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HEALTH EFFECTS AND PESTICIDE PERCEPTION AS DETERMINANTS OF PESTICIDE USE: EVIDENCE FROM BANGLADESH

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Abstract - In a recent survey of 820 Boro (winter rice), potato, bean, eggplant, cabbage, sugarcane and mango farmers in Bangladesh, over 47% of farmers were found to be overusing pesticides. With only 4% of farmers formally trained in pesticide use or handling, and over 87% openly admitting to using little or no protective measures while applying pesticides, overuse is potentially a very threatening problem to farmer health as well as the environment.

To model pesticide overuse, we used a 3-equation, trivariate probit framework with health effects and misperception of pesticide risk as endogenous dummy variables. Health effects (the 1st equation) were found to be strictly a function of the *amount of pesticides* used in production, while misperception of pesticide risk (the 2nd equation) was determined by *health impairments* from pesticides and the *toxicity of chemicals* used. Pesticide overuse (the 3rd equation) was a significantly determined by variation in *income, farm ownership, the toxicity of chemicals used, crop composition* and *geographical location*.

The results highlight the necessity of policymakers to design effective and targeted outreach programs which deal specifically with pesticide risk, safe handling and averting behavior. Ideally, the approach would be participatory in nature to address key informational gaps, as well as increasing a farmers' awareness retention. The results also point to specific crops and locations experiencing a higher prevalence of overuse - bean and eggplant in general, and overall production in the districts of *Chapainawabganj, Chittagong, Comilla, Jessore, Narshingdi, Rajshahi* and *Rangpur*. Focusing efforts in these crop and geographical areas may have the most measurable effects on pesticide overuse.

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1. Introduction

During the past three decades, indiscriminate use of chemical pesticides in agriculture has created serious health and environmental problems in many developing countries (World Resources, 1998-99). The World Health Organization (WHO) and the United Nations Environment Program estimate pesticide poisoning rates of 2-3 per minute, with approximately 20,000 workers dying from exposure every year, the majority in developing countries (WHO, 1990; Kishi et al., 1995; Pimental *et al*., 1992; Rosenstock *et al*., 1991). From an environmental perspective, chemically-polluted runoff from fields has contaminated surface and ground waters, damaged fisheries, destroyed freshwater ecosystems and created growing "dead zones" in ocean areas proximate to the mouths of rivers that drain agricultural regions (Pimental and Lehman, 1993; Tardiff, 1992).[1]

Many of these impacts are a direct result of the overuse and misuse of pesticides, often wildly deviating from recommended application procedures. Several recent studies investigating this behavior found that inadequate product labeling and farmers' lack of information often lead to widespread overuse or misuse of dangerous pesticides in developing countries (Huan *et al*., 2000; Dung and Dung, 1999; Dung *et al*., 1999). Anecdotal evidence also suggests that farmers use toxic chemicals extensively due to their reputation for speed and effectiveness; sometimes associating higher amounts with increased effectiveness.

The health and environmental hazards of pesticides can be partly avoided by education and the creation of incentives to curb the trend of overuse. However, a clear understanding of farmers' perception of risk and pesticide application behavior is necessary in the design of any policy intervention. Currently, systematic studies of the application of pesticides are scarce in developing countries. This paper is an attempt to close this research gap by providing quantitative estimates of pesticide overuse as well as

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[1] In addition, what was initially deemed as localized pollution has now become a global problem, as toxic compounds from pesticides accumulate in oceanic food chains, and even in the tissues of land mammals in "pristine" polar regions (Blais *et al*., 1998).

an analytical perspective of its determinants drawing on new survey data from Bangladesh.

We randomly selected and interviewed over 821 farmers across Bangladesh with structured questionnaires containing information on their input use & yield; farmers' characteristics; knowledge of pesticides and sources of information, precautions and damage-averting behavior along with any associated health effects. From their responses, we developed a simultaneous three-equation model of farmers' overuse, risk perception and health effects of pesticides. Our analysis indicates that the toxicity of pesticides, crop composition, location and other socio-demographic factors determine the incidence of overuse. To the best of our knowledge, such in-depth studies of overuse of pesticides are non-existent in the literature, especially in the context of developing countries. The current study did not permit us to investigate issues such as the use of faulty equipment leading to overuse, mis-labeling or content switching, nor the role of pesticide subsidies in pesticide overuse. These issues remain as important research issues that should be the focus of further studies into the farmers' behavior of pesticide overuse.

The remainder of the paper is organized as follows. In Section 2 we describe the trend of pesticide use and the associated problems in Bangladesh. In Section 3 we present the survey, and in Section 4 we describe the dataset. The models, along with our econometric findings, are documented in Section 5. In Section 6 we conclude and offer some implications of our findings.

