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Why Don't Pesticide Applicators Protect Themselves? Exploring the Use of Personal Protective Equipment among Colombian Smallholders

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ABSTRACT

The misuse of personal protective equipment (PPE) during pesticide application was investigated among smallholders in Colombia. The integrative agent-centered (IAC) framework and a logistic regression approach were adopted. The results suggest that the descriptive social norm was significantly influencing PPE use. The following were also important: (1)In addition, i) having experienced pesticide-related health problems; (2) age; (3) the share of pesticide application carried out; and (4) the perception of PPE hindering work. Interestingly, the influence of these factors differed for different pieces of PPE. Since conformity to the social norm is a source of rigidity in the system, behavioral change may take the form of a discontinuous transition. In conclusion, five suggestions for triggering a transition towards more sustainable PPE use are formulated: (1) diversifying targets/tools; (2) addressing structural aspects; (3) sustaining interventions in the long-term; (4) targeting farmers' learning-by-experience; and (5) targeting PPE use on a collective level.

Key words: pesticides, personal protective equipment (PPE), IAC framework, transition, intervention, Colombia

INTRODUCTION

Pesticide misuse in agriculture causes major health problems among smallholders in least developed countries (LDC) and for this reason has attracted the attention of international agencies and has been targeted by specific intervention programmes.[1,2,3,4,5] Exposure to pesticides can have both long-term health effects—such as neurological impairment, and cancer—and short-term health effects—such as skin or eye irritation, dizziness, and nausea.[6] The majority of the intoxications recorded in LDCs can be attributed to farmers' occupational exposure to pesticides.[6] Pesticides enter the body to a large extent via inhalation and dermal absorption mainly during application, but also, for example, during the preparation of pesticides, and the cleaning and repairing of the application equipment. [7,8] The most common way of applying pesticide in LDCs is by means of a lever-operated knapsack sprayer[9] which potentially exposes the applicator to a high dose of the pesticide.[10,11]

In order to minimize exposure and consequently health risk during the application phase, the International Labour Organization (ILO)[12] and the World Health Organization (WHO)[4] suggest the use of specific Personal Protective Equipment (PPE): overalls, gloves, goggles, and boots. Unfortunately, it is often the case that smallholders in developing countries fail to comply with these safety standards. Inadequate use of PPE has been reported and investigated, for instance, in Asia,[11,13,14,15,16],the Middle East,[17,18] Africa,[19,20,21,22,23] and Latin America.[8,24,25,26,27,28]

Previous studies on farmers' PPE use can be divided into four main strands. First, farmers' behavior is often explained in terms of socio-demographic factors (such as age, education, and gender) and/or socio-economic factors (such as income). Several authors, for example, show that the use of PPE is positively correlated to education.[18,20] Second, some authors report that the high cost of PPE affects farmers' decision not to use PPE.[29] A third strand focuses on the importance of contingent and/or external factors. Gomes et al.[17] and Waichmann et al.,[27] for example, demonstrated that the labels which are present on pesticide packages were not properly designed to be understood, being based on graphic conventions and a language which were unknown to local users; Cole et al.[30] reported the opinion of Ecuadorian farmers, who consider PPE uncomfortable to be worn during work in the field. Fourth, some authors[16,31] stress the role of values and cultural orientation, factors which influence risk perception and therefore the adoption of adequate safety practices. Palis et al.,[16] for example, referring to three farming communities in the Philippines, suggested that farmers' beliefs on how illness is brought about leads to underestimation of risk and inadequate protection.

Despite the amount of work carried out on PPE use, few studies have investigated the role of yet another factor, namely social norms, which may influence farmers' personal protection choices. Baumberger suggests that farmers might be negatively influenced by peer pressure in their decisions about personal protection.[32] That is, there may be a social norm implicitly defined according to the most widely accepted behavior in the region (such as *not* using PPE) which leads farmers to conform in order to avoid a symbolic sanction (such as mockery).[32]

Given the variety of behavioral drivers which potentially influence farmers' PPE use, knowing which ones are relevant in a specific context is essential to develop effective intervention strategies against PPE misuse. In effect, any intervention's effectiveness depends on the ability of specifically targeting different combinations of drivers. In this respect, the potential influence of social norms on farmers' PPE use is a critical issue.

Social norms differ from other factors (such as socio-demographic factors, costs, and external factors) in that they activate a self-reinforcing social process: people tend to comply or conform to social norms and, in so doing, reinforce them by confirming their normative value to other members of the social system.[33].This self-stabilizing feedback may lock the social system into a stable mode so that individuals and groups demonstrate fixed attitudes and modes of behavior.[34,35].An undesirable lock-in situation, that is, one leading to undesirable consequences, is referred to as a "trap." [35] One result of the trap is that the system becomes more resistant to change, or "rigid," even if the change would reduce those unwanted consequences.[35] Such a lock-in situation will be referred to as a "rigidity trap," and will be distinguished from the other type of barriers that are not characterized by a self-stabilizing feedback.

Scheffer et al.[36] demonstrate that, in the presence of a rigidity trap and "in societies with little difference among individuals and high peer pressure," the relationship between the level of action against a problem and the perceived pay-off for taking action is discontinuous (Figure 1). That is, when a seemingly resistant system reaches a threshold point (TP1 in Figure 1), it shifts radically from one state to another. Such a shift is also called "critical transition" [35] or "regime shift."[34] Once the system shifts to the other state, it shows rigidity, that is, it will stay in that state even if the severity of the problem is reduced, until a new threshold is reached (TP2 in Figure 1). Such a bi-stability, triggered and maintained by a lock-in effect, essentially distinguishes a critical transition from a simple diffusion process.

