Why Do Smallholder Cotton Growers in Zimbabwe Adopt IPM?

The Role of Pesticide-Related Health Risks and Technology Awareness

by

Blessing M. Maumbe and Scott M. Swinton[1]

Michigan State University
Department of Agricultural Economics
East Lansing, Michigan 48824-1039

May, 2000

Selected paper for presentation at the annual meeting of the American Agricultural Economics Association, Tampa, FL, July 30-August 2, 2000.

---

[1] Blessing, M. Maumbe is a doctoral student and Scott M. Swinton is an Associate Professor in the Department of Agricultural Economics at Michigan Sate University. We gratefully acknowledge the financial support of a Rockefeller African Dissertation Internship Award and a W.K. Kellogg Foundation Fellowship awarded Mr Maumbe. Special thanks to Africa University, Mutare, Zimbabwe for providing institutional support. We also acknowledge all the Africa University College of Agriculture students who participated in the survey and especially Monica Chiunda and Richard Mupfiga for their dedication.

Why Do Smallholder Cotton Growers in Zimbabwe Adopt IPM?

The Role of Pesticide-Related Health Risks and Technology Awareness

ABSTRACT

In order to test whether farmer training and farmer health risks determine adoption of Integrated Pest and Production Management (IPPM) in Zimbabwe, a Poisson regression model was developed. The empirical analysis uses measures of farmer awareness of IPPM practices, pesticide health risks, labor and capital availability, expected pest damage and other conditioning variables.

The results of the analysis show that farmer awareness of IPPM practices is significantly associated with their adoption. Pesticide-related health risks however had no significant influence on the adoption of IPPM technologies. This evidence suggests that the government of Zimbabwe should expand its use of farmer field schools and other farmer-to-farmer approaches that diffuse IPPM awareness.

Why Do Smallholder Cotton Growers Adopt Integrated Pest Management? The Role of Technology Awareness and Pesticide-Related Health Risks

INTRODUCTION

Pest management in smallholder cotton production has relied on chemical pesticides although the limitations of chemical pest control have become increasingly clear to both farmers and policy makers. The application of chemical pesticides has alleviated pest problems in the short term, but pesticide use has led to negative externalities such as secondary pest outbreaks, development of pesticide resistance and the destruction of natural enemies thereby putting farmers in a vicious pesticide treadmill [Burrows, 1983;World Bank, 1996]. Rising concern for public health risks of pesticide use as well as its burden on the environment has added momentum to the need to re-evaluate the current chemical-based pest management practices [Rola and Pingali,1993].

Besides, traditional chemical-based pest management tactics have failed to provide essential ingredients for sustainable crop production, which includes the attainment of multiple benefits such as effective pest control, raising agricultural productivity and the improvement of environmental and human health benefits. This disregard for public health and environmental effects of pesticide use has led to the growing debate advocating new approaches such integrated pest management [IPM][2]. In Africa, crop protection is still centered on chemical control of pests and alternative approaches are still minimal [Adesina, 1994; Ajayi, 1999].

[2] IPM is a sustainable approach to managing pests by combining biological, cultural, physical, and chemical tools in a way that minimizes economic, health, and environmental risks [Vandeman *et al* 1994].

The benefits of knowledge-based technologies such as IPM in reducing over-application of pesticides thus improving productivity, human health and environment has been demonstrated in a number of studies conducted mostly in developed countries [Fernandez-Cornejo, 1998; Swinton *et al.*, 1999; Norton and Mullen, 1993; Thomas *et al*, 1990] and also in Asia [Antle and Pingali, 1994] and South America [Antle, Cole and Crissman, 1998]. But a few such studies have focused on Africa [Ajayi, 1999].

In Sub-Saharan Africa, local constituents advocating the protection of the environment and public health are still in their development stages. Yet the low level of literacy and education makes the overall risk of exposure to pesticide greater than elsewhere in the world [Kiss and Meerman, 1993]. The momentum for the development of IPM technologies is relatively high in Asia but is still very limited in Africa [Adesina, 1994]. The general consensus on IPM recognizes that the control of pests with pesticides can satisfy only a short-term need. The potential negative environmental and health impacts of excessive as well as inefficient use of pesticides has been well documented [Cole *et al*, 1998; Loewenson and Nhachi 1996].

The proposed route for smallholder African cotton growers to make the transition out of poverty resulting from the use of calendar-based chemical pest management is through the introduction of Farmer Field School [FFS][3]. This approach is being used to disseminate Integrated Production and Pest Management [IPPM][4] technology widely viewed as the means to ameliorate the pesticide menace. IPPM, unlike single item

---

[3] FFS is a participatory training approach that uses discovery-based learning techniques in pest and crop management. Its aim is to help farmer groups understand agro-ecosystems analysis in order to cope with biotic [insect, pests and weeds] and abiotic [water soil and weather] stresses [Rola, undated].

[3]IPPM combines IPM approaches to manage pests and improve crop production management under mixed farming systems in rural areas of Zimbabwe; it aims to increase crop productivity through interventions in both pests and production management.

innovations such as high-yielding varieties, relies on multiple pest management practices, soil and water conservation, and weather assessments in making pest management interventions. Therefore, it is essential to understand how such an information-intensive technology is adopted in practice if its prospects for widespread implementation are to be fulfilled.

Although several studies have examined adoption of IPM in cotton in the USA [Thomas, *et al*., 1990; Fernandez-Cornejo, 1996; Napit *et al*, 1988], none addresses the smallholder context and none focuses on Africa. This study looks at the adoption of different cotton pest management practices by smallholders in transition from conventional calendar-based chemical pest control to FFS-IPPM strategy. In particular it examines the roles of 1) IPM technology awareness and 2) health experience related to pesticide use.

PROBLEM OVERVIEW

Although IPM is now the preferred approach in pest management world wide, the question is how best can it be implemented under smallholder cropping systems in Africa. IPM approach has been well received in Asia, Indonesia and Philippines in particular, but the next question is can the Asian success be replicated in Africa or does the continent present a different challenge? Besides, the opportunity cost of not adopting IPM is relatively high in Africa were most farmers using toxic pesticides have the additional burden of being illiterate and lack protective clothing [Kiss and Meerman, 1993].

Despite the fact that IPM is widely recommended, it is still less widely used particularly in developing countries. For instance, pesticides remain the dominant pest management tactic in most African countries even though majority farmers cannot afford pesticides [Ajayi,1999; Kiss, 1995]. Currently, there is little information about actual adoption of IPM in smallholder agricultural production in Africa.