2. Pesticide Use in Bangladesh at a Glance

As in many developing countries, Bangladesh[2] has promoted the use of pesticides to expand agricultural land and increase output per acre. Promotional activities have included extension services and significant subsidies (Rasul and Thapa, 2003; Hossain 1988). As a consequence of this expansive policy, pesticide use has more than doubled since 1992, rising from 7,350 metric tons to 16,200 metric tons in 2001 (See Figure 1). A

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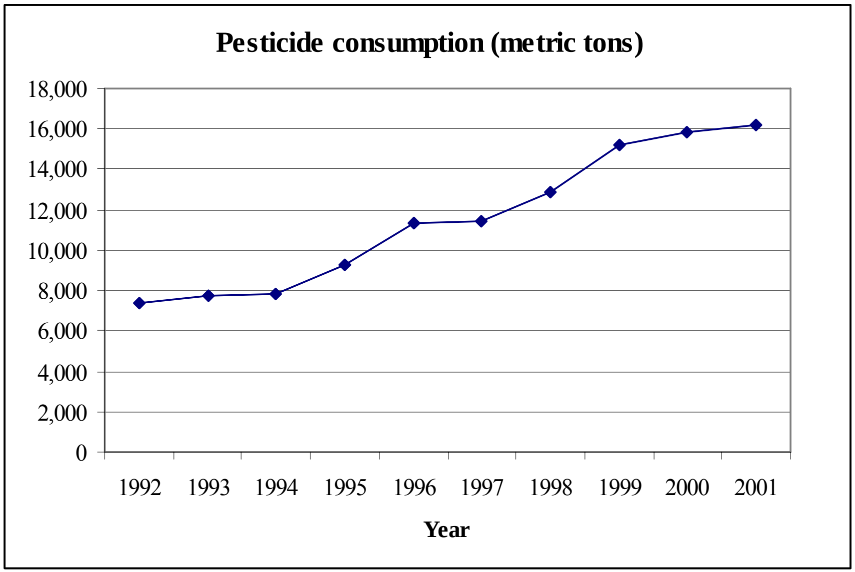
[2] Approximately 84% of Bangladesh's people are directly or indirectly dependent on agriculture for their livelihood, and agriculture contributes about 24% of gross domestic product (Bangladesh Bureau of Statistics, 2001).

FAO analysis of pesticide composition revealed high shares of toxic chemicals (for example, carbamates and organophosphates in insecticides, and dithiocarbamates and inorganics in fungicides) which have been known to cause cancer, genetic damage, fetal damage, and severe allergic responses in exposed populations (Zahm, Ward and Blair, 1997).

Figure 1: Trends in Pesticide Use, 1992-2001



Source: Department of Agricultural Extension, Plant Protection Wing, Bangladesh

Many pesticides used in Bangladesh are also banned or restricted under international agreements (Meisner, 2004; NOVIB, 1993; SOS-arsenic.net, 2004, SUNS, 1998). Pesticide suppliers in Bangladesh even continue to sell the 12 particularly controversial pesticides known by activists campaigning worldwide as the “dirty dozen” (SUNS, 1998; SOS-arsenic.net, 2004). In addition, substantial anecdotal evidence suggests that users’ lack of information have led to widespread overuse or misuse of pesticides. As a result, pesticide poisonings and ecological damage have become common in Bangladesh (Ramaswamy, 1992).

3. Survey Data

The research reported in this paper is based on a large survey of Bangladeshi farmers, carried out by the World Bank in the summer of 2003. We used structured questionnaires to collect information on pesticide use and practices, risk perceptions, knowledge, precautions and damage-averting behavior, and health effects from 821 farmers, randomly selected.[3] The survey, by design, focused on major pesticide intensive crops such as Boro (winter rice), potato, bean, eggplant, cabbage, sugarcane and mango. To provide greater depth, we also interviewed 68 randomly-selected farmers who currently use Integrated Pest Management (IPM). The sample was also geographically stratified among 11 districts of Bangladesh as: Bogra, Chapainawabganj, Rajshahi, and Rangpur districts in the Rajshahi division (Northwest); Chittagong and Comilla in the Chittagong division (East); Jessore in the Khulna division (West); and Kishoreganj, Munshiganj, Narsingdi, and Mymensingh in the Dhaka division (North - see Figure 2). Table 1 displays the regional distribution of farmers in our sample.

