Chapter 2: Literature Review

2.1. Introduction

The purpose of this chapter is to provide a selective review of the techniques used in estimating the benefits and costs of IPM research and to introduce the assessment framework. The second section discusses techniques for measuring economic impact. It also discusses factors and constraints involved in the adoption of IPM technologies; and explains the importance of geographic information systems (GIS) in the analysis of IPM adoption across agro-ecological boundaries. The last section discusses the nature and principles of the framework.

2.2. Techniques for Measuring Economic Impacts

The purpose of this section is to review and examine the literature on the economic evaluation of IPM programs. Before undertaking the task of reviewing the different methods of assessing economic impacts, it is essential to define what economic impact assessment (EIA) is. In its core purpose, EIA of research provides research leaders, scientists, and decision-makers information and knowledge on the benefits and costs of the research involved. Impacts of IPM practices on profitability, production and income risk, pesticide applicator safety, and other potential private benefits and costs must be assessed in order to help farmers decide whether they should adopt particular IPM practices (Norton and Mullen, 1994). Information on the expected benefits and costs of alternative research strategies is needed to set research priorities, to design research, and to evaluate research (Antle and Capalbo, 1993). It is generally accepted that impact assessment must be an integral part of doing IPM research and extension. A successful pest management strategy must be profitable to individual farmers and for the industry as a whole if it is to be adopted. In collaboration with the biological researchers, economists can estimate changes in pesticide use, labor, other inputs, and yields associated with alternative research strategies. There are numerous methods and approaches for impact assessment that are described in the literature.

2.2.1. Economic Evaluations

Focusing on costs and benefits, economists distinguish between two broad types of evaluations: ex-ante and ex-post. Ex-post evaluations can provide managers with evidence of the value of past research to argue for continued investments. Ex-ante evaluations can provide managers with a basis for allocation resources among competing research demands. Economic evaluation can assist in planning research, in estimating research payoffs and in guiding research and technology policies. There are several approaches for economic evaluation of agricultural research. In this chapter, we will focus on economic surplus method.

2.2.1.1. Economic Surplus Methods

A principal catalyst (Whitaker et al, 1984) for economic development in a predominately agrarian society is modernization of the agricultural sector, with concomitant increases in resource productivity and improved production technologies. Sustained increases in the productivity of resources used in the agricultural production process—land, labor, and capital—result in increased output with attendant downward pressure on the prices of agricultural products and a tendency for the internal terms of trade to move against the sector. Rising agricultural productivity and the subsequent decline of the relative prices of commodities sets into motion a series of interrelated events and changes, which

result in a change in economic surplus to producers and consumers. The method in which to measure this surplus is called the economic surplus method.

The economic surplus method (ESM) measures benefits that can be included in a benefit/cost analysis and the latter can be used to calculate the net economic (efficiency) benefits associated with research alternatives (Alston, et al., 1995). The ESM method takes account of the fact that all but the last, or "marginal", consumer would have been willing to pay more for a unit of a particular product than he or she actually has to pay (consumer surplus). It also recognizes that all but the last or marginal producer would have been willing and able to produce this unit for less than he or she receives for it (producer surplus). The ESM shows to what extent research-induced reductions in production costs may reduce market prices, and thus change the distribution of benefits between consumers and/or producers of a commodity in a way, which simpler versions of benefit/cost analysis do not (Mills, 1998). Moreover, analysis in economic surplus terms can be used to show how economic policy interventions, such as commodity price ceilings, over-valued exchange rates, and/or subsidies and taxes, distort or even eliminate the welfare gains that might otherwise have been obtained from research (Norton and Dey, 1993). Economic surplus analysis involves two fundamental economic concepts: (a) per unit cost reductions and price responses to research-induced quantity shifts and (b) assessment of the level and distribution of research benefits.

The literature in economic studies suggests that producers supply more of a commodity at higher prices. A linearly upward sloping supply curve in a graph with price on the vertical axis and quantity on the horizontal axis depicts a specific case where quantity increases are associated with price increases. As with benefit/cost analysis, for a given price the period-specific research-induced change in quantity equals the product of the expected net yield gain and the period-specific rate of adoption. The associated shift in the supply curve is assumed to be parallel, which is equivalent to assuming that the quantity shift is of similar absolute magnitude at all other potential prices. Finally, this quantity shift can be translated into a per unit cost reduction (K_t) along the price axis by multiplying the period specific expected percentage change in quantity times initial price and dividing by the supply elasticity. The shift in the supply curve is depicted in the Figure 2-1.