Empirical evidence from Asia shows that pesticide use can have negative effects on farmer health causing reductions in farmer productivity [Antle and Pingali, 1994]. Assessment of the Indonesia National IPM program and Philippine IPM for rice farmers reveals that IPM is a successful framework for alleviating pest problems that leads to higher crop returns and a reduction of both environmental liabilities and human health risks associated with intensive use of agro-chemicals [Rola and Pingali,1993; Cuyno, 1999; World Bank, 1997]. However, a slow down in IPM adoption in the Philippines has been attributed to the fact that its benefits are not apparent in the short-run [Rola, undated].

Only a few systematic studies exist on the adoption of IPM in Africa [Jowa,1993; Foti, 1999]. In Kenya, FFS has empowered local farmers to make more efficient crop management decisions that include assessing crop health and natural enemy activity prior to applying pesticide treatment [Loevinsohn, *et al*, 1998]. The strength of the discovery-based, experimental group-learning model relative to the traditional 'top-down' pest control recommendations is that it takes into account important crop interactions and prevailing field conditions. The FFS approach is now considered the standard procedure to implement IPM in Asia and is spreading to Latin America and Africa [Fleischer *et al*, 1999].

Zimbabwe cotton offers a useful test case for determinants of IPM adoption among smallholders with and without exposure to comprehensive extension training. Zimbabwe cotton growers make intensive use of pesticides to control major pests such as aphids, heliothis bollworm, stainers and red spider mites. Cotton IPM-FFS was initiated among smallholders in the Sanyati district of the Midlands Province in north central Zimbabwe during 1997 with help from FAO's IPM Global Facility. By 1999, two classes of farmers had graduated from FFSs with IPPM training in cotton production. This early stage of IPPM awareness offers a timely opportunity to compare IPM adoption determinants among Sanyati cotton farmers, including the technology awareness effect embodied in FFS training.

Study Objectives

The purpose of this paper is to determine the factors that influence the adoption of IPM practices in smallholder cotton production in Zimbabwe, and to explore the resulting policy implications. Identification of the relative importance of key factors driving the adoption of IPM will facilitate policy formulation, program planning and targeting, and diagnosing constraints in existing methods of IPM dissemination. The study addresses a serious challenge facing researchers, extension workers and policy makers involved in the development and implementation of an appropriate IPM strategy for smallholder mixed-cropping systems in Africa. Results also provide insights into the prospects for widespread implementation of IPM in Africa.

The remainder of the paper will be organized in the following way. First, the evolution and adoption of IPM in developing countries are highlighted. Second, we develop a working definition of IPM for Zimbabwe cotton. Third, we present an economic behavioral model for IPM adoption followed by specification of the empirical model. Next, results of the econometric estimation are presented and discussed. The final section summarizes the paper and discusses key policy implications.

The Evolution IPM Technologies in Developing Countries

In a few countries where IPM has been introduced in Africa [e.g. cotton in Uganda, Sudan and Zimbabwe is now in IPM mode even if only recently], implementation weaknesses in some cases have been associated with failure by farmers to distinguish between water and temperature stress with disease and insect damage. Further, inability to recognize both key pests and beneficial insects has presented problems as well. However, the impact of factors that constrain early phases of diffusion processes tends to differ and decline as the technology reaches final stage of the diffusion process [Feder and Umali, 1993].

One of the essential aspects of IPM diffusion is the integration of technical and social knowledge [World Bank, 1997]. In particular, knowledge about specific pests as well as location specific farm management systems is critical for the successful design and dissemination of IPM approaches. Some major limiting factors to the successful implementation of IPM-related technologies are lack of farmer-focused research and the availability of effective and competitive alternative non-chemical techniques [World Bank, 1997].

Apart from Asia, there is also growing evidence of successful development and use of IPM in South America [soybeans in Brazil] [Gallagher, 1988]. In Africa, smallholder farmers still consider pesticides an essential element of production, but most such farmers are illiterate and cannot afford pesticides. High illiteracy among pesticide users is however a common problem in developing countries. Therefore, one of the leading concerns of pesticide use in developing countries is that farmer's health is seriously compromised by unsafe application practices [Rola and Pingali, 1993; Tjornhom *et* al, 1997]. Widespread ignorance of pesticide poisoning symptoms and lack of personal protective equipment puts many Ecuador farmers at risk of excessive exposure [Crissman *et al*, 1994]. The claim that problems of pest resistance, pest resurgence and emergence of secondary pests in Africa have motivated the spread of alternative approaches like IPM requires further research as farmer health is increasingly becoming a critical consideration world wide.

Despite successes in a few countries, widespread implementation of IPM is still an elusive goal in most parts of the world. The momentum for the diffusion of improved technology such as IPM is slowed by policies that discriminate against agriculture in many countries [Birkhaeuser *et al*, 1991]. Past experience shows that immediate and uniform adoption of agricultural innovations is very rare. Furthermore, technology adoption and diffusion differs across socio-economic groups and over time [Feder *et al*, 1982]. In Africa, the use of Economic Threshold Levels[ETL][5] is still underdeveloped and requires refinement [Kiss and Meerman, 1993]. Besides, IPM technologies oriented toward single pests pose serious weaknesses as the challenge lies with development of ETL that deal with several pests [Rola and Pingali, 1993].

[5] Economic Threshold Level is the breakeven point at which the dollar value for an increment of loss in yield quantity or quality is equal to the cost of a control method that successfully eliminates pest damage and yield loss [Kiss and Meerman, 1993].

Following from the success of IPM programs in rice production in Asia, FFS have recently been introduced in Africa and are being used to diffuse IPM in cotton. FSS concept revolves on four principles; (1) growing a healthy crop, (2) weekly field observations, (3) conserving natural enemies and (4) understanding the field ecology including water and nutrient management [Fleischer *et al*, 1999]. The philosophy arose from the dual problem of development of pesticide resistance and increasing health risks among farmers in rice –based monocultures in Asia.

Existing Evidence on the Adoption of IPM Technologies in Developing Countries

Experiences from developing countries suggest that successful adoption of IPM on a wide scale requires the following key elements;1) creating an enabling environment for IPM by eradicating policies in support of environmentally unsustainable pest management and strengthening regulatory institutions, and 2) targeted support for measures that promote the uptake of IPM such as public awareness, research, extension and training with an emphasis on decentralized farmer centered initiatives [World Bank, 1997].