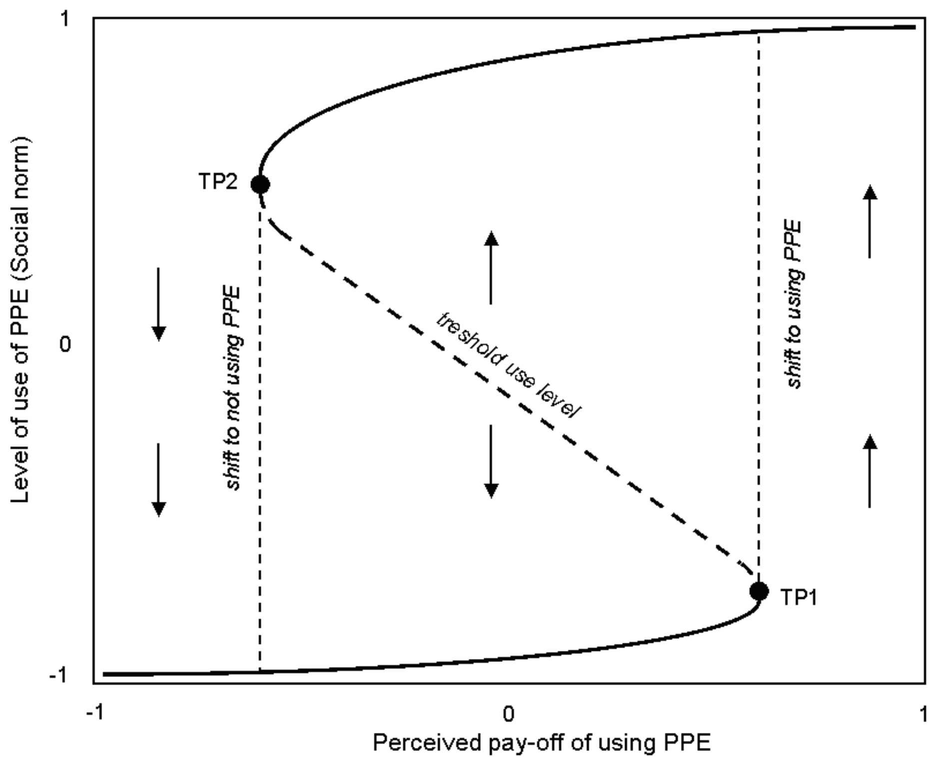

Figure 1 - Relationship between level of action and perceived pay-off for taking action (after Scheffer et al.[34]).

The presence of an active rigidity trap in a local agricultural system would imply the existence of specific social dynamics that intervention programs would have to target in order to effectively foster wider PPE use. Therefore, to improve the ability of intervention strategies to target PPE misuse in local systems of smallholding farmers in LDCs, it is essential to analyze what behavioral drivers are relevant in that context, and in particular, whether a rigidity trap exists.

With reference to the case study of the region of Boyacá, Colombia, this paper: (1) investigates what factors influence farmers' behavior concerning the use of PPE; (2) applies a conceptual tool, that is, the integrative agent-centered (IAC) framework, which allows for integrating social norms as potential relevant behavioral drivers along with the other traditionally used explanatory variables; and (3) points out five key issues which should be considered by intervention programs to effectively trigger a transition towards more sustainable PPE use.

MATERIALS AND METHOD

Study Area

The Department of Boyacá is located on the eastern chain of the Colombian Andes and is a rural region mainly devoted to the cultivation of potatoes in addition to other crops such as carrots, maize, wheat, beans, and oats (Figure 2). [37]

The production of potatoes in Boyacá relies mainly on smallholders, who make up more than the 95% of the workforce, farm more than the 56% of the potato-cultivated land, and provide 45% of the total production.[42] Smallholders cultivate an average of three hectares subdivided in different plots, on terrain that is usually not appropriate for mechanization, leading to low average production rates. Due to the lack of irrigation devices, smallholders are significantly dependent on the rain cycles for production. Therefore, the production of potatoes is generally organized in two cycles—March to September and October to February—corresponding to the two rainy seasons.[38]

Potato crops in this region are vulnerable to three major pests: the soil-dwelling larvae of the Andean weevil (*Premnotrypes vorax*, or “Gusano blanco”), the late blight fungus (*Phytophthora infestans*, or “Gota”), and the Guatemalan potato moth (*Tecia solanivora*, or “Polilla guatemalteca”). These pests make potatoes the crop with the highest demand for fungicides and insecticides in Colombia.[37]

The predominant pesticides used for potato production are carbofuran (insecticide), mancozeb (fungicide), and methamidophos (insecticide). Pesticide misuse has been observed, among other issues, with respect to safety practices.[8,32,38]

Figure 2- Study area (after Oehler[39]).

Theoretical Background

To investigate farmers' PPE use, the integrative agent-centered (IAC) framework was applied.[40,41] This conceptual tool allows for integrating social norms as potential relevant behavioral drivers along with the other traditionally used explanatory variables such as education and costs. Therefore, it is considered appropriate to investigate a relatively homogeneous local agricultural system like the study area, in which a social norm-based rigidity trap might exist.

In the IAC framework, which is based on Triandis' Theory of Interpersonal Behavior[42] and Giddens' Structuration Theory,[33] an agent's decision to enact a specific behavior is influenced by external and internal drivers. The external drivers consist of contextual factors (such as facilitating conditions or barriers), whereas the internal ones include habits (that is, the frequency of past behavior), physiological arousal (that is, the physiological state of the individual), and intention. The latter is determined by: (1) expectations (the beliefs about the outcomes, their probability, and their value); (2) subjective culture factors (social norms, roles, and values); and (3) affect (the feelings associated with the act). The agent's actions have consequences that give rise to a double feedback loop towards internal and external behavioral drivers, which thus influences decisions in the future (Figure 3).