Research-Induced Supply Shift in Period t.

$K_t =$ (Expected net yield gain)   x
           (Expected adoption rate at time t)   x
           (Intial price)   /
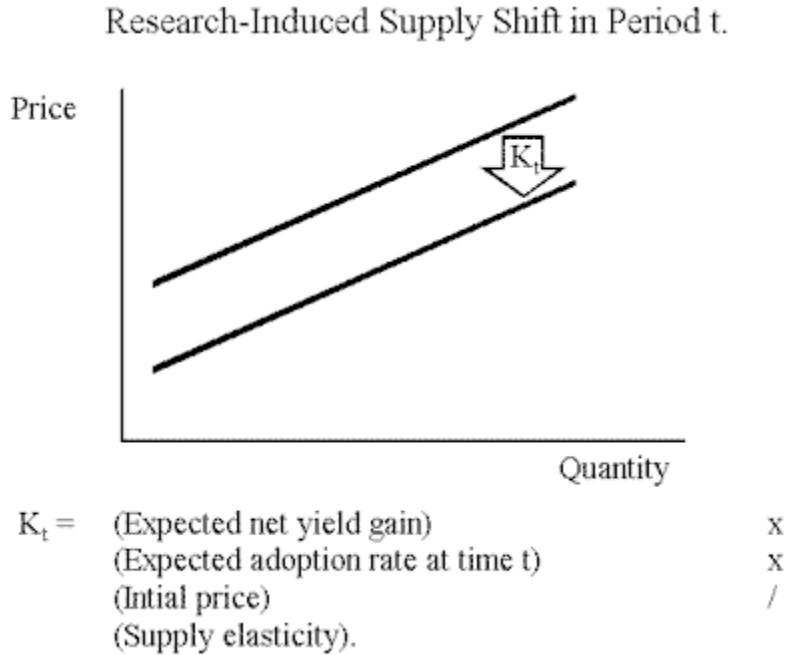   (Supply elasticity).

Figure 2-1: Price response to research-induced supply shifts.

The above abstraction illustrates how new technologies can increase agricultural productivity, and that in turn induces prices to fall. Falling prices also affect the welfare of both consumers and producers. Therefore, the economic surplus method is a relevant tool for assessing the impacts of new innovations on the agricultural sector and the aggregate economy. A more detailed explanation of ESM is given in chapter three.

The most commonly used approach in the evaluations of research and technology is indeed the economic surplus method. The economic surplus approach estimates returns to investment by estimating the benefits from research in terms of the change in consumer and producer surpluses that results from technological change, and using the estimated economic surplus together with research costs to estimate an internal rate of return (IRR), or other benefit-

cost measurements. The most common measures are benefit-cost ratios, internal rates of return, and net present values of benefits generated by agricultural research. The number of studies related to an ex-ante impact assessment of IPM programs is limited. Most of the literature has been on ex-post assessment of research programs. However, some studies similar to this study have been conducted in the recent past.

Alston et al (1995) illustrated numerous ways of doing impact assessment of technology or research. They presented the principles and practice of ex-post and ex-ante economic evaluation methods and their use in research priority setting. A wide range of approaches are reviewed, synthesized, and assessed using a unifying conceptual framework. In fact, the working model for this study is adopted from their book. Norton and Davis (1981) earlier reviewed and compared the most common approaches used to evaluate public-sector investments in agricultural research.

Norton et al. (1987) gave a brief background of the nature of economic evaluations and extended previous studies by considering an ex-ante framework in the context of Peru's agricultural research program. An ex-ante economic surplus framework was used to assess the benefits of agricultural research and extension for five commodities. The study also examined the effects of demand shifts over time and the influence of government pricing policies on research and extension benefits. The paper suggested that there is a substantial amount of benefit to investments in both research and extension.

Palomino and Norton (1993) carried out evaluation of Ecuador's agricultural research programs. They used a scoring model with an economic surplus model built in it, to rank national commodity research programs and program areas within regions.