The desired broad constituency in favor of IPM can be achieved through clear definition of institutional roles and responsibilities of pest management stakeholders. Also, the adoption of a national IPM strategy is a necessary condition for IPM implementation. Such a strategy can secure broad institutional support by addressing both upstream policy elements and on-farm IPM implementation. The introduction of a national IPM strategy has been adopted relatively easily in countries where research evidence has proved that pesticides are not increasing yields significantly [World Bank, 1997].

In Africa, rice IPM pilot programs based on the FFS concept were launched in Ghana, Mali, Cote D'Ivoire and Burkina Faso in as early as 1994. Over the past five years, IPM FFS's have expanded to Sudan, East and Central, and Southern Africa regions. Increasingly, the IPM approach has become popular with both governments and development agencies interested in broader issues of integrated crop and pest management, and various versions of IPM have been tried in the different countries [Gallagher, 1998].

A critical constraint to IPM adoption in Sub-Saharan Africa is the shortage of low-cost IPM technologies that are relevant to the mixed farming systems prevalent on the continent. Besides, encouraging a broad base of farmers to experiment with new practices remains a challenge [World Bank, 1997]. IPM adoption relies on farmer-to-farmer diffusion, yet knowledge diffusion by graduates reveals gender bias as men diffuse to men and women to women. Similarly, an age bias among graduates of FFS has been reported in the literature as older farmer tend to dominate younger farmers a critical constraint to IPM dissemination [Loevinsohn, *et al*,1998]. Inadequate interaction between researchers, extension workers and farmers has inhibited local understanding and adoption of the IPM technologies that are being introduced in Africa [Gallagher, 1998].

Evidence from Philippines shows that farmers have misconceptions about pests and natural enemies; with leaf eaters generally considered as most important pests. Mismatch between pest damage and responsible pests and confusion between rice and vegetable pests seemed common among farmers. Further, additional IPM implementation hurdle in Asia has been the widespread lack of knowledge about pest resurgence and action thresholds among rice and vegetable farmers [Lazaro *et al*, 1995]. According to Rola and Pingali [1993], biological control tended to receive less attention in most IPM activities in Asia. Similar deficiencies were identified during cotton-IPM awareness campaigns in Uganda where farmers failed to recognize some species of insects as beneficiaries [Kiss, 1995].

Empirical evidence on whether multi-component technology like IPM is adopted individually or in package has been mixed and it still requires further research [Feder and Umali, 1993]. Evidence of stepwise adoption patterns of agro-chemical technological components has been reported in the literature [Byerlee and Hesse de Polanco, 1986]. Conversely, the sequential adoption hypothesis was later disputed in a study of maize production in Swaziland where farmers were reported to adopt technologies in clusters [Rauniyar and Goode, 1992]. Since uncertainty about productive performance of a technological package decreases with experience, while confidence increases with positive experience, usually early adopters choose to adopt only parts of a package rather than a complete package [Feder and Umali, 1993]. Generalizing adoption patterns is difficult due to differences in technology adoption arising from diverse agro-climatic regions.

While there are many studies of determinants of technology adoption and diffusion [Feder *et al*, 1982; Harper *et al*, 1990], relatively few have specifically sought to measure the relative importance of factors affecting non-conventional technology [D'Souza *et al*., 1993]. Our study differs from previous studies in that we focus on an emerging innovation still in its early stage of the diffusion cycle in a region that has received relatively few similar systematic studies in the past.

Defining Smallholder Cotton-IPM Adoption

The successful assessment of any IPM strategy begins with a clear definition of what is being assessed**.** Typically, IPM involves a number of pest management practices that are both location and crop specific. There is no agreement in the literature as to what specific pest management practices constitute IPM. IPM definitions have been classified as either "input-oriented" or "output oriented" [Swinton and Williams, 1998]. The later focus on desired outcomes such as profitability, human health and environmental quality while the former relate to specific IPM practices. Assuming an input-oriented approach, pest management practices can be grouped together and IPM defined as low, medium and high level [Vandeman, 1994; Mullen *et al*, 1997]. Other studies have assigned points to different practices and defined adoption along a scale [Hollingsworth *et al.* as cited in Swinton and Williams, 1998]. Yet others have considered both the proportion of practices and the degree of economic importance of the pest. In our study we use the "input oriented approach" and focus on the number of IPM practices. We characterize the cotton growers in terms of how much IPM practices adopted.

For the purpose of this study, the specific cotton IPM and production practices examined include: (1) alternating pesticides to slow development of pest resistance, (2) use of less toxic and safer chemicals, (3) adjusting pesticide application frequency and timing, (4) pest scouting, (5) adjusting planting dates, (6) use of beneficial insects in pest management, and cultural practices such as (7) crop rotation, (8) legally enforced closed season [or field sanitation] to stop pest carry-over, and (9) use of trap crops. However, we did not examine the relative importance of each IPM practice to the farmer.

METHODOLOGY AND DATA

Economic Behavioral Model

Typically, individual households are the primary decision makers concerning agricultural innovations, implying that a household behavioral model is key to understanding the adoption-diffusion process [Feder *et al*, 1993]. Assume the model of an individual household producing multiple crop outputs using multiple inputs that include pesticides. The household maximizes a utility-function $U(\pi)$ that is increasing in net returns (π) subject to constraints from fixed factors.

Several assumptions are made in specifying the model. First, we assume that farmers consider health costs as cost of production. This implies that farmers care about both economic and pesticide-related health problems associated with the use of agro-chemicals. Also agrochemical exposure is assumed to reduce health status of the farmer. Second, cotton production and management decisions can be described as static profit maximization or cost minimization. Third, farmers are sensitive to downside yield risk. Fourth, family and hired labor are homogenous and are considered as perfect substitutes when used in cotton production. The labor market is competitive and the returns to farm work and off-farm work are equilibrated. Finally, we also assume that agro-chemicals contribute to cotton productivity only indirectly via reduction in the population of pest damage agents.