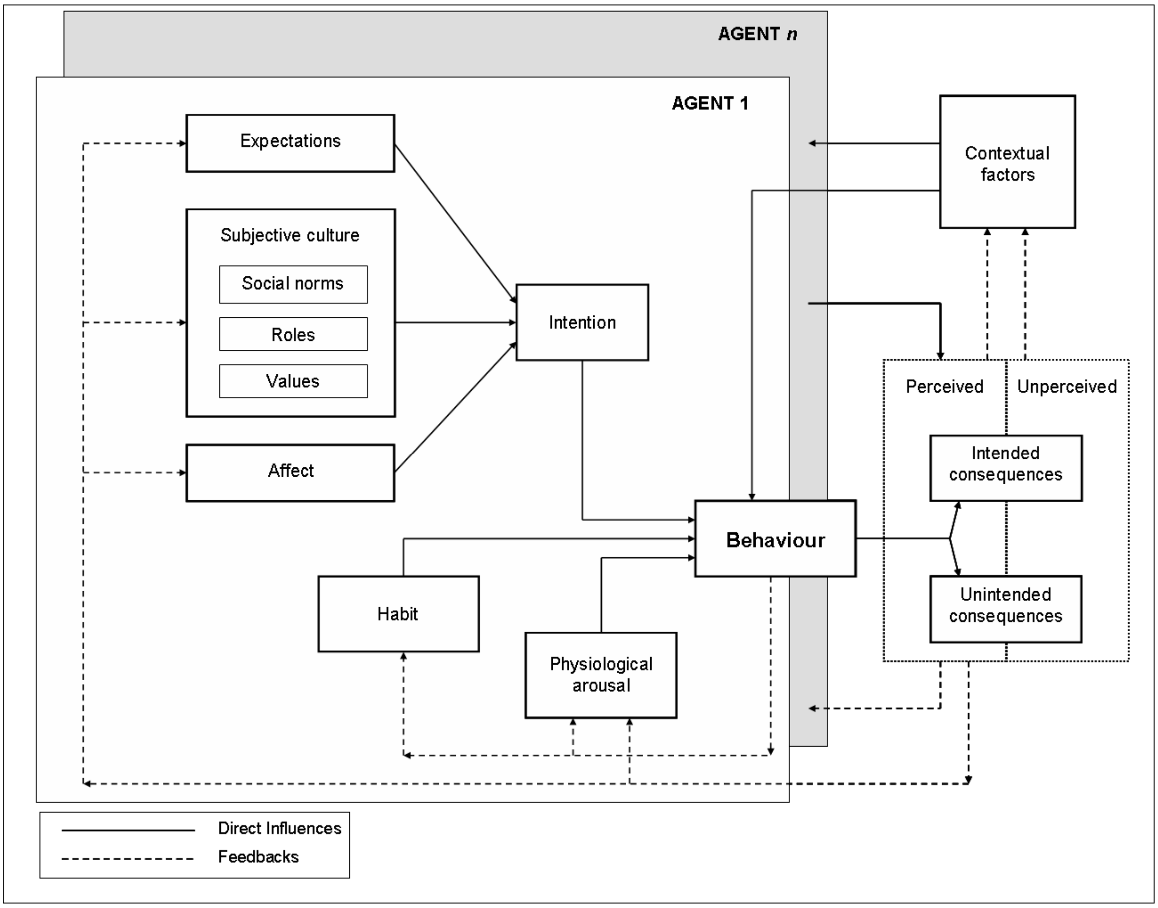

***Figure 3—The Integrative Agency Centered (IAC) Framework*[40]**

Study Design

The IAC framework was used as a basis for compiling a structured questionnaire for data collection. Based on a literature review, the components of the IAC framework, that is, the class of behavioral drivers, were operationalized in one or more variables, which are described in Table 1. Physiological arousal was assumed to be the same for all farmers, who were assumed to be highly roused during pesticide application, and therefore was excluded from the analysis. The questionnaire was structured in sections with each section corresponding to a class of behavioral drivers and containing one or more questions for each variable.

TABLE 1 - Description of the Behavioral Drivers Considered in the Study

Class of behavioural drivers	Behavioural driver	Description
Consequences	Adverse health effects	Health problems suffered by the farmer and perceived to be pesticide-related.
	Social consequences	The reference groups' judgment on the applicator using PPE
Expectations	Interference of PPE	Interference with work when using PPE
	Cost of PPE	Judgment on the expensiveness of PPE
	Cost of doctors	Monetary expenses for visiting doctors for pesticide-related illnesses
	Cost of medications	Monetary expenses for buying medications for pesticide-related illnesses
	Work days lost	Work days lost due to pesticide-related illnesses
Subjective culture: Social norms	Descriptive norm	The PPE use that is observed with highest frequency in the population, or the beliefs about it
	Prescriptive norm: reference groups	The reference groups' prescriptions indicating to the farmer the appropriate behaviour concerning PPE
	Sense of compliance with prescriptive norm	The farmer's sense of urgency about behaving in a desired way (the prescriptive norm - reference groups)
	Prescriptive norm: pesticide labels	Awareness of pesticide label indications on what ought to be done by the farmer concerning personal protection
	Sense of compliance with pesticide labels	The farmer's sense of urgency about behaving in a desired way (prescriptive norm - pesticide labels)
Subjective culture: roles	Farmer	Priorities and defining characteristics of a good farmer in the region
	Sense of compliance with the role of Farmer	The farmer's sense of urgency about behaving in a desired way (the role of farmer)
	Head of family (when applicable)	Priorities and defining characteristics of a good head of family in the region
	Sense of compliance with the role of Head of family	The farmer's sense of urgency about behaving in a desired way (the role of head of the family)
Affect		Emotions associated with the use of a certain piece of PPE
Habit		Practice of use of a certain PPE in the past and duration of that practice
Contextual factors	Education	Formal education of the farmer
	Technical assistance	Training received on pesticide use and/or personal protection
	Age	Age of the farmer
	Past health effects	Experience of pesticide-related adverse health effects in the past
	Work organization	Share of pesticide application work
	Weather	Weather/Climatic conditions

A survey was conducted focussing on the decision to use PPE during the pesticide application phase with the questions referring to the timeframe of the last cultivation cycle in which the farmer cultivated potatoes in a reference parcel. In the survey a total of 197 smallholder potato growers, 88.3% of them male, were involved in four selected areas: a main study area (Vereda La Hoya, Province of Tunja [81 farmers]), and three comparative areas (Puente Boyacá, Province of Ventaquemada [47 farmers]; Hato de Ventaquemada, Province of Ventaquemada [23 farmers]; San Francisco, Province of Toca [46 farmers]). In Vereda La Hoya, the sampling goal consisted in the total coverage of the population, which was achieved with the exception of refusals (three farmers), farmers not growing potato in the reference period (28), and farmers not available at the time of the survey (12). In the comparative areas, the farmers were sampled in a number statistically comparable with the main study area and according to the snowball sampling method because a reliable list of the population was not available and because this method resulted in building a more trustful relationships with the farmers.