Mills (1998) carried out an ex-ante evaluation of technology generation of sorghum in Kenya. Specific attention was given to determinants of the magnitude and distribution of research benefits. The paper found that Agro-ecological conditions and commodity market-structure are the two most important factors for technology generation and adoption. In its economic analysis, the paper used economic surplus analysis to calculate research benefits for specific research themes within Agro-ecological zones of Kenya. The author concluded that it is population-induced demand growth, not technological development, which will have the greatest influence and impact on future sorghum markets.

However, studies specifically focused on IPM research benefits are relatively few. Most IPM programs do not incorporate socio-economic factors as a component of developing sustainable IPM technologies. Among this handful of studies, the one by Napit et al (1988) gives detailed information on impact assessment of IPM practices. The study found that farmers who adopt IPM technology benefited significantly with higher yields, lower costs, and lower pesticide use (Napit et al, 1988).

Araji (1981) reported on the economic impact of investment in IPM. His inquiry was based on an ex-ante evaluation of the impacts of present and future investments in IPM. Using the results of the benefit−cost ratios of various commodities, Araji drew three fundamental conclusions: active extension involvement is required for IPM success, IPM leads to a dramatic aggregate reduction in pesticide misuse; and IPM technology could be transferable depending the nature of the crops and pests.

Antle and Capalbo (1996) reviewed the principles and the applications of assessing IPM impacts on the economy, environment, and the public health sector. They argued that impact assessment should be an integral part of IPM research. The authors provided justification for why impact assessment should be part of IPM research. They argued that EIA facilitates interdisciplinary collaboration in the design and implementation of data collection and analysis; it ensures that IPM research is useful and relevant in economic, environmental, and pubic-health terms, and it affirms that impact assessments are timely and cost-effective. Furthermore, the authors indicated that a successful pest-management program must be profitable to farmers and for the industry as a whole if it is to be widely adopted; thus implying economic impact assessments are critical to the success of IPM programs.

Norgaard (1988) employed a benefit-cost model to quantify the benefits of a biological control IPM technology called *E. Lopezi* for cassava mealybug in Africa. The study found *E. Lopezi* has a very high benefit-cost ratio and has enjoyed

widespread popularity among farmers. It attributed its success to the very nature of the technology: it requires neither investment nor maintenance expenditures. White and Wetzstein (1995) used economic surplus methods to address the distributional consequences of factor saving cotton IPM technological change. Norton et al. (1996) reviewed different methods employed to evaluate IPM programs within the context of economic principles and environmental and health assessment. They discuss farm level and aggregate level evaluation methods in detail. Economic surplus analysis is discussed as a primary tool for aggregate level economic evaluations of IPM programs. Moreover, the significance of benefit-cost analysis is discussed as a complementary tool to economic surplus measurements.

2.2.2. Adoption Pattern Analysis

Estimation of the degree of adoption is critical to any economic analysis of IPM. Land, labor, capital, knowledge, and cropping system factors may facilitate or constrain adoption of IPM technologies. There are also technical, socio-economic, institutional, and political constraints that need to be investigated in such an analysis. Technically IPM is rooted in biology and ecology. As it seeks to harness indigenous regulatory mechanisms for pest population control and exploit physiological and behavioral characteristics of pest species in their management, it requires a detailed understanding of the characteristics of agro-ecosystems and their dynamics in response to intervention.

Also, farmers are generally reluctant to adopt technology when they are unsure how it will fit within their production system. It is self evident that the crop protection specialist won't be able to anticipate the full effect of a given technology on an individual farmer's system. Moreover, the complexity of biological controls limits the full participation of farmers due to lack of education among farmers, and in return limits adoption. As far as socio-economic factors are concerned, farmer's education and input resource ownership are the most critical to the adoption success. Institutionally, IPM is an inter-disciplinary, multifunctional approach to solving pest problems. Current institutional structures in Bangladesh do little to simplify the task of the farmer practitioner. The management of research, extension, and technical support services are frequently operated independently of one another, center in different institutions and often with conflicting goals and interests. Politically, an appropriate policy environment is essential to the establishment of IPM. Policies such as pesticide subsidies have done a great deal to undermine their rational and judicious use, eventually to the farmers' disadvantages.

There are conceptual and analytical issues that hinder or promote the adoption of any technology. Most of the theoretical studies of the adoption pattern of individual farmers use static analysis that relates the degree of adoption to factors affecting it. Feder and *et al* (1985) point out that theoretical studies define adoption variables rigorously, set precise relationships for estimation, and suggest hypotheses that can be tested empirically. Fernandez-

Cornejo (1996) indicated that the adoption of a new technology is essentially a choice between two alternatives, the traditional technology and the new one.