In that respect, smallholder cotton yields are an indirect function of pesticides applied since production functions that treat pesticides as yield increasing inputs over-estimate marginal productivity. Lichtenberg and Zilberman [1986] were among the first to point out that pesticides should be modeled as damage control inputs just like sprinklers for frost protection. Suppose that the actual cotton yield ***(Y)*** is given by:

$$(1)\ Y = Y^0[1-D\{N(1-k(X^p))\}] \text{ and } Y^0=f(p_y, p_x, K, L, I, Z)$$

where the potential pest-free cotton yield Y^0 is a function of cotton price, p_y, prices p_x for variable inputs including labor, fertilizer, seeds, and credit, K is fixed physical capital such as land, and Z represents conditioning factors such as soil type, rainfall, farmer's education, gender, experience and managerial capacity. But the actual yield Y, depends on pest damage and its abatement. Therefore, $D(.)$ represents the pest damage function[6], N is the pest pressure and X^p is the pesticide or damage control agent purchased at price p_p**.** Pesticide efficacy range is such that $0<k(X^p)<1$ where $k(X^p)$ describes the "kill function". When a chemical is completely effective, that is $k(X^p)=1$, then $Y = Y^0$. Following from the work of Antle *et al* [1994] and Swinton [1998], we specify the relevant smallholder maximization problem as follows**:**

$$(2)\ \underset{X^p}{Max}\ \bullet = P_y Y(p_y, p_x, p_p, I, K, L, Z,) - p_x X^0 - p_p X^p - p_h H^s$$

$$s.t\quad (i)\ Y = f(X^p, X^o) - D(N+\bullet\ )[1- k(X^p)] + \mu$$

$$(ii)\ EXP \leq P_a(Q_a-S_c)-w(L-F) + R$$

$$(iii)\ L^e \leq L_f + L_h + L_s$$

$$(iv)\ I_t = \Psi(I_0, FFS, Age, Educ, Experience, V\ )$$

$$(iv)\ H = h(H^0, H^s, A^p, X^p, X^{o,} I)$$

where *(i)* cotton output ***(Y)*** is increasing in non-pest inputs X^o, ***D(.)*** is a concave function increasing in pest population ***(N),*** but ***N*** is reduced by concave “kill function” ***k(.)*** which is increasing in pest management input X^p. Both cotton yield and pest population are stochastic; $Y+\mu$ where $\mu \sim N(0, \bullet_{\mu}{}^{2})$ and $N+\bullet$ where $\bullet \sim N(0 \bullet . {}^{2})$. Pesticides and non-chemical production inputs are distinguished by variables X^p and X^o at prices p_p and p_x, respectively. In Equation 2(ii), ***EXP*** is expenditure on non-agricultural products, P_aQ_a is cash receipts from agriculture, P_aS_c is value of household consumption of self-produced agricultural staple, ***R*** is remittances from relatives and ***w*** is wage rate. In Equation 2(iii), L^e is total effective labor requirement, L_h is total hired labor input, L_f is family labor and L_s is shared labor from the community. In Equation 2(iv), I_t refers to farmer’s pest information knowledge, I_o represents farmer’s initial level of pest management information before exposure to IPM training, ***FFS*** refers to participation in FFS-based IPM training. I_t is also affected by among others farmer’s personal and village level characteristics ***(V)***. In Equation 2(v), ***H*** is a measure of farmer’s health endowment, H^s are health services, and A^p is pesticide-averting behavior. Beside human health, pesticide use X^p also influences environmental quality. However, the data in this study does not provide sufficient farm-level variation to identify this effect, so it is not included in the presentation of the economic behavioral model..

Solving the constrained maximization problem, we can derive a factor demand function for X^p, which is stated as follows:

$$(3)\ X^p = g[P_y, P_x, P_h, H, L, I, K, Z]$$

[6] Damage function expresses the relationship between pest pressure and yield loss; it varies with presence of different pests and the abundance of natural enemy species that feed on pests [Rola and Pingali, 1993].

In particular, the demand for IPPM practices $\boldsymbol{X^p}$ will depend on farmer characteristics ***(Z)*** available farm resources ***(L, K),*** biophysical characteristics of the farm setting ***(Z),*** pest pressure ***N,*** institutional and relative prices ***(P)***, health effects of pesticides ***(H)*** and IPM awareness ***(I)***. The specific empirical measures of these attributes are presented in Table 1 and discussed below. It is hypothesized that exposure to IPPM training through FFS will do the following; (i) improve farmer's cotton pest management knowledge, (ii) raise cotton yields, (iii) lower pesticide use, (iv) improve farmer's health status and (v) raise farm profitability [Waibel, et al 1998]. The expected outcomes can be summarized mathematically as follows:(i) $\boldsymbol{\delta I/\delta FFS \geq 0}$, (ii) $\boldsymbol{\partial Y/\partial I \geq 0}$**,** (iii) $\boldsymbol{\partial X^p/\partial I \leq 0}$, (iv) $\boldsymbol{\partial H/\partial I \geq 0}$**,** and (v) $\boldsymbol{\partial \pi/\partial I \geq 0}$.

Cross-sectional analysis of cotton-IPPM a recently introduced technology in Zimbabwe will provide important signals to the fundamental characteristics driving the uptake of IPPM by both current and future adopters who will ultimately accept the technology. The inclusion of farmers with different years of experience with IPPM can form the basis to explore the adoption process itself. Such information provides more timely strategic adjustments in future IPPM implementation.

Data and Estimation

The empirical model of IPPM adoption among smallholder cotton growers is estimated using cross-sectional data obtained from a survey conducted through personal interviews in Sanyati, one of the leading cotton growing districts in Zimbabwe. Sanyati district is located in the north central part of the country in the Midlands province. It lies in Natural Regions [NR] III and IV[7]. Farmers in Sanyati have a mean cotton growing experience of 14 years. Sanyati was one of the first districts to offer FFS IPPM training to local cotton farmers in 1997. Survey farmers in Sanyati were identified using stratified random sampling approach on the basis of villages with FFS groups. The second level of stratification was based on the cotton farmer participation in FFS-based IPPM training groups. A total of 141 farmers were interviewed in Sanyati.

Data used in the analysis was collected at two different levels; household and field. The unit of observation was the household. Table 1 presents model variables grouped by type. Farmer characteristics that condition adoption behavior include farmer's age (HHAGE), number of extension meetings attended (COTEXTMTG), cotton growing experience (COTYEARS), level of formal education (EDUYEARS), gender of head of household (HGENDER) and whether certified as a Master Farmer (MASTERFM).

