Chapter 17
From the Farmers' Perspective: Pesticide Use and Pest Control

Seyyed Mahmoud Hashemi, Rajinder Peshin and Giuseppe Feola

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S. M. Hashemi (✉)
Department of Agricultural Extension and Education, College of Agriculture, University of Tehran, Karaj, Iran
e-mail: seyyedmahmoodhashemi@gmail.com; s.m.hashemi@ut.ac.ir

R. Peshin
Division of Agricultural Extension Education, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Chatha, Jammu 180 009, India
e-mail: rpeshin@rediffmail.com

G. Feola
Department of Geography and Environmental Science, University of Reading, Reading, UK
e-mail: g.feola@reading.ac.uk

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Abstract Many studies have shown that farmers in developing countries often overuse pesticides and do not adopt safety practices. Policies and interventions to promote a safer use of pesticides are often based on a limited understanding of the farmers' own perspective of pesticide use. This often results in ineffective policies and the persistence of significant pesticide-related health and environmental problems, especially in developing countries. This chapter explores potentials and limitations of different approaches to study pesticide use in agriculture from the farmers' perspective. In contrast to the reductionist and mono-disciplinary approaches often adopted, this chapter calls for integrative methodological approaches to provide a realistic and thorough understanding of the farmers' perspective on pesticide use and illustrates the added value of such an approach with three case studies of pesticide use in Iran, India, and Colombia.

Keywords Integrative approach · Integrated pest management · Pest control · Pesticide use · Safe use of pesticides

List of acronyms and abbreviations

CICR	Central Institute for Cotton Research
FFS	Farmer Field School
IAC	Integrative Agent-centred
IPM	Integrated Pest Management
IRM	Insecticide Resistance Management
IRMIPM	Insecticide Resistance Management–based IPM
NGO	Non-governmental Organization
PPE	Personal Protective Equipment
SES	Social–Ecological Systems

17.1 Introduction

Pest control as a matter of concern is as old as agriculture itself. Given the present growing demand for food, however, food loss to pests is more critical today than ever (Pimentel 2009). The potential losses as a result of pest infestations may vary, depending on crop and pest, from less than 50% to more than 80% (Oerke and Dehne 2004). For decades, chemical pesticides have been used as one of the many pest control tools in agricultural production to ensure high-quality and quantity of safe and inexpensive food to meet the consumer demand (Ecobichon 2001; Damalas 2009).

Although current literature lacks accurate data on the impact of pesticides on public health and the environment (Pimentel 2009), their negative impacts are widely acknowledged. Acute poisonings by agricultural pesticides are currently considered to be an important cause of human morbidity and mortality worldwide, with some 26 million human pesticide poisonings and with about 220,000 deaths per annum in the world (Pimentel 2009; Kesavachandran et al. 2009). In addition, ecosystems are also being affected by pesticides (Dhawan and Peshin 2009). The negative impacts of pesticides are particularly severe in developing countries. Although only 20% of the world's agrochemicals are used in the developing countries, such countries suffer 99 % of deaths from pesticide poisonings (Jeyaratnam and Chia 1994).

Many programs and initiatives for the safe use of pesticides have been initiated worldwide, but often fail to achieve their goals (e.g., Orr 2003; Wyckhuys and O'Neill 2007