Table 1: Regional Distribution of Survey Respondents

District	No. of Farmers	Percent
Bogra	39	4.8
Chapainawabganj	8	1.0
Chittagong	76	9.3
Comilla	80	9.7
Jessore	195	23.8
Kishoreganj	41	5.0
Munshiganj	27	3.3
Narsingdi	86	10.5
Rajshahi	158	19.2
Rangpur	36	4.4
Mymensingh	75	9.1
Total	821	100.0

To minimize reporting bias, the survey was implemented under the agreement that the team would not reveal the identity of the farms surveyed or the respondents who participated.

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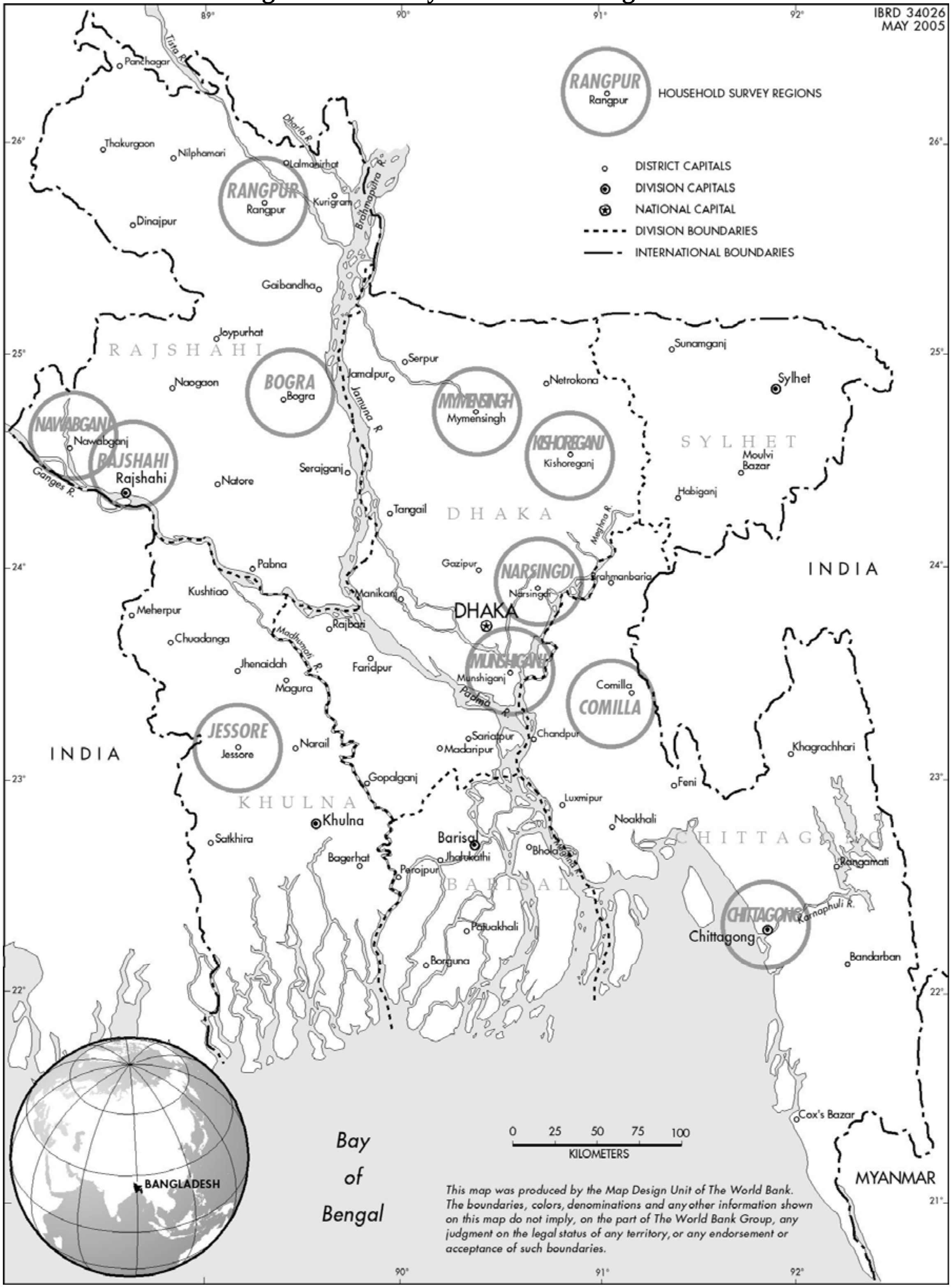
[3] The survey was designed and supervised by the World Bank team, and conducted by the Development Policy Group in Bangladesh.

Figure 2: Survey Districts in Bangladesh.