Farm resource endowment variables include total cotton labor (LABDAYS), cotton land area cultivated (COTAREA), value of productive assets (PROASSESTS), ownership of draft animals (DRAFTOWN), use of credit (CREDIT) and farmer's participation in formal off-farm employment (FOMEMPLT). Farm management practices that could influence pest management include use of improved cotton variety (ALBARFQ902), production of staple maize crop (ALTCROPM), whether the cotton field was fallowed the previous season (FALLOW), absence of specific three-year cotton rotation program (NROTPROG) and number of tillage practices used (TILPRACS) in cotton production. Pest pressure is designated by the index variable (PSTPRESS).

[7] A NR is an agro-ecological zone demarcated on the basis of rainfall pattern, as well as crop and livestock production potential in the region. Average annual rainfall for NRs III and IV are 800mm and 400 mm.

Institutional and relative price factors are access to information media (MEDIA), average walking time from homestead to cotton fields (AVEWALKT) and distance to cotton markets (DISTMKT).

The health risk variables used to estimate the empirical model are number of pesticide-related acute symptoms (ACUTESYM), number of individual protective clothing units used by the farmer in making pesticides treatments (SAFINDEX), measure of farmers ability to rank the toxicity level of pesticides based on color codes on pesticide container labels (LABELIT) and whether or not the head of the household drinks alcohol (HHDRINK). The last category of the determinants of IPM adoption is the awareness and perception variables. IPMAWARE measures years since FFS IPPM training. Farmer's perception of downside yield risk (YLDRISK) and current chemical-based pest management strategies (VIEWPMGT) were also used in the regression model.

Empirical Model

In this study, we utilize a Poisson maximum likelihood regression model to predict the number of IPPM practices used by cotton growers in Zimbabwe. The shortcomings of using least squares, ordinary probit and logit regression for count data are highlighted in the econometric literature [Greene, 1997; Madalla, 1983]. The number of additional pest management practices used on a given crop indicates the farmer's reliance on multiple biological and cultural pest management, a key ingredient of IPM use [Vandeman *et al*, 1994]. Since an integrated package of cotton-IPM as an off-the-shelf system does not yet exist, farmers have the flexibility to combine different practices that address specific pest complex in their fields. The predicted values $\boldsymbol{Y_1}$ $\boldsymbol{Y_2, \ldots, Y_n}$ are assumed to have independent Poisson distribution with parameters $\lambda_1, \lambda_2, \ldots, \lambda_n$ respectively [Madalla, 1983]. According to Greene [1997], the basic equation for the Poisson regression is represented as follows:

$$(2)\ Prob(Y_i = y_i) = [e^{-\lambda i}\lambda_i]/y_i \text{ where } y_i = 0, 1, 2, \ldots..$$

The parameter λ_i is assumed to be log-linearly related to regressors x_i. Therefore,

$$(3)\ Ln(\lambda_i) = \beta' x_i$$

The log-likelihood function is given by :

$$(4)\ Ln\ L = \Sigma_{i=1,\ldots,n}[-\lambda_i + y_i\beta' x_i - ln\ y_i!]$$

The expected number of IPPM practices per farm is given by;

$$(5)\ E[y_i/x_i] = Var[y_i/x_i] = \lambda_i = e^{\beta' xi + \mu i}$$

Based on the conceptual framework above, the empirical model is estimated using the following groups of regressors; (1) farmer characteristics **[FC]**, (2) farm resource endowment **[FR]**, (3) farm management practices **[FP]**, (4) pest damage **[PD]**, (5) institutional environment and relative prices **[IP]**, (6) health risk **[HR]**, and (7) awareness and perception variables **[AP]**. The general form of the empirical model estimated is stated as follows:

$$(6)\ \sum IPPM\ Practice_i = [FC, FR, FP, PD, IP, HR, AP] + v_i$$

Descriptive Results:

Farmer's Adoption Patterns and Pest Management Perspectives

The majority of farmers use at least three IPPM practices identified above during the 1998/99 season. The mean number of IPPM practices used is 4.36. About 11 percent reported using as many as 7 IPPM practices. All the farmers reported using at least two

IPPM practices. A cluster analysis of the different IPPM practices did not reveal any discernible pattern in terms of adoption of IPPM practices. The leading IPPM practices adopted were pest scouting [89%], field sanitation [97%] and crop rotations [90%], alternating pesticides [32%] and preservation of beneficial insects [30%]. Correlation analysis suggests practices were adopted independently.

Survey farmers expressed diverse views about motivations for pesticide interventions and use of IPPM. Among those exposed to IPPM training, 85 percent believed that IPPM knowledge is an effective pest management tool and 8 percent felt the opposite. The rest were either not sure or had no opinion about IPPM. Including the non-FFS graduates the beliefs about IPPM were that 40 percent felt it was effective and while 54 percent had no idea. The rest felt IPPM was not effective or simply that it could not be superior to the traditional chemical control of pests.

Chemical interventions were made for different reasons with 30 percent of the respondents stating that they spray on fixed calendar basis, while 66 percent said they applied chemicals only after scouting. Other reasons cited for guiding chemical interventions were specific growth stages for the cotton plant.

Only 14 percent of the farmers felt that the major problem in cotton production today was pest management. A majority felt that poor prices [53%] were most important, and some felt drought [6%] was a serious problem needing urgent attention.

Regression Results:

Factors Affecting IPPM Adoption among Smallholder Cotton Farmers

Poisson regression results on the determinants of adoption of aggregate IPPM practices in Sanyati District are summarized in Table 2. The analysis was carried out using STATA version 6.0. Data from Chipinge District in the lowveld were subjected to the same estimation but the results were insignificant, perhaps due to the absence of farmer field schools.

The Poisson regression model was significant, with a Chi-square value of 53.32, which was significant at the one percent level. However, much variability in IPPM practices adopted was not explained by the model, which had a McFadden R^2 of only 10.2 percent.

The most striking result is the technology awareness coefficient that is significant at the one percent level. Farmers exposed to cotton-IPPM techniques through the Farmer Field Schools, are more likely to use several IPPM related practices in cotton pest management. The coefficient for the total area cultivated to cotton is significant at the 10 percent level. This implies a scale-effect in the use of IPPM technology. Cotton farmers with larger acreage under cotton are likely to have easier access to technical information thus use more IPPM practices in reducing cotton pest damage. In addition, the coefficient for the cotton variety ALBARFQ902 is significant at 10 percent. This is implies that farmers growing this high-yielding cotton variety are more inclined to use IPPM practices. The unique characteristics of this variety are that it is resistant to bacteria blight and jassids, and is more tolerant to aphids and drought. Although it is susceptible to verticillium wilt, ALBARFQ902 has the highest score on pest and disease resistance among all the cotton varieties grown in the middleveld in Zimbabwe.