Local professionals (*Sistemas Especializados de Información*, SEI s.a.) contributed to the translation of the questionnaire and carried out the interviews. The questionnaire was tested in August 2007 on 17 farmers in a neighboring and comparable area (Vereda Guantoque, Province of Samacá). The survey was then conducted in September and October 2007. A short description of the study was given at the beginning of the interview. Consent was given by farmers at this time. In case farmers did not want to give consent, the interview would not take place. Therefore this could read: „At the beginning of each interview, explicit information about the
study was provided and verbal informed consent was obtained

Data were collected by means of handheld electronic devices for data capture, which allowed for a real-time crosscheck of inconsistencies, and were subsequently analyzed with SPSS 14.0.

Modelling Approach and Model Specification

The influence of the different behavioral drivers on PPE use was investigated by adopting a logistic regression approach. Accordingly, PPE use was defined in terms of a dichotomous outcome. Two quantitative measures of PPE use were defined: the first considered the "use" versus "non-use" of PPE at least once in one agricultural cycle (use coded as 1; non-use coded as 0); the second considered regular versus sporadic use ("always" and "often," use coded as 1; "sometimes" to "never" use coded as 0).

Five models were estimated: models PPE-USE, GLOVES-USE, and FACIAL-USE estimated the probability of using any kind of PPE, gloves, or facial protection at least once in an agricultural cycle, respectively. Models GLOVES-FREQ and FACIAL-FREQ estimated the probability of using gloves or facial protection on a regular basis (that is, "always" and "often"), respectively.

The models are specified as follows:

$$\ln [P/(1 - P)] = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + ... + \beta_k X_k$$

Where:

P is the probability of the outcome

β_0 is the intercept term

$\beta_1, \beta_2, \ldots \beta_k$ are the coefficients associated with each explanatory variable

X_1, X_2, X_k are the explanatory variables

the subscript *k* denotes the *k*-th variable in the model (see Neupane et al. for further details)[43]

The explanatory variables included in the models are shown in Table 2. The interaction effects of “area,” “age,” and “education” with all the other variables were tested. Only the significant ones are retained in the models discussed in the present paper. In addition, the interaction effects of the prescriptive norms and the respondents’ sense of compliance with them was considered, as these variables were defined in strict relationship to each other and expected to be statistically related.

Some of the behavioral drivers considered by the IAC framework (Table 1), although operationalized and considered in the survey, were not included in any of the regression models. In effect, the low variance in the distribution of cases for these variables rendered them not useful in distinguishing users from non-users of PPE. Nevertheless, they provide essential additional information for the interpretation of the regression models’ results, and are presented later in the paper.

TABLE 2 - Explanatory Variables included in the Regression Models

Class of behavioral drivers	Variable name	Description	Mean	SD
Consequences	Social consequences	Dummy variable. Value 1 if the respondent expects (either positive or negative) judgment for using PPE by all the reference groups. 0 if he does not expect any judgment.	0.59	0.49
Expectations	Cost of gloves (only for Models GLOVES-USE and GLOVES-FREQ)	Dummy variable. Value 1 if the respondent thinks the gloves are *neither cheap nor expensive* or *expensive* 0 if he thinks they are *cheap.*	0.56	0.50
	Interference of PPE (only for Model PPE-USE)	Dummy variable. Value 1 if the respondent finds it easy to work wearing PPE. 0 otherwise.	0.56	0.50
	Interference of gloves (only for Models GLOVES-USE and GLOVES-FREQ)	Dummy variable. Value 1 if the respondent finds it easy to work wearing gloves. 0 otherwise.	0.55	0.49
	Interference of facial protection (only for Models FACIAL-USE and FACIAL-FREQ)	Dummy variable. Value 1 if the respondent finds it easy to work wearing facial protection. 0 otherwise.	0.66	0.47
Subjective culture	Descriptive norm use (Only for models gloves-use and facial-use)	Dummy variable. Value 1 if the respondent thinks other farmers use PPE. 0 otherwise.	0.68	0.47
	Descriptive norm freq (only for Models GLOVES-FREQ and FACIAL-FREQ)	Dummy variable. Value 1 if the respondent thinks other farmers use PPE *always*, *often*. 0 if he thinks other farmers use PPE *sometimes, seldom* or *never*.	0.26	0.44
	Prescriptive norm (partner)	Dummy variable. Value 1 if the respondent talked about PPE with the partner (wife or husband) at least every second week, and the partner suggested using PPE differently, and the respondent trusts the partner *much* or *completely*. 0 otherwise.	0.26	0.44
	Compliance with prescriptive norm (partner)	Dummy variable. Value 1 if the respondent carried out *all* or *almost all* of the partner's (wife or husband) suggestions. 0 otherwise	0.24	0.43
	Prescriptive norm (pesticide labels)	Dummy variable. Value 1 if the respondent is aware of pesticide labels and of their safety instructions and has read them. 0 otherwise.	0.40	0.49
	Compliance with prescriptive norm (pesticide labels)	Dummy variable. Value 1 if the respondent reports *always* complying with the instructions of the pesticide labels. 0 otherwise.	0.39	0.49
Contextual factors	Work organization	Dummy variable. Value 1 if the respondent *always* or *often* hires external workers for the application of pesticide. 0 if he hired external workers *sometimes*, *seldom* or *never*.		
	Age	Respondent's age (years).	47.50	15.87
	Education	Years of formal education.	4.32	2.32
	Past health effects	Dummy variable. Value 1 if the respondent has experienced pesticide-related adverse health effects. 0 otherwise.	0.70	0.46
	Area	Dummy variable. Value 0 if the respondent lives in the Province of Ventaquemada. Value 1 if the respondent lives in the Province of Tunja. Value 2 if the respondent lives in the province of Toca.		