This map was produced by the Map Design Unit of The World Bank. The boundaries, colors, denominations and any other information shown on this map do not imply, on the part of The World Bank Group, any judgment on the legal status of any territory, or any endorsement or acceptance of such boundaries.

4. Data

Farmer characteristics

Of the 821 farmers surveyed, all were male, averaging 35 years in age (range 16 – 75), and half with at least primary education. 80% of the farmers own their farms with the average farm size of 1.14 acres. Each farmer grows rice and a variety of vegetables. The average annual income reported was BGD Taka 97,057 ($1 USD=63.2 Taka) ($1,536 USD).

Pesticides in Use

In terms of the number of pesticides applied, there were a total of 161 formulations (using 50 different active ingredients). Classifying these by the WHO risk classification system, on average, 19% were extremely hazardous (WHO class I), 51% very hazardous (WHO class II), 10% moderately hazardous (WHO class III) and 20% were low risk (class U). The number of applications per season varied between 1 and 16, with an average of 4 applications.

Pesticide Overuse

Overuse of pesticides, for this research, was calculated as the amount by which the farmer exceeded the recommended dose indicated on the label of the pesticide container. Recommended dosages were also cross-referenced with those conventionally followed in developed countries (e.g. in particular, with those stated in *The e-Pesticide Manual*, British Crop Protection Council (editor: Tomlin, 2003) and the Extension Toxicology Network, 2004). If the farmer used less than the recommended dose, overuse was coded as zero. This calculation was performed for all chemicals used in each application, then summed across individuals.[4] Approximately 47% of the sample was found to have overused pesticides, to some extent, and with an average overuse rate of 3.4 kg per growing season. The overuse amount was then set to 1 to facilitate probit model estimation.

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[4] Overuse per WHO class could also be conducted, however, our exercise accounts for toxicity through WHO class proportions in the final regression.

Misperception of risk

Misperception of a pesticides' toxicity is also of interest as this may influence the dose decision by farmers. A priori, we expect farmers would be less likely to use a pesticide that is relatively higher in toxicity, if an equivalently effective and less toxic pesticide is available to the farmer. Studies have shown that farmers tend to rank pesticides more generally, with less distinction at the higher levels of toxicity (Warburton, Palis and Pingali, 1995). During the interview, farmers were asked to rank each chemical they applied in terms of its relative toxicity. Four categories were presented and scaled according to the corresponding WHO class description (1=slightly hazardous (WHO class III); 2=moderately hazardous (WHO class II); 3=highly hazardous (WHO class Ib); and 4=extremely hazardous (WHO class Ia). Misperception was then defined as any deviation from the true toxicity class.[5] This procedure was repeated for each chemical and summed by farmer and toxicity class (four of them). Misperception was then set =1 if the farmer was incorrect at least 50% of the time, 0 otherwise. By coding in this manner, on average, over 48% of farmers incorrectly classified at least one of the pesticides they are using, and over 34% were incorrect at least 50% of the time.

Training and averting behavior

As farmers mix and spray pesticides, they are naturally exposed to the toxicity of the chemicals. Exposure to pesticides can lead to an array of health effects, depending on the pesticide's toxicity and the dose absorbed by the body.[6] However, the health effects of pesticide use can often be reduced significantly by averting behavior - wearing protective clothing (Cropper, 1994) and exercising precaution. The extent of averting behavior of a

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[5] For example, if a farmer reported a 2 (class II), when in fact the chemical was a 3 (class Ib), this represented a deviation of 1. If a farmer was more precautious, and reported a class higher than actual, this yielded a negative coding.

[6] For pesticides with high acute toxicity, exposure can produce intoxication symptoms within minutes or hours, and these acute effects run from mild headaches and flu like symptoms, to skin rashes, blurred vision, and other neurological disorders (World Resources, 1998-99). In addition, prolonged exposure to pesticides can cause many chronic health effects: cardiopulmonary problems, neurological and hematological symptoms, and adverse dermal effects (Davies, Freed, and Whittemore, 1982; Spear, 1991).

farmer, in turn, depends on the perception of risk and training received on safe handling of pesticides. In our survey, only 4% farmers reported receiving basic training on the use of pesticides and safe handling[7], while 87% openly admitted that they do not take any protective measures during the handling of pesticides.