Contrary to expectation, the pesticide-related health risk variables ACUTESYM SAFINDEX, LABELIT and HHDRINK came out insignificant. The lack of statistical significance associated with health risk variables does not support the hypothesis that IPM adoption decisions are based on pesticide-related health risks.

Conclusion

The main conclusion is that technology awareness embodied in access to IPM training through FFS is important in motivating the use of multiple components of risk-reducing technologies such as IPM. Investment in IPM farmer education and literacy programs targeted to non-adopters will have long-term beneficial impacts on IPM use. IPM use requires an experimental cotton plot and farmers with more land are more likely to adopt IPM practices. In addition, cotton growers who planted the leading pest resistant variety ALBARFQ902 were likely to adopt more IPM practices. Experience with pesticide-related health problems did not significantly affect IPM adoption, suggesting there is still a greater need to sensitize farmers about the health risks of using pesticides. It may be that using IPM does not significantly reduce these risks, hence the link between pesticides and human health should be further explored in the context of Zimbabwean smallholder cotton production.

Policy Implications and Suggestion for Future Research

An analysis of IPM practices being adopted, the characteristics of smallholders that are adopting and the factors motivating adoption of FFS-IPPM is still fragmentary [Adesina,1994]. Our results indicate that diffusion factors such as FFS-IPPM training and farmer-to-farmer extension delivery approaches will play a critical role in the delivery and adoption of IPM. Success of IPM adoption will depend on farmer's knowledge and awareness of the technology. Further, rapid adoption could occur if farmers complement adoption of IPPM practices with a conscious choice on varieties that confer pest and disease resistance qualities such as ALBARFQ902. Both economists and policy makers involved in crafting incentives for widespread diffusion and adoption of FFS-based cotton IPM need to address these important issues when planning future IPM programs in Africa. In addition, information about the type of farmers most likely to adopt IPM technology and the extent of its adoption is expected to guide agro-chemical firms in future new product development and marketing strategies, given that one dimension of IPM is to emphasize the use of safer and less toxic products. The links between pesticide-related health effects and cotton productivity requires further research to determine whether farmers should pay more attention to health factors in adopting IPM practices. Also, gaps exist in terms of understanding the sequence followed by smallholders in adopting individual IPM practices during its diffusion cycle. Future research must therefore address the relative importance of individual IPM practices and the bundling strategies used by smallholder cotton growers in adopting compatible combinations of emerging technologies such as IPM.

Table 1:Description of independent variables used in Poisson Regression Model

Variable Name	Definition	Units	Mean	Standard Deviation
Dependent Variable				
Number of IPM practices	Count of IPM practices	count	4.13	1.62
Farmer's Characteristics				
HHAGE	Farmer's age	years	46.25	14.26
COTYEARS	Cotton growing experience	years	14.21	10.37
COTEXMTG	Number of extension meetings	number	4.64	6.36
EDUCYEARS	Number of years in formal education	years	6.57	3.72
HGENDER	Head of household's gender	[0,1]	0.83	-
MASTERFM	Certified Master Farmer	[0,1]	0.26	-
Farm Resource Endowment				
LABDAYS	Total labor used in production	man-days	80.93	43.06
COTAREA	Land area cultivated to cotton	[Ha]	4.55	3.97
PROASSET	Value of productive assets	[Z$]	9506.41	8298.98
CREDIT	Farmer used credit	[0,1]	0.18	-
DRAFTOWN	Farmer owns draft power	[0,1]	0.69	-
FOMEMPLT	Farmer is in formal employment	[0,1]	0.47	-
Farm Management Practices				
ALTCROPM	Maize is major alternative crop	[0,1]	0.08	-
ALBFQ902	Cotton variety ALBARFQ902 grown	[0,1]	0.81	-
FALLOW	Field was fallowed previous year	[0,1]	0.42	-
NROTPROG	No specific crop rotation program	[0,1]	0.13	-
TILPRACS	Number of tillage practices	number	1.43	0.87
Pest Damage Variable				
PSTPRESS[8]	Pest pressure [scale 0-1]	index	0.46	0.61
Institutional and Relative Prices				
MEDIA	Farmer has access to information media	[0,1]	0.67	-
AVEWALKT	Average walking time to cotton fields	minutes	12.97	15.78
DISTMKT	Distance to markets	[km]	13.49	7.69
Pesticide-Related Health Risks				
ACUTESYM	Pesticide-related acute symptoms	number	1.13	0.84
SAFINDEX	Count of protective clothing	count	3.75	1.53
LABELIT	Count of correct label interpretation	count	2.16	1.26
HHDRINK	Farmer drinks alcohol	[0,1]	0.48	-
Technology Awareness and Perception				
IPMAWARE [9]	Farmer's experience in FFS-IPM	years	0.83	0.93
YLDRISK[10]	Downside yield risk perception	index	2.61	2.82
PMGTVIEW	Maintain calendar-based methods	[0,1]	0.65	-

[8] Pest Pressure Index =∑ [pest pressure]/39. The pest pressure indicators are 0=None, 1= Light 2= Average and 3=Severe. The pest pressure is assessed for 13 different cotton pests where a count of 39 represents severe cases for all cotton pests.

[9] IPMAWARE is measured as post FFS-IPM training years; 0=no IPM training, 1= 1998/99 FFS graduate and 2=1997/98 FFS graduate.

[10] Downside yield risk=$[Y_M-Y_L]^2$ where Y_M represents mean cotton yield and Y_L is the perceived lowest cotton yield from the main cotton field during a poor season. The assumption is that farmers care more about downside yield risk.