RESULTS

Behavior

Overall, 61% of the farmers used at least one piece of equipment at least once, while 39% of the farmers reported no use of PPE during pesticide application in the reference period. Facial protection and gloves were by far the most common PPE used (Table 3), for which the frequency of regular use ("always" and "often") was about 39% and 32% respectively (data not shown). However, a simple piece of cloth instead of the recommended facial shield and goggles[12] was often used as facial protection.

TABLE 3 - Type of PPE Used

Equipment	**n**	**% (n = 197)**
Facial protection	96	48.7
Gloves	81	41.1
Overall	26	13.2
Waterproof jacket	15	7.6
Waterproof trousers	7	3.6
Goggles	6	3.0

The Regression Models

In the logistic regression models characterizing PPE use, maximum likelihood estimates of parameters are presented along with their significance level and the odds ratio (OR) exp (β), which is the factor by which the odds of PPE use changes for a one unit change in the explanatory variable (Tables 4 and 5).

Use of Personal Protective Equipment

The use of PPE is significantly associated with five variables, two of which are normative and are classified in the IAC framework as "subjective culture": "descriptive norm use" and "compliance with prescriptive norm (pesticide labels)" (Figure 3 and Table 1). Three other variables refer to contextual factors: "work organization," "age," and "past health effects" (Table 2). In particular, the variable "compliance with prescriptive norm (pesticide labels)" was associated with the highest odds of PPE use. That is, the odds of using PPE (vs. non-using) increased by a factor of 4.855 for farmers with a high sense of compliance with the safety instructions that are normally on pesticide packages. This confirms the importance of pesticide labels and their informative and normative influence on farmers.

"Descriptive norm use" is another variable that was significantly and positively related to PPE use. This suggests that those farmers who believed other farmers were using PPE were more likely to use PPE themselves (the odds in favor of PPE use increased by a factor of 2.631), which interestingly suggests that indirect social influence played a role in the farmers' individual decision-making process about personal safety: farmers tend to observe each other and conform to other farmers’ behavior.

Moreover, three contextual factors were also significantly associated with PPE use. First, the variable “work organization” showed a high negative OR for PPE use. That is, the odds of PPE use decreases by a factor of 0.053 for farmers who were less directly involved in the application of pesticides and consequently less exposed to health risks due to pesticides. Second, the variable “age” showed a negative association with PPE use: older farmers were less likely to use PPE. However, the OR of “age” is low. In addition, the interaction effect of the variables “age” and “work organization” indicates that among the external workers hired to apply pesticides, the older farmers were more likely to use PPE. This coefficient counterbalances the coefficients of “age” and “work organization” taken individually. Third, the variable “past health effects” also has a high OR. That is, farmers who experienced adverse health effects related to pesticide use were more likely to use PPE, which suggests that farmers learned from their previous personal experiences. Finally, the coefficients for the variables “prescriptive norm (partner),” and “compliance with prescriptive norm (partner)” as well as the interaction of these variables, although not statistically significant, show a negative association with PPE use.. This suggests that partners tended to effect farmers’ decision-making and discourage farmers’ PPE use.

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TABLE 4 - Maximum Likelihood Estimates of the Models PPE-USE, GLOVES-USE and FACIAL-USE

Class of behavioural drivers	Variable	Model PPE-USE						Model GLOVES-USE						Model FACIAL-USE					
		β		Wald	Exp(β)	95.0% C.I.for Exp(β)		β		Wald	Exp(β)	95.0% C.I.for Exp(β)		β		Wald	Exp(β)	95.0% C.I.for Exp(β)	
						Lower	Upper					Lower	Upper					Lower	Upper
	Constant	-0.278		0.057	0.757			-2.021		2.491	0.133			-0.496		0.184	0.609		
Consequences	SOCIAL CONSEQUENCES	0.211		0.306	1.234	0.585	2.604	-0.306		0.667	0.736	0.353	1.535	0.215		0.345	1.240	0.604	2.547
Expectations	INTERFERENCE OF PPE	0.341		0.900	1.407	0.695	2.848	-		-	-	-	-	-		-	-	-	-
	COST OF GLOVES	-		-	-	-	-	-0.149		0.164	0.861	0.418	1.773	-		-	-	-	-
	INTERFERENCE OF GLOVES	-		-	-	-	-	0.819	**	4.967	2.269	1.104	4.665	-		-	-	-	-
	INTERFERENCE OF FACIAL PROTECTION	-		-	-	-	-	-		-	-	-	-	0.591		2.559	1.806	0.875	3.728
Subjective culture	DESCRIPTIVE NORM USE	0.967	***	6.556	2.631	1.255	5.515	0.636		2.485	1.889	0.857	4.165	0.899	**	5.605	2.457	1.167	5.170
	PRESCRIPTIVE NORM (PARTNER)	-0.460		0.307	0.631	0.124	3.220	-1.232		1.772	0.292	0.048	1.790	-0.292		0.138	0.746	0.159	3.499
	COMPLIANCE WITH PRESCRIPTIVE NORM (PARTNER)	-0.243		0.039	0.784	0.071	8.674	-0.630		0.221	0.533	0.039	7.359	0.039		0.001	1.040	0.103	10.517
	PRESCRIPTIVE NORM (PARTNER)*COMPLIANCE WITH PRESCRIPTIVE NORM (PARTNER)	1.075		0.496	2.929	0.147	58.255	2.083		1.581	8.027	0.312	206.352	1.058		0.522	2.880	0.164	50.727
	PRESCRIPTIVE NORM (PESTICIDE LABELS)	0.641		1.694	1.898	0.723	4.979	0.148		0.078	1.160	0.410	3.285	0.803		2.466	2.233	0.819	6.084
	COMPLIANCE WITH PRESCRIPTIVE NORM (PESTICIDE LABELS)	1.580	**	6.327	4.855	1.417	16.628	1.142	*	3.625	3.133	0.967	10.153	1.130	*	3.755	3.094	0.987	9.701
	PRESCRIPTIVE NORM (PESTICIDE LABELS)*COMPLIANCE WITH PRESCRIPTIVE NORM (PESTICIDE LABELS)	-0.941		1.505	0.390	0.087	1.755	-0.331		0.195	0.719	0.166	3.116	-0.487		0.461	0.614	0.150	2.508
Contextual factors	WORK ORGANIZATION	-2.933	**	6.459	0.053	0.006	0.511	-2.335	**	3.893	0.097	0.010	0.985	-3.115	***	7.458	0.044	0.005	0.415
	AGE	-0.037	**	4.556	0.964	0.932	0.997	-0.024		1.808	0.976	0.942	1.011	-0.040	**	5.499	0.961	0.930	0.994
	AGE*WORK ORGANIZATION	0.059	**	6.515	1.061	1.014	1.110	0.058	**	5.679	1.060	1.010	1.112	0.062	***	7.457	1.064	1.018	1.113
	EDUCATION	0.074		0.713	1.077	0.906	1.280	0.159		3.222	1.172	0.986	1.394	-0.034		0.156	0.967	0.819	1.142
	PAST HEALTH EFFECTS	1.136	***	7.878	3.116	1.409	6.889	1.133	**	6.479	3.106	1.298	7.433	0.991	**	5.819	2.695	1.204	6.031
	AREA			3.606						1.442						3.685			
	AREA (1)	-0.652		2.278	0.521	0.223	1.215	-0.071		0.030	0.932	0.419	2.072	-0.686	*	2.711	0.504	0.223	1.139
	AREA (2)	-0.761		2.650	0.467	0.187	1.168	-0.595		1.387	0.552	0.205	1.484	-0.679		2.152	0.507	0.205	1.256
Hosmer and Lemershow test				6.711						6.549						6.961			
Nagelkerke R square		0.306						0.317						0.283					