Health effects

A detailed medical examination of sample farmers was beyond the scope of the study. Instead our analysis relied solely on self-assessed/ reported health effects, where farmers were questioned if they experienced any health impairment after mixing and spraying pesticides.[8] Over 49% of farmers experienced at least one symptom, with the most commonly reported as neurological (headaches: 27%, dizziness: 8%), eye (irritation: 26%), dermal (skin: 13%), and gastrointestinal (vomiting: 9%). The interviews further revealed that 26% of the respondents experienced multiple health effects, with an average of 3 and a maximum of 5. Upon asking sick farmers whether they believed that these symptoms were related to pesticide use, 82% believed this to be true. The health effects variable, "sick" was defined as whether a farmer experienced at least one symptom (=1) or not (=0).

5. Determinants of Farmer's Pesticide Overuse

The model

To model pesticide overuse, we used a trivariate probit framework with farmers' misperception of risk and health effects as endogenous dummy variables. The structure of the model follows a three-equation form where the estimation outcome of the first equation is used as a regressor in the second equation, and the second outcome in the third as follows:

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[7] The primary sources of information for pesticide use and handling were: pesticide suppliers or companies (67.27%), the Agricultural Ministry (19.09%) and "personal knowledge" (10.91%).

[8] Are self-reported health effects a credible measure? Detailed information for Bangladeshi farmers is virtually non-existent, however, medical tests of the farming population in other Asian countries may be indicative. Several clinical studies conducted on rice and vegetable farmers in Indonesia, Philippines, and Vietnam revealed 58% - 99% of the farmers exposed to pesticides had at least one health effect (Xuyen *et al.*, 1998; Kishi *et al.*, 1995; Antle and Pingali, 1994; Rola and Pingali, 1993). This evidence suggests that the degree of upward bias, if at all in a self-assessment of health effects in Bangladesh may not be large.

$$\begin{aligned} y_{1i}^* &= \beta_1 x_{1i} + u_{1i} \\ y_{2i}^* &= \delta_1 y_{1i} + \delta_2 z_{2i} + u_{2i} \\ y_{3i}^* &= \delta_3 y_{2i} + \delta_4 z_{3i} + u_{3i} \end{aligned} \tag{1}$$

where y_{1i}^*, y_{2i}^* and y_{3i}^* are latent variables, and y_{1i}, y_{2i} and y_{3i} are the observed dichotomous variables following the rule:

$$\begin{cases} y_{ki} = 1, & \text{if } y_{ki}^* > 0 \\ y_{ki} = 0, & \text{otherwise; } k = 1, 2, 3 \end{cases} \tag{2}$$

where x_{1i}, z_{2i}, and z_{3i} are vectors of exogenous variables, β_1, δ_2 and δ_4 are parameter vectors and δ_1 and δ_3 are scalar parameters. The three covariate vectors, x_{1i}, z_{2i}, and z_{3i} are not restricted to containing the same variables of interest, as long as there exists at least one varying exogenous regressor in each equation in (1) (Wilde, 2000). The error terms are assumed to be independently and identically distributed as trivariate normal:

$$\begin{pmatrix} u_{1i} \\ u_{2i} \\ u_{3i} \end{pmatrix} \sim IID\, N \left(\begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 & \rho_{12} & \rho_{13} \\ \rho_{12} & 1 & \rho_{23} \\ \rho_{13} & \rho_{23} & 1 \end{bmatrix} \right) \tag{3}$$

where ρ is the correlation between the unobservable explanatory variables, u_{1i}, u_{2i}, and u_{3i} of the three equations. In estimation, the coefficient of $\rho \neq 0$ can interpreted as the degree of endogeneity between y_{1i} and u_{2i} and u_{3i}, since they are correlated; and likewise between y_{2i} and u_{1i} and u_{3i}. The condition $\rho = 0$ can be tested using a likelihood ratio (LR) test, which has been shown to be appropriate when testing for exogeneity in the simultaneous estimation of the bivariate probit model (Fabbri, Monfardini and Radice, 2004). A similar reasoning is used here in the trivariate case.

For the empirical model, we began by specifying the health effects equation as the first equation in (1) above, and simultaneously modeled farmer misperception as the second equation, with the overuse of pesticides as the third equation. According to the medical literature, the type and severity of pesticide poisoning depends on: (a) the toxicity of the pesticide, (b) the amount of pesticide involved in the exposure, (c) the route of exposure, and (d) the duration of exposure (Extension Toxicology Network, 2004). The health effects specification accounted for these factors, and following Antle and Pingali (1994), we also included age, nutritional status, income, the number of protections taken while handling pesticides and location.[9] A farmers' perception of pesticides can be shaped by a variety of factors including the potential health implications, formal education and pesticide training (Warburton, Palis and Pingali, 1995). Thus in the second equation, farmers' misperception was specified as a function of the health effect, the degree of highly toxic use, age, education, training and location. In the third equation, overuse was specified as a function of farmer misperception, toxic use, age, income, education, farm size, ownership, training, practicing IPM and location. As crops differ substantially with respect to their vulnerability to pests, crop area proportions were also added to the overuse equation (see Appendix 1 for variable details).

