of the information is the use of regression to keep constant many of the non-IPM variables when testing for significant differences due to the adoption of IPM programs by farmers.

Risk perception of farmers is extremely important when recommending the best combination of IPM tactics (Shapiro *et al.*, 1993). The risk perception of Honduran farmers is mainly associated with biological, technical, and economic factors (e.g., pest population density can vary from one growing season to another, so pest management practices may be used improperly, thus affecting costs and returns). In order to evaluate the changes in net returns due to uncertainty of IPM practices, a pay-off matrix can be developed. The matrix will list projected net returns for different pest management practices under uncertain events (e.g., light/severe pest density). In these cases, the decision to adopt a particular IPM program under risk uncertainty depends on the farmer's ability to deal with risk and the probability of occurrence of the worst scenario predicted. Historical information could be very useful in calculating the probabilities of occurrence of the various scenarios. Unfortunately, this type of information is limited in the rural areas of Honduras, and farmers typically have high levels of risk aversion. They are willing to trade potential increases in monetary gain for reduced risk of crop loss, even if the IPM practice has potentially higher net returns than their conventional practices. This approach, although it may be considered "illogical" in a market economy, has different priorities than maximization of profit. These include securing family food reserves for use during the dry season and utilizing family labor during the growing season.

Honduran farmers are especially cautious in adopting pest control programs that reduce considerably the amount of family labor by replacing it with technology that must be purchased, (e.g., use of herbicides instead of manual weeding of the fields), even if these programs are proven to dramatically increase net returns. The main argument is that unemployed family members would leave the fields and emigrate to cities to find an alternate job. Entomologists and economists should be aware that actual pest management decisions are based on normative considerations and therefore are subjective, no matter how carefully the costs and benefits have been assessed. Consequently, the economics of decision-making in IPM is not just concerned with the dollars associated with pest damage and control, but with the traditions, perceptions, values, goals and behavior of the clients, in this case the resource-poor Honduran farmers (Mumford and Norton 1984).

Pest monitoring (scouting) can be used to provide current information on pest population levels and hence further reduce uncertainty in pest control decisions (Norton and Mullen 1994). Because scouting is a time consuming activity that involves an opportunity cost to the farmer, this cost should be projected in the budgets. For high manual labor consuming systems, such as the resource-poor Honduran farmer's crop production system, the opportunity cost of the farmer's time that can be freed (or kept) by the implementation of IPM programs is very important and may be another parameter for adoption or rejection of the proposed program. Anderson et al. (1977) define opportunity cost of farm labor as the "rate of monetary profit that could be earned in the most attractive alternative investment of available time (or equivalent risk, if risk is assumed)". Makeham and Malcolm (1986) define opportunity cost of farm labor as the "amount of money which is given up by choosing one alternative rather than another". Seitz *et al.* (1994) consider the opportunity cost of farm labor as the "implicit cost of using farm labor to produce a given product that is equal to the payment that could be received if the resource (farm labor) were used in the production of another product". Finally, Leftwich (1979) defines opportunity cost of farm labor as the "value of the resource (farm labor) needed to produce a good or service in its best alternative use".

The attractiveness of alternative pest management practices under risk can also be evaluated using a technique called stochastic dominance (Norton and Mullen 1994). Stochastic dominance allows for comparisons of probability distributions to determine the most preferred choice for different classes of farmers. There are three basic types of stochastic dominance analysis. First-degree stochastic dominance ranks distributions for all types of farmers. Second-degree stochastic dominance ranks distributions for farmers with risk aversion. The third type of stochastic dominance is generalistic and can be used to determine whether or not all farmers (within the same rank of risk aversion) will prefer one cumulative distribution of net income associated with the adoption of one IPM program or another, or have no preferences (Norton and Mullen 1994).

On-farm economic evaluations of IPM programs are often concerned not only with the choice of practices, but with the optimal level of pest control by a particular IPM program. Assuming that the goal is profit maximization, the optimal use of IPM practices occurs when the marginal increase in net returns from applying another unit of the practice equals the marginal cost of its application. Headley (1972) related the concept of economic optimization to earlier work on economic thresholds by Stern (1959), who defined economic threshold as the "pest population that produces incremental damage equal to the cost of preventing that damage". The economic threshold concept in pest control decision-making has been developed on two fronts: one associated with contributions made by entomologists, the other with those made by economists (Mumford and Norton 1984).

These approaches have been shown to be very different. That is why several alternative definitions of economic threshold have been developed. Headley (1972) pointed out that the minimum pest density that economically justifies treatment is usually larger than the lowest one causing some minimal crop loss. Stern (1973) later defined the economic threshold as the "pest density at which control measures should be used to prevent an increasing pest population from reaching the economic injury level".

Determination of economic thresholds for small farming systems is especially complex. In diversified cropping patterns such as the maize-sorghum intercropped system, the designation of key pest status by crop growth stage is difficult, because the various crops in an intercropping system may or may not be attacked by common pests, and each crop has different phenologies. The situation is more complicated when crops are planted at various times (Altieri *et al.*, 1984). Nevertheless, the economic threshold for the lepidopterous pests on subsistence farms in southern Honduras has been set at 0.4 larvae per plant (Andrews 1989). This low value is intended to provide risk protection for uncertainty and early protection to the crops.

The determination of what the economic threshold should be is difficult because it is influenced by a large number of factors. Damage functions are needed that relate pest levels to crop losses. Pesticide costs, output prices, effects of pesticide use on the development of pest resistance, and effect of pesticide use on predators and parasitoids are some of the important factors that influence economic threshold. Also, if farmer's risk aversion and environmental cost of pesticide pollution are considered, then the economic thresholds might differ substantially from those that only consider direct effects on net returns to the farmers.