Table 2: Determinants of Cotton IPM Practice Adoption in Sanyati District, 1998/99

Variable	Coefficient	Standard Error	z-value
Farmer Characteristics			
HHAGE	-0.00020	0.00443	-0.046
COTEXMTG	0.00715	0.00739	0.968
COTYEARS	0.00081	0.00575	0.141
EDUYEARS	0.01029	0.01377	0.748
HGENDER	0.12038	0.14273	0.843
MASTERFM	-0.11137	0.11458	-0.972
Farm Resource Endowment			
LABDAYS	-0.00030	0.00130	-0.231
COTAREA	0.02346*	0.01221	1.921
PROASSET	3.17e-06	6.35e-06	0.500
CREDIT	0.04268	0.12592	0.339
DRAFTOWN	-0.17080	0.12242	-1.395
FOMEMPLT	-0.03769	0.10400	-0.362
Farm Management Practices			
ALTCROPM	-0.12055	0.19698	-0.612
ALBFQ902	0.26005*	0.14045	1.852
FFALLOW	0.11101	0.09692	1.145
NROTPROG	-0.05785	0.15187	-0.381
TILPRACS	0.03348	0.07071	0.474
Pest Damage			
PSTPRESS	0.00302	0.07316	0.041
Institutional and Environmental			
MEDIA	-0.05383	0.10922	-0.493
AVEWALKT	-0.00057	0.00301	-0.190
DISTMKT	0.00663	0.00811	0.818
Pesticide-Related Health Risks			
ACUTESYM	0.01993	0.06545	0.305
SAFINDEX	0.03387	0.03418	0,991
LABELIT	-0.01509	0.03993	-0.378
HHDRINK	-0.10361	0.10889	-0.951
Technology Awareness and Perception			
IPMAWARE	.0.19049 ** *	0.06677	2.853
YLDRISK	-0.00797	0.01741	-0.458
PMGTVIEW	-0.03678	0.10416	-0.353
N	136		
McFadden R^2	0.1022		
Log Likelihood Ratio (χ^2)	53. 32		
χ^2 p-value	0.0027		

* Significant at 10%

** Significant at 5%

***Significant at 1%

REFERENCES

Adesina, A., A. Pesticide Use and Policy in West Africa: An Overview. In Proceedings of the Gottingen Workshop on Pesticide Policies, Gottingen, Germany. Edited by S. Agne, G. Fleischer and H. Waibel. 28 February-4 March, 1994.

Ajayi, O. Measuring the Indirect Health Benefits of IPM: Methodology for Estimating Pesticide Health Costs in Africa. Paper presented at the international workshop on "Evaluation of IPM Programs: Towards a Framework for Economic Evaluation", Garbsen Hannover Germany 25-27 May, 1999.

Antle J.M., Cole, D.C., and C.C. Crissman. The Role of Pesticides in Farm Productivity and Farmer Health. In Economic, Environmental, and Health Trade-offs in Agriculture: Pesticides and the Sustainability of the Andean Potato Production. Edited by Charles C. Crissman, John M. Antle and Susan M. Capalbo. Kluwer Academic Publishers.1998.

Antle J.M and Pingali P.L., Pesticides, Productivity, and Farmer Health: A Philippine Case Study. In *American Journal of Agricultural Economics*, 76, 3:418-429 [1994].

Besley, T., and Anne Case. Modeling Technology Adoption in Developing Countries. *Journal of American Economic Review*, 83,2[396-402],1993.

Birkhaeuser, D, Evenson R.E., and G. Feder. The Economic Impact of Agricultural Extension: A Review. In *Economic Development and Cultural Change*, 39,3[607-650], 1991.

Burrows, M.T., Pesticide Demand and Integrated Pest Management: A Limited Dependent Variable Analysis. In *American Journal of Agricultural Economics*, 65, 4:806-810 [1983].

Byerlee, D. and Hesse de Polanco, E. Farmers' Step-wise Adoption of Technological Packages: Evidence from the Mexican Altiplano, *In American Journal of Agricultural Economics Association*, 68, 519-527 [1986].

Cole, D.C., Carpio F., Julian, J.A.,and N Leon. Health Impacts of Pesticide Use in Carchi Farm Populations. In Economic, and Environmental, Health Tradeoffs in Agriculture: Pesticides and the Sustainability of Andean Potato Production. Edited by Charles C. Crissman , John, M. Antle and Susan M. Capalbo. Kluwer Academic Publishers. 1998.

Cuyno, L.C.M. An Economic Evaluation of the Health and Environmental Benefits of the IPM Program (IPM CRSP) in the Philippines. Dissertation submitted to the Faculty of the Virginia Polytechnic Institute and State University, Blacksburg, Virginia. USA. 1999.

Crissman, C.C., Cole, D.C., and F. Carpio. Pesticide Use and Farm Worker Health in Ecuadorian Potato Production. In *American Journal of Agricultural Economics*, 76[593-597], 1994.

D'Souza, G., Cyphers, D., and T. Phipps. Factors Affecting the Adoption of Sustainable Agricultural Practices. In *Agricultural and Resource Economics Review,* 22,2 [159-165], 1993.

Feder, Gershon, and Jaime Quizon, Integrated Pest Management in Asia: Are There Real Returns to IPM and its Diffusion? In Evaluation of IPM Programs-Concepts and Methodologies. Papers Presented at the Workshop on Evaluation of IPM Programs, Hannover; Pesticide Policy Project in cooperation with FAO. March 16-18 1998.

Feder, G., Just, R.E., and D. Zilberman. Adoption of Agricultural Innovations in Developing Countries: A Survey. In *Economic Development and Cultural Change*, 225, 65p, 1982.

Feder, G., and D. L. Umali. The Adoption of Agricultural Innovations: A Review. In *Technological Forecasting and Social Change*, 43[215-239], 1993.

Fernandez-Cornejo, J., Environmental and Economic Consequences of Technology Adoption: IPM in Viticulture. In *Journal of Agricultural Economics,* 18[145-155], 1998.

Fleischer, G, Jungbluth, F., Waibel, H., and J.C. Zadoks. A Field Practitioner's Guide to Economic Evaluation of IPM. Pesticide Policy Project in Cooperation with Food and Agriculture Organization. University of Hannover, Germany, Publication Series No.9.1999.

Foti, R. Comparative Economics of Integrated Pest Mnagement and Pesticide Use for Smallholder Cotton Farmers in Gokwe. MSc Thesis Research Proposal, University of Zimbabwe, Department of Agricultural Economics and Extension, Harare, 1999.

Gallagher, K.D. Farmer Field Schools for Integrated Pest Management in Africa with Special Reference to East Africa. In Proceedings of the National Pre-Season Planning Workshop on the Implementation of Field School Groups for Integrated Production and Pest Management. 31 August-1 September, 1998. ZIPAM, Darwendale. Government of Zimbabwe and FAO Global IPM Facility, Rome, Italy.