$$
\begin{aligned}
&SICKNESS = f\,(PESTAMT,\ PWHOIab,\ PWHOII,\ PWHOIII,\ NUTRTON,\ AGE,\ INCOME,\\
&\quad NPROTECT,\ District\ Dummies)\\
&MISPERCEPTION = f\,(SICKNESS,\ AGE,\ EDUCATION,\ TRAIN,\ PWHOIab,\ PWHOII,\\
&\quad PWHOIII,\ District\ Dummies)\\
&OVERUSE = f\,(MISPERCEPTION,\ AGE,\ FARMSIZE,\ OWNER,\ INCOME,\ EDUCATION,\\
&\quad TRAIN,\ IPM\ Dummy,\ PWHOIab,\ PWHOII,\ PWHOIII,\ Crop\ proportions,\ District\\
&\quad Dummies)
\end{aligned}
\tag{4}
$$

Estimation results

We estimated the three probit equations in (4) simultaneously, with the results presented in Table 2. The correlation coefficient between the error terms of the health effects and misperception equations is significantly different from zero at 1% level of significance, indicating that the unobserved variables influencing health effects are positively correlated with the unobserved characteristics affecting the misperception of pesticide risk. The other two correlation coefficients are not significant, suggesting that health and misperception are not endogenous in the overuse equation.

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[9] Location controls were also included in the regression to take into account any possible pervasive contamination from neighboring pesticide use.

Table 2: Triprobit results

Variables	Health effects	Misperception	Overuse
Pestamt	0.017 ***		
	(3.21)		
Sickness		-1.032 ***	
		(-4.28)	
Misperception			-0.491
			(-1.42)
Age	-0.006	-0.003	0.008 *
	(-1.36)	(-0.61)	(1.65)
Nutrition	1.691		
	(1.27)		
Education		0.034	0.061
		(0.82)	(1.21)
Farm size			0.022
			(0.51)
Owner			0.307 **
			(2.11)
Income	0.000001 ***		0.000001 **
	(2.94)		(2.12)
Training		-0.210	-0.284
		(-0.88)	(-1.00)
Nprotect	0.152		
	(1.07)		
Ipmd			0.152
			(0.73)
PwhoIab	0.001	0.014 ***	-0.012 ***
	(0.29)	(6.23)	(-3.37)
PwhoII	0.002	0.006 ***	0.004 *
	(0.89)	(3.18)	(1.84)
PwhoIII	0.002	0.002	0.0004
	(0.68)	(0.76)	(0.13)
Bogra	0.948 ***	0.117	0.441
	(2.99)	(0.36)	(0.97)
Chapi	-0.385	-0.054	2.157 ***
	(-0.65)	(-0.10)	(3.01)
Chitta	0.242	-0.306	1.995 ***
	(0.96)	(-1.19)	(4.97)
Comilla	0.306	0.537 **	0.850 **
	(1.22)	(2.21)	(2.32)
Jessore	0.332	0.324	1.754 ***
	(1.37)	(1.39)	(4.98)
Munsh	-0.867 **	-0.711 *	0.613
	(-2.13)	(-1.74)	(1.24)
Narsh	0.252	-0.200	1.115 ***
	(1.03)	(-0.81)	(3.11)
Rajshahi	0.148	-0.074	2.054 ***
	(0.62)	(-0.31)	(5.49)
Rangpur	-0.012	0.187	0.774 *
	(-0.04)	(0.64)	(1.82)
Mymen	-0.033	-0.376	0.510
	(-0.13)	(-1.52)	(1.40)
Riceall			-1.613 ***
			(-5.44)
Potato			-1.051 **
			(-2.10)
Bean			-0.437
			(-0.82)
Eggplant			-0.596
			(-1.37)
Cabbage			-0.979 *
			(-1.73)
Sugarcane			-2.239 ***
			(-4.38)
Mango			-2.368 ***
			(-4.61)
Constant	-0.942 *	-0.443	-0.822

	(-1.83)	(-1.22)	(-1.57)
$\rho_{Health\ x\ Misperception}$	0.631***		
	(2.68)		
$\rho_{Health\ x\ Overuse}$	-0.062		
	(-1.01)		
$\rho_{Misperception\ x\ Overuse}$	0.087		
	(0.48)		
Observations	820		
Log likelihood	-1398.210		

z-scores in parenthesis; * - significant at the 10% level; ** - significant at the 5% level; *** - significant at the 1% level