Significance: *10%; **5%; ***1%

Use of Gloves and Facial Protection

The estimates of the use of gloves and facial protection models allow further insight into farmers' decisions with respect to these two specific pieces of equipment (Tables 4 and 5). While "social consequences," "prescriptive norm (labels)", and "area" are confirmed as not being significantly associated either with the use of gloves or of facial protection, a first relevant difference can be noted with reference to the variable "interference of PPE." The analogous variable "interference of gloves," in fact, showed both high significance and a high OR in both models GLOVES-USE and GLOVES-FREQ. In contrast, the variable "interference of facial protection" was not significantly associated with the use of facial protection. In other words, expectations about the interference of gloves with work were much more relevant than for facial protection or PPE in general.

A second difference can be observed with respect to the variable "descriptive norm use." While it was significantly associated with the use of facial protection (confirming the estimates of the model PPE-USE), it was not associated with the use of gloves.

Differences can also be noted with reference to the variables "work organization" and "past health effects." Both variables were significantly associated with the use of gloves and facial protection and had a high OR in favor of these behaviors. However, they were either not, or only slightly, significantly associated with the frequency of use of gloves or of facial protection. This suggests that hiring external workers for the application of pesticides (and thus being personally less exposed to chemicals) reduced the probability of using such pieces of equipment, but not the frequency of their use, while the experience of adverse health effects moved farmers towards using such pieces of equipment, but not significantly towards using them regularly. In particular concerning "past health effects," this evidence might reveal a negative feedback loop: a farmer using PPE even seldom reduces his probability of experiencing adverse health effects and is therefore less likely to use PPE regularly to avoid those consequences.

Finally, "compliance with prescriptive norm (pesticide labels)" is also slightly significant, confirming that while on the one hand, farmers with a high sense of compliance towards this norm tend to use gloves and facial protection, on the other hand, they tend to use gloves, but not a facial protection, more frequently. This latter difference may be related to the perception of health risks being related to the contact with pesticides more than to inhalation, as suggested also by Baumberger (private communication).

Table 5 - Maximum Likelihood Estimates of the Models GLOVES-FREQ and FACIAL-FREQ

Class of behavioural drivers	Variable	Model GLOVES-FREQ						Model FACIAL-FREQ					
		β		Wald	Exp(β)	95.0% C.I.for Exp(β)		β		Wald	Exp(β)	95.0% C.I.for Exp(β)	
						Lower	Upper					Lower	Upper
	Constant	-2.024		2.462	0.132			-0.160		0.020	0.852		
Consequences	SOCIAL CONSEQUENCES	0.084		0.046	1.087	0.506	2.336	0.317		0.730	1.373	0.664	2.838
Expectations	COST OF GLOVES	-0.156		0.168	0.856	0.407	1.800	-		-	-	-	-
	INTERFERENCE OF GLOVES	0.864	**	4.771	2.372	1.093	5.149	-		-	-	-	-
	INTERFERENCE OF FACIAL PROTECTION	-		-	-	-	-	0.307		0.676	1.359	0.654	2.826
Subjective culture	DESCRIPTIVE NORM USE	0.756	*	3.662	2.130	0.982	4.622	1.109	***	8.922	3.032	1.464	6.278
	PRESCRIPTIVE NORM (PARTNER)	-1.863		2.492	0.155	0.015	1.569	0.242		0.096	1.274	0.276	5.887
	COMPLIANCE WITH PRESCRIPTIVE NORM (PARTNER)	-0.196		0.022	0.822	0.060	11.195	0.212		0.035	1.236	0.136	11.194
	PRESCRIPTIVE NORM (PARTNER)*COMPLIANCE WITH PRESCRIPTIVE NORM (PARTNER)	2.105		1.360	8.205	0.239	282.175	-0.114		0.007	0.892	0.057	14.040
	PRESCRIPTIVE NORM (PESTICIDE LABELS)	0.019		0.001	1.019	0.341	3.048	0.755		2.031	2.128	0.753	6.012
	COMPLIANCE WITH PRESCRIPTIVE NORM (PESTICIDE LABELS)	1.027	*	2.870	2.794	0.851	9.172	0.950		2.414	2.586	0.780	8.575
	PRESCRIPTIVE NORM (PESTICIDE LABELS)*COMPLIANCE WITH PRESCRIPTIVE NORM (PESTICIDE LABELS)	-0.410		0.289	0.664	0.149	2.958	-0.546		0.559	0.579	0.138	2.424
Contextual factors	WORK ORGANIZATION	-1.629		1.794	0.196	0.018	2.127	-2.110	*	3.420	0.121	0.013	1.135
	AGE	-0.020		1.189	0.980	0.944	1.016	-0.037	**	4.718	0.964	0.933	0.996
	AGE*WORK ORGANIZATION	0.047	*	3.492	1.048	0.998	1.100	0.048	**	4.378	1.049	1.003	1.097
	EDUCATION	0.132		2.236	1.141	0.960	1.357	-0.089		1.050	0.915	0.771	1.085
	PAST HEALTH EFFECTS	0.816	*	3.147	2.262	0.918	5.572	0.543		1.807	1.722	0.780	3.802
	AREA			2.021						1.752			
	AREA (1)	-0.402		0.873	0.669	0.288	1.554	-0.491		1.449	0.612	0.275	1.361
	AREA (2)	-0.688		1.750	0.503	0.182	1.393	-0.418		0.862	0.658	0.272	1.592
Hosmer and Lemershow test				8.306						9.154			
Nagelkerke R square					0.268						0.204		