Greene, W.H. Econometric Analysis. Third Edition. New York University. Prentice Hall, New Jersey. USA. 1997.

Harper, J.K., M.E. Rister, J.W. Mjelde, B.M. Drees, and M.O. Way. Factors Influencing the Adoption of Insect Management Technology, In *American Journal of Agricultural Economics* 72[997-1005], 1990.

Jowa, P. Cotton IPM in Zimbabwe. In IPM implementation workshop for East, Central and Southern Africa. Harare, Zimbabwe. Edited by Natural Resource Institute, Edingburg, United Kingdom,1993.

Khanna M., Epouhe O.F., and Robert Hornbaker. Site Specific Crop Management: Adoption Patterns and Incentives. *Review of Agricultural Economics*, 21,2:455-472. USA.

Kiss, A. Pest Management Needs and Trends in Africa Today. Paper Presented at the International Food Policy Research Institute Workshop on "Pest Management, Food Security, and the Environment; The Future to 2020." Nairobi, Kenya. May 10-11. 1995.

Kiss, A and F. Meerman. Integrated Pest Management and African Agriculture. World Bank Technical Paper Number 142. African Technical Paper Department Series. Washington DC, USA. 1993.

Lazaro, A.A., Heong K.L., Canapi, B., Gapud V. and G.W.Norton. Farmers' Pest Management Knowledge, Attitudes and Practices in San Jose, Philippines: A Baseline Survey. Integrated Pest Management Collaborative Research Support Program [IPM CRSP] Working Paper 95-2. Virginia Tech. Blacksburg, VA, USA. 1995.

Loevinsohn, M, Meijerink G. and Beatrice Salasya. Integrated Pest Management in Smallholder Farming Systems in Kenya. Kenya Agricultural Research Institute. Narobi, Kenya, 1998.

Loewenson, R and C.F.B. Nhachi., "Epidemiology of health impact of pesticide use in Zimbabwe." In Pesticides in Zimbabwe:Toxicity and Health Implications. Edited by Charles, F. B. Nhachi and Ossy M. Kasilo. University of Zimbabwe Publications, Harare, Zimbabwe, 1996.

Lichtenberg, E., and D. Zilberman. The Econometrics of Damage Control: Why Specification Matters. In *American Journal of Agricultural Economics,* 68 [261-273], 1986.

Maddala, G.S., Limited-Dependent and Qualitative Variables in Econometrics. Econometric Society Monographs No, 3. Cambridge University Press. USA. 1983.

Mulugetta M, An Economic Analysis of Smallholder Wheat Production and Technology Adoption in the South-Eastern Highlands of Ethiopia. PhD Dissertation, Michigan State University, East Lansing, USA.1994.

Mullen, D.J., Norton, G.W., and Dixie, W., Reaves. Economic Analysis of Environmental Benefits of Integrated Pest Management. In *Journal of Agricultural and Applied Economics,* 29, 2[243-253], 1997.

Napit, K. B., Norton, G.W., Kazmierczak, R.F. Jr., and E.G. Rajotte. Economic Impacts of Extension Integrated Pest Management Programs in Several States. In *Journal of Economic Entomology*, 81[1]:[251-256], 1988.

National Research Council. Ecologically Based Pest Management: New Solutions for a New Century. National Academy Press, Washington D.C. 1996.

Norton, G.W., and J.D.Mullen, Economic Evaluation of Integrated Pest Management Programs. Publication No. 446140. Virginia Polytechnic Institute and State University, Blacksburg. USA. 1993.

Rauniyar G.P., and F.M. Goode. Technology Adoption on Small Farms. In *World Development,*20 [275-282], 1992.

Rola, A.C. Farmer Field School, IPM Knowledge and Farmer Efficiency: The Iloilo-Philippines Case Study. University of Philippines at Los Banos, College, Laguna, Philippines, undated.

Rola, A.C., and P.L. Pingali, Pesticides, Rice Productivity and Farmers' Health: An Economic Assessment. Washington D.C: World Resources and International Rice Research Institute, 1993.

Swinton, S.M. Less is More: Why Agro-Chemical use Will Decline in Industrialized Countries. In Economics of Agro-Chemicals: An International Overview of Use Patterns, Technical and Institutional Determinants, Policies and Perspectives.

Edited by G.A.A. Wossink, K.C. van Kooten, and G.H. Peters, Aldershot, UK: Ashgate, 1998. Pages 359-372.

Swinton, S.M, Owens, N.N., and Eileen O. van Ravenswaay. Health Risk Information to Reduce Water Pollution. In Flexible Incentives for the Adoption of Environmental Technologies in Agriculture. Edited by F. Casey, A. Schmitz, S. Swinton, and D. Zilberman. Kluwer Academic Publishers, 1999. Pages 263-271.

Swinton, S.M. and M.B. Williams. Assessing the Economic Impacts of Integrated Pest Management: Lessons from the Past, Directions for the Future. Staff Paper 98-12. Department of Agricultural Economics, Michigan State University. East Lansing, MI, USA. 1998.

Thomas, J.K., Ladewig H, and Wm. Alex McIntosh. The Adoption of Integrated Pest Management Practices Among Texas Cotton Growers. In *Rural Sociology*, 55, 3[395-410], 1990.

Tjornhom, J.D., Norton, G.W., Heong, K.L., Talekar, N.S., and V.P Gapud. Determinants of Pesticide Misuse in Philippines Onion Production. *Phillip. Ent.* 11(12):139-149, 1997.

Vandeman Ann, Jorge Fernandez-Cornejo, Sharon Jans and Biing-Hwan Lin. Adoption of Integrated Pest Management in US Agriculture. United States Department of Agriculture. Economic Research Service. Agriculture Information Bulletin Number 707. Washington D.C. USA. 1994.

Waibel.,H, G., Fleischer, P.E. Kenmore and G. Feder. Evaluation of IPM Programs-Concepts and Methodologies. Pesticide Policy Project in cooperation with FAO. Papers presented at the first workshop on Evaluation of IPM Programs, Hannover, Germany, March 16-18, 1998.

World Bank. Integrated Pest Management: Strategies and Policies for Effective Implementation. Environmentally Sustainable Development Studies and Monographs Series No.13. Washington D.C. USA. 1997

Yee, J., and Walter Ferguson. Cotton Pest Management Strategies and Related Pesticide Use and Yield. *Journal of Production Agriculture***,** 12, 4:[618-623], 1999.