Empirical studies of adoption by far dominate the adoption analysis literature. They include econometric and mathematical programming approaches. Most of the empirical models are specified based on prior theoretical work. Fernandez-Cornejo (1996) develops a methodology to calculate the impact of integrated pest management (IPM) on pesticide use, yields, and farm profits. The methodology is applied to the case of IPM adoption among fresh market tomato farmers in eight states. It finds that factors such as pesticide prices, farm location, and farm size are statistically significant in determining pesticide demand.

Weil (1970) examined the hypothesis that large fixed costs reduce the tendency to adopt and slow the rate of technology adoption by farms. The study finds that adopters of ox cultivation cropped larger areas and operated significantly larger farms than those using hand cultivation. The study further indicates that the negative relationship between adoption of lumpy technology and farm size may be caused by credit constraints. Jamison and Lau (1982) also found a positive relationship between the adoption of fertilizers and farm size in a study of Thai farmers.

Ruttan (1977) generalized several factors that affect the adoption of high yielding varieties (HYV) during the green revolution. He suggested technically and economically superior areas and labor availability are important factors in

the adoption process. However, the study finds that farm size and land tenure are not very important in the adoption process.

It is becoming increasingly evident that earth's resources are becoming scarcer. The continuing global population growth, environmental degradation, and stagnation in agricultural productivity in some developing countries are the main concerns regarding sustainability of development. Agriculture, which encompasses all food production, is really the cornerstone of development. Thus, it is only through the use of advanced technology that we can meet the challenge of sustainable development. Of the new technologies that have emerged recently, geographic information systems (GIS) and remote sensing show a great deal of hope in integrating different disciplines in finding mechanisms to increase agricultural production. The importance of the spatial dimension in examining issues such as regional development; land use planning and environmental monitoring is now widely recognized. In work of this kind it is necessary to interrelate information derived from sources such as censuses, maps, surveys, aerial photography, and satellite imagery, each of which may utilize a variety of methods of spatial referencing. The methods required for these types of investigation and the analysis of the resulting database, which link information to maps stored in digital form, constitute the field of GIS (Mack, 1997).

This study will incorporate GIS as a component of analysis of the potential transferability of developed IPM technologies to regions where similar pest

infestations and crops prevail. The study will rely on agro-ecological zones in order to explore the spatial dimension of pest infestation and IPM adoption patterns. Numerous socio-economic studies have been done that utilize GIS to supplement the spatial dimensions of research problems. Mills *et al*. (1998) discusses the importance of a spatial framework for research evaluation. The study examined different approaches and information bases for developing spatial classification; it also laid out a basic foundation for data collection and the classification of the data as it relates to agro ecological zones. They further point out the significant role GIS technologies play in spatial classifications to supplement research evaluations.

Bhat and Bergstrom (1997) examined the use of an object-oriented GIS framework to generate and analyze spatial data in recreation demand analysis. A case study of camping activities in Cherokee National Forest, North Carolina is used to illustrate that calculated journey distance and duration from GIS imposed calculations performed better than respondent's stated values.

2.3. Nature of the framework

Prior to designing a framework as set out in this study, it is essential to clearly define what the nature and principles of the framework are. The framework constitutes an evaluation system, but it does not suggest that the proposed evaluation system is the sole methodology to do impact assessments. The range of possible methodologies is so wide that no one system could hope to take account of all of them. It was recognition of this situation, coupled with the

need for some degree of standardization or compatibility within the IPM CRSP that led to the establishment of this framework. The framework is a set of principles and concepts, on the basis of which local, national or regional research evaluations can be constructed. Thus the framework is not an evaluation manual. However, it can be used as a guideline in the process of estimating the benefits of research to a given locality. The framework accomplishes this task by setting out a number of principles, some basic concepts, and procedures necessary to carry out an economic impact assessment study.

The principles and procedures given in the framework can be applied in all parts of the world where the IPM CRSP is operating. The framework is written mainly for those actively involved in the development and dissemination of IPM technology. The principles and procedures can be applied either to economic evaluation of individual IPM technologies or to the construction of local and national economic evaluation systems. The following chapter outlines the details of the framework step by step.