In order to deal with a multi-factorial analysis of optimal use of IPM practices, several mathematical programming techniques can be used.

The most common are linear programming, non-linear programming and dynamic programming (Norton and Mullen 1994).

Linear programming can be used to maximize an objective function (e.g., net return from a specific IPM program) subject to resource constraints (e.g., land, labor, capital, water, off-farm inputs). Linear programming assumes that all activities and constraints can be cast in linear form. Non-linear programming is an extension of linear programming that allows for non-linear relationships.

Despite their relative simplicity, the time involved in constructing the mathematical models is the main reason for their limited use for on-farm decision-making.

Dynamic programming is used to design optimal pest management actions given a set of variables such as potential plant production, pest susceptibility to pesticides, and pesticide resistance buildup. These variables are generally difficult to measure empirically, that being one of the main reasons for the limited use of this technique for IPM purposes.

Analysis of Aggregate Economic Impact of IPM Programs

Methods for analysis of aggregate economic impact of IPM programs are used to measure changes that occur beyond the farm gate. The purpose may be to estimate regional benefits of IPM or help design pest management policies.

When widespread adoption of IPM occurs across large areas, changes in crop prices, cropping patterns, farmer's profit, and social welfare can occur. These situations arise because of changes in costs and because greater supplies affect prices to farmers and consumers (Bishop and Toussaint 1958). Adoption of IPM lowers the cost of production per unit of output. The Honduran population could have more grains available at a lower price, while farmers supply more at a lower cost of production and at a lower price. The population gains a consumer surplus. It might be expected that resource-poor farmers will not lose money as a result of adopting new technologies of IPM because the demand for grains in Honduras fluctuates throughout the year (Ministerio de Economía 1990).

Once changes in economic surplus are calculated or projected over time, benefit/cost analysis can be completed in which net present values, internal rates of return or benefit/cost ratios are calculated. Net present value is the sum of the discounted values of the future income and costs associated with the given IPM program (Makeham and Malcolm 1986). Internal rate of return is the percentage rate of return on investment that farmers may expect from additional sums used to implement an IPM program (Hyman 1989). Benefit/cost ratio is a procedure for comparing the benefits and costs of an IPM program, often used in determining whether or not a government should spend funds on that activity (Seitz *et al.*, 1994).

Analysis of Aggregate Environmental Impact of IPM Programs

During past years in Honduras, the public has increased its attention to the actual or potential environmental benefits of IPM programs (Andrews 1989). Nevertheless, measurement of benefits is difficult for two primary reasons. First, the measure of physical or biological effects of various levels of pesticide use under various IPM practices is not an easy task. Second, the economic value associated with environmental effects generally lacks a market price (Norton and Mullen 1994). One approach to economic evaluation of the environmental impact of IPM programs is the calculation of environmental impact quotients for each pesticide used. These quotients are calculated based on dermal and chronic toxicity, leaching potential, surface loss potential, soil half-life, and hazardous effects to plants, birds, fish, mammals and beneficial insects. Finally, the quotient is multiplied by the percent active ingredient and application rates for each pesticide used. Once an economic value is assigned to these differences, the IPM evaluator can choose those products with the least environmental impact (Higley and Wintersteen 1992).

Another method available for measuring the environmental impact of IPM programs is the use of contingent valuation (CV) to assess the relative importance that individuals place on environmental risk categories (such as water quality, non-target organisms and human health) and the amounts of money they would be willing to pay to avoid high, moderate or low levels of risk from a specific type of pesticide. When this survey is made among a large number of farmers, their answers are used to estimate the environmental cost per pesticide. Therefore, if the amount of change in pesticide use as a result of the adoption of an IPM program is calculated, then the environmental cost or environmental "savings" can be calculated (Norton and Mullen 1994). The use of the CV technique may be of limited application in Honduras because of cultural, behavioral and educational reasons. Basically, the CV method relies on farm surveys. It is possible that resource-poor Honduran farmers may provide marginally accurate answers to the survey because they may not completely understand the questions. Nevertheless, the CV technique together with the environmental impact quotient are the most important procedures currently available for estimating the aggregate environmental impact of IPM programs.

Conclusions

In order to achieve a better understanding of the maize-sorghum crop production system in southern Honduras and to recommend the most suitable IPM program to benefit resource-poor farmers in this region, economic evaluation of entomological practices becomes a key factor. Nevertheless, the literature reveals that most of the economic analyses of IPM programs are simple per planted area budgets. Few evaluations address the aggregate effects of IPM on either income or environment. Also, many of the most sophisticated studies have developed theoretical models with little practical content.

It is evident that economic analyses are needed for on-farm decisions on choice and optimal use of the best IPM program to be implemented in maize-sorghum production in southern Honduras. Budgeting and calculation of economic thresholds are the minimum analyses required. Dominance analysis can contribute to calculations of risk effects of IPM, but improvements are needed in the procedures used to calculate environmental costs before these effects can readily be incorporated into economic thresholds.

Consumer and farmer surplus analysis can be used to estimate aggregate income benefits of IPM for the Honduran society. Benefit/cost analysis that incorporates economic surplus measures can be used to estimate net social benefits. An environmental component can be added if the procedures for environmental benefits from reduced pesticide use are refined. Finally, simulation models can be useful for measuring the implications of government policies in encouraging adoption of IPM and reducing problems with pesticide resistance.

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