Significance: *10%; **5% ; ***1%

The Role of the Behavioral Drivers Not Included in the Regression Models

Some of the behavioral drivers considered by the IAC framework, although operationalized and considered in the survey, were not included in any of the regression models. In effect, the low variance in the distribution of cases for these variables rendered them not particularly useful in discriminating users from non-users of PPE. Nevertheless, they provide essential information for the interpretation of the regression model results, which is illustrated in the present section.

Expectations

More than 90% of the respondents expected “adverse health effects” related to an improper use of PPE. This indicates confirmation that the farmers in the region were aware of the disadvantages of not protecting themselves and of the usefulness of PPE in this respect.

Despite the fact that more than two thirds of the farmers reported adverse health effects due to pesticide use, few farmers had medical costs (such as doctors’ fees, medication costs, or work days lost) in the reference period. In particular, only 8.1% of the respondents went to the doctor, 13.7% had to buy medications, and 7.1% lost work days (between half a day and three days) in the reference period. These data show that health services were scarcely or irregularly visited for pesticide-related sickness.

Subjective Culture

Seven reference groups were identified based on Schöll and Binder[31] : partner, sons, relatives, other farmers, pesticide sellers, experts from governmental agencies, and pesticide producers. For each group, the prescriptive norm was investigated. However, with the exception of the farmers’ partners, the data show that only a minimum percentage of farmers (less than 10%) were subject to prescriptive normative judgement from at least one of these groups concerning PPE use. These data suggest that PPE is neither a topic of open discussion nor of explicit judgement in the study region.

Regarding the “roles” of a typical good farmer or typical good head of the family, more than 95% of the respondents indicated no safety-related issues among their priorities. These data suggest that for the social definition of these two roles an appropriate use of PPE was not considered relevant.

Affect, Contextual Factors, Habit

Regarding "affect," 94.4% of the respondents associated positive feelings with the use of PPE. Therefore the non-use of PPE cannot be attributed to farmers' negative feelings towards PPE. Among the contextual factors, access to "technical assistance" was hypothesised to be influential for farmers' safety-related behavior. However, less than 5% of the respondents received technical assistance concerning pesticide use or safety issues during the reference period. This suggests that technical assistance did not play a relevant role in influencing farmers' decisions on PPE use.

Finally, "habit" was not included in the regression models, but analyzed separately for the respondents using gloves and facial protection. No significant correlation was found between habit and the predicted probabilities calculated in any of the estimated models.

DISCUSSION AND CONCLUSIONS

This paper explored the use of PPE among smallholder potato growers in four agricultural communities in the Region of Boyacá, Colombia, and identified the relevant factors influencing farmers' behavior. The analysis was focussed on PPE use during the pesticide application phase, during which farmers are potentially more exposed to chemicals.[13,14] It did not consider other tasks, such as pesticide mixing or cleaning of equipment, which are potentially less dangerous to farmers.[7,8]

The study was based on the IAC framework, which permitted us to identify important drivers and relationships among them to be investigated. However, some variables (in particular weather conditions and physiological arousal) were not considered, which represents a limit of the current study. A second limitation is that no historical data were collected. Future studies may improve the research design by carrying out longitudinal studies in order to provide better information to investigate the feedbacks identified by the IAC framework.

The analysis suggests that the social mechanism of conformity to the descriptive norm defined by the behavior of the majority of the farmers may drive them to a rigidity trap. Thus, according to Scheffer et al.,[36] in such relatively small and homogeneous social systems where the social norm is strong, a critical transition may be expected. However, a transition towards a more sustainable PPE use may also be triggered by designing interventions which either trigger or are based on other factors, namely age, work organization, interference, the sense of compliance towards pesticide labels, and past health effects, whose influence may vary for different pieces of equipment. In the present section the factors influencing PPE use are discussed and some implications are derived for developing effective interventions aimed at triggering a transition towards more sustainable PPE use.

Factors Influencing PPE Use

Descriptive social norm. The results suggest that a process of conformity to the descriptive social norm characterized the local system gave birth to a lock-in effect. In effect, the decision to use PPE while applying pesticides was strongly associated with the observation of other farmers' behavior or to beliefs about it (descriptive norm). The desire for conformity to the descriptive norm seems to influence both regular users and non-users in their respective behavior. For example, considering the probability of using PPE, 93.7% of the farmers in the first quartile, who had a low estimated probability of PPE use, believe that the other farmers do not use PPE, while in the fourth quartile, representating farmers with high estimated probability of PPE use, 95.8% of the farmers believe that other farmers are using PPE. Therefore, it seems possible to distinguish between a tendency towards a *desirable* and an *undesirable* lock-in effect: the former concerns those reporting a use of PPE; the latter concerns those reporting non-use and is identified as a rigidity trap.

Concerning the motivation to conform, the results suggest that it may be related to the goal of maintaining a positive self-concept[44] in terms of the farmers' identity as a good farmer and head of family. In support of this point, the cultural definitions of both the roles of farmer and that of head of the family do not generally comprise personal protection as a priority or defining trait.

Finally, the analysis suggests that the normative control about personal protection takes a much more implicit (compliance with other farmers' behavior), than explicit (expressed judgements or behavioral indications between farmers) form. That is, farmers tend to comply with their belief about other farmers' behavior, but they tend not to talk with each other about this topic and tend not to express opinions about other farmers' personal protection choices explicitly.