The first column of Table 2 presents the determinants of the *health effects* equation. Variables found to be significantly associated with the probability of a farmers' health impairment from pesticides are: *the amount of pesticides applied* and *income*. As expected, the probability of sickness increases significantly with greater use of pesticides. After controlling for the amount of pesticides, however, we did not find any statistical significance for the toxicity of pesticides. Income, although significant, has a perverse sign which we could not explain.[10] Neither the age nor the nutritional status of the exposed had any significant effect on health. The number of protections taken by the farmer is also insignificant, however, low variation in the sample may be a possible explanation. District controls reveal that health impairments from pesticides are more likely in the *Bogra* district, and less likely in the district of *Munshiganj*.

The second column of Table 2 gives the determinants of the farmers' *misperception of pesticide risk*. The negative sign and significance (at the 1% level) of *health impairment* clearly shows that the probability of misperception is lower with increases in health impairments. The positive and significant sign of two *pesticide toxicity* variables in the misperception equation reveal the incidence of misperception is higher for farmers with higher proportional use of WHO Ia & Ib (extremely and highly hazardous) and WHO II (moderately hazardous) pesticides. This finding is analogous to that found by Warburton, Palis and Pingali (1995), where farmers tended to group WHO I and II pesticides as equally hazardous. It is worth noting that neither formal education nor training in use/ safe-handling had any effect on misperception. Once again, the very low (4%) number of farmers actually trained in the sample may be the cause of its

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[10] A t-test among income groups confirms the statistical difference in pesticide use. Note however that the marginal impact of changes in income is relatively small.

insignificance. Among the districts, misperception appears to be most prevalent in *Comilla*, and significantly lower in *Munshiganj*.

The third column of Table 2 presents the determinants of the farmers' *overuse* of pesticides. Unfortunately, misperception did not yield the expected sign, however, it was not a significant determinant of overuse.[11] Among the individual characteristics, *income* and *ownership* influence the propensity to overuse. For pesticide toxicity class, farmers with higher proportions of *highly hazardous* (WHO Ia & Ib) pesticides are less likely to overuse, and farmers with higher proportions of *moderately hazardous* (WHO II) *pesticides* are more likely to overuse. Neither training in safe-handling nor use of IPM techniques has the expected effect. However, the application of pesticides revealed strong crop patterns. The incidence of overuse is less likely in the case of *potato*, *rice*, *cabbage*, *sugarcane* and *mango* as compared to *eggplant* and *beans*. In addition, even after controlling for individual circumstances and crops, we find a strong locational pattern. Overuse is more prevalent in the districts of *Chapainawabganj, Chittagong, Comilla, Jessore, Narshingdi, Rajshahi* and *Rangpur* than in *Bogra*, *Mymensingh*, *Munshiganj* and *Kishoreganj* (excluded).

6. Summary and Conclusions

Empirical evidence on pesticide application in developing countries is rather thin. Drawing on a new survey conducted in Bangladesh, this paper is an attempt to address this gap. In our survey, 47% of the farmers were found to have overused pesticides, with an average overuse rate of 3.4 kg per growing season. To model pesticide overuse, we used a trivariate probit framework with health effects and misperception of pesticide risk as endogenous dummy variables.

The results, to some extent, are consistent with our expectations. The variable found to be significantly associated with the probability of a farmers' health impairment from pesticides is: *amount of pesticide applied*. Among the determinants of probability of

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[11] One possible explanation could be that with prolonged use over time, pesticide resistance necessitates greater use to achieve similar outcomes.

misperception, *health impairment from pesticides* and *toxicity of pesticides* are significant. Among the determinants of overuse of pesticides, *income, ownership*, *toxicity of pesticides, crop composition* and *location* dominate.

When questioned, 49% of the farmers reported frequent health symptoms commonly associated with acute pesticide poisoning such as eye irritation, headaches, dizziness, vomiting and skin effects. Yet, 87% openly admitted that they do not take any protective measures during the handling of pesticides. The health effects of pesticide use can be reduced significantly by averting behavior – such as wearing gloves, eye glasses or a mask while handling pesticides and washing their hands after touching pesticides. There is an urgent need for active promotion of suitable averting behavior and hygienic practices among pesticide applicators/ farmers in Bangladesh.