Other behavioral drivers. The results suggest that other drivers also significantly influenced the decision of using PPE. First, farmers' age and the share of pesticide application work were negatively associated, while the sense of compliance with pesticide labels was positively associated with the probability of using PPE. Second, the data suggest that a previous experience of adverse pesticide-related health effects acted as a stimulus for using PPE. That is, farmers learn by their own negative experience. However, as pointed out, for example, by Schöll and Binder[31] and Palis et al.,[16] farmers might tend to underestimate the health effects for cultural reasons or may want to to maintain a high self-concept in order to avoid showing weakness. Moreover, the presented data show that the equipment was often not used regularly enough to prevent adverse health effects, so that the possibilities for learning by positive experience may not occur.

Furthermore, the data show that some drivers may be relevant only for some pieces of PPE. Interference seemed to make a greater difference for gloves than for facial protection, probably due to the fact that the former hinder handling and movement more than the latter. On the other hand, the descriptive norm seemed to exert more influence on the use of facial protection, which is more visible and for this reason might be perceived as exposing the farmer to social judgment or control.

The results also suggest that the factors moving a farmer towards the use of PPE can be different from those influencing him or her in using the equipment regularly. For example, the share of pesticide application work or the experience of adverse health effects significantly influenced the probability of deciding to use both gloves and facial protection, but not the probability of using these items regularly.

In summary, no unique pattern of decision about PPE use can be identified, but different ones, depending both on the piece of equipment and then on its frequency of use.

IMPLICATIONS: FIVE KEY ISSUES FOR EFFECTIVE INTERVENTIONS

Education and information programs are usually proposed to trigger more sustainable PPE use among smallholder farmers and pesticide applicators. However, such programs may not be the most appropriate in the case of farmers who already show a relatively high level of awareness of the risks involved and their potential adverse health effects.[45] In such cases, different strategies and tools[46,47,48] might be more effective in fostering a behavioral change at individual and collective levels.

The results of the present study suggest that five strategies should be considered to develop interventions which can effectively trigger a transition towards more sustainable PPE use in communities of smallholders such as those in the study area: (1) diversifying targets and tools; (2) addressing structural aspects (particularly social structures); (3) sustaining the interventions in the medium- and long-term; (4) targeting farmers' learning-by-experience; (5) addressing the issue of PPE use at a collective rather than an individual level.

First, diversification seems necessary in order to address the drivers acting as barriers in the individual decision-making process. For example, moving a non-user to use of PPE may be different than moving an inconstant sometimes user to a regular use of gloves. The results suggest that the descriptive norm may influence use much more in the second than in the first case. In addition, the drivers influencing the decision to use certain pieces of equipment differ from those influencing the decision to use others. Finally, farmers with different personal characteristics, such as age and sense of compliance with the prescriptive norms, may make dissimilar decisions. Thus, a set of diverse, appropriately selected tools is more likely to yield good results.

Second, structural issues should be addressed; this is essential in supporting a change at social level.[49] One social structure, the cultural construction of the identity of farmer, seemed particularly to reinforce PPE misuse in the study area. Structural aspects can require higher intervention costs and a longer duration, but, as the analysis suggests, a change in structural aspects might cause a significant change in the system and, eventually trigger a critical transition. Addressing other structural aspects beside the social structure may also trigger behavioral change. For example, innovation in the materials from which the equipment is made is likely to decrease the feeling that the equipment is hindering the farmers, thus increasing the probability of use.

Third, because structural drivers are unlikely to change in the short-term,[49,50,51] it seems essential to sustain the interventions in the medium- and long-term.

Fourth, farmers' learning-by-experience should be targeted in order to trigger the transition towards more sustainable PPE use. The present study provided evidence that farmers tend to learn by their direct negative experiences. Combined with the low significance of formal education influencing PPE use, this indicates that farmers' learning processes are more practice- than theory-based. This is in accordance with the concept of "repeated experience,"[49] through which agents have the opportunity to develop adaptive strategies by introducing new cultural orientations which are collectively shared and accepted.

This leads to the fifth and final issue, namely that inadequate PPE use should be addressed collectively instead of individually. This might be counterintuitive for farmers, as they tend to consider health as an individual and not as a social problem. However, individual farmers are unlikely to change their behavior alone since the process of compliance to the descriptive social norm is so strongly related to farmers' personal protection choices. Furthermore, it has been demonstrated that the promotion of dialogue concerning pesticide issues may result in a behavioral change.[25] In addition, identifying active social networks and involving the "exceptional few," that is, farmers who are particularly influential in the social community, might prove to be an effective strategy.[36,52,53]

These five strategies could also be considered within the framework of already existing intervention programmes, such as the Farmer Field Schools,[54,55] which were probably the most effective intervention for farmers in rural communities in LDCs[55] and in the Andes,[56,57] but which so far have only marginally addressed PPE use. Such strategies could address not only PPE use during the application of pesticides, but also other issues such as selection of appropriate PPE or PPE maintenance, which were not addressed in the present study, but which are likely to increase the probability of reducing pesticide exposure and its related health effects. Either within the framework of the Farmer Field Schools, or in other kinds of interventions, the results of the present research suggest that an intervention strategy based on the above mentioned five key issues may indeed trigger a transition process and that such a process may take the form of a discontinuous change, that is a critical transition, at system level, as suggested by Scheffer et al.[36]

Such a conclusion opens the door to further research investigating the dynamics of such a transitional change. This change depends, ultimately, on the continuous interaction of the individual and systemic level, that is, individual decisions taken in the context of social and physical structures over time. From this perspective, it is interesting to understand under which conditions individual choices about pesticide use may produce a structural change and which interventions and strategies can foster such a behavioral change at a collective, systemic level. These research questions require the use of a dynamic perspective, which could be based either on simulation modelling or on case-study research, where appropriate historical data are available.

Further research into the dynamics of transitional change would not only help in designing more effective interventions addressing PPE and pesticide use, but would also provide insights that are key to understanding the more general process of change in social and social-ecological systems.

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