Our analysis further indicated that there is dearth of formal training and information on use and safe handling in Bangladesh. Only 4% of the farmers surveyed reported receiving basic training on the use of pesticides and safe handling. This lack of training is reflected in the misperception of pesticide risks, where over 34% of respondents under-classified their pesticide hazard. This emphasizes the need for targeted outreach programs in agricultural communities, including farmer field schools and farmer participatory research. Participation by the farmer is a key element of any program, as he/she will retain more information and put this into practice (Heong, Escalada and Lazaro, 1995). The information content of training programs should include more specific information on the health hazards of pesticides and averting behavior. In the design of these training programs, it would be advisable to include farmers, to better reflect their needs and current informational gaps.

Our cross-section regression results suggest widespread pesticide overuse in the districts of *Chapainawabganj, Chittagong, Comilla, Jessore, Narshingdi, Rajshahi* and *Rangpur*. Our results also highlight that pesticide overuse in Bangladesh is heavily skewed towards a few selected vegetables – beans and eggplant. These findings suggest policies targeted towards these locations and crops may have measurable effects on pesticide overuse. Steps could include stricter enforcement of existing regulations, the promotion of integrated pest management programs, and further research on alternative pest control methods.

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Appendix 1: Variable description

Variable	Description
SICKNESS	= 1 if farmer reported any eye irritation, headache, dizziness, vomiting, diarrhea, fever, convulsion, shortness of breath or skin irritation; = 0 otherwise
MISPERCEPTION	= 1 if the farmer was incorrect at least 50% of the time; = 0 otherwise
OVERUSE	= 1 if farmer reported overusing; = 0 otherwise
	Exposure
PESTAMT	Pesticide amount used in production (kilograms)
PWHOIab	Proportion of pesticides applied and classified as WHO category Ia or Ib (extremely or highly hazardous)
PWHOII	Proportion of pesticides applied and classified as WHO category II (moderately hazardous)
PWHOIII	Proportion of pesticides applied and classified as WHO category III (slightly hazardous)
PWHOU	Proportion of pesticides applied and classified as WHO category U (unlikely to present any acute hazard in normal use) (Dropped in estimation)
	Socio-economic
NUTRTON	Nutritional ratio of weight/height
AGE	Age in years
EDUCATION	0 = can't read or write/can read, but can write 1 = Primary (≤ 5 years of schooling) 2 = Junior high school (6-10 years of schooling) 3 = Secondary or Higher Secondary (11-12 years of schooling) 4 = Above High Secondary (more than 12 years of schooling)
INCOME	Annual income (Taka)
FARMSIZE	1 = less than 0.5 acres; 2 = 0.5 to less than 1 acre; 3 = 1 to less than 1.5 acres; 4 = 1.5 to less than 2.5 acres; 5 = 2.5 to less than 5 acres; 6 = 5 to less than 7.5 acres; 7 = 7.5 to more than 7.5 acres
OWNER	= 1 if farmer owned the farm; = 0 otherwise
TRAIN	= 1 if farmer received training on pesticide use and safe handling; = 0 otherwise
IPMD	= 1 if farmer received was currently practicing Integrated Pest Management; = 0 otherwise
NPROTECT	= 1 if farmer used more than 2 protective measures; = 0 otherwise
	Other controls
RICE	Proportion of area devoted to rice production (acres)
POTATO	Proportion of area devoted to potato production (acres)
BEAN	Proportion of area devoted to bean production (acres)
EGGPLANT	Proportion of area devoted to eggplant production (acres)
CABBAGE	Proportion of area devoted to cabbage production (acres)
SUGARCANE	Proportion of area devoted to sugarcane production (acres)
MANGO	Proportion of area devoted to mango production (acres)
BOGRA	= 1 if the farmer is located in the district of Bogra; 0 = otherwise
CHAPINAWABGANJ	= 1 if the farmer is located in the district of Chapinawabanj; 0 = otherwise
CHITTAGONG	= 1 if the farmer is located in the district of Chittagong; 0 = otherwise
COMILLA	= 1 if the farmer is located in the district of Comilla; 0 = otherwise
JESSORE	= 1 if the farmer is located in the district of Jessore; 0 = otherwise
KISHOREGANJ	= 1 if the farmer is located in the district of Kishoreganj; 0 = otherwise (Dropped in estimation)
MUNSHIGANJ	= 1 if the farmer is located in the district of Munshiganj; 0 = otherwise
NARSHINGDI	= 1 if the farmer is located in the district of Narshingdi; 0 = otherwise
RAJSHAHI	= 1 if the farmer is located in the district of Rajshahi; 0 = otherwise
RANGPUR	= 1 if the farmer is located in the district of Tangpur; 0 = otherwise
MYMENSINGH	= 1 if the farmer is located in the district of Mymensingh; 0 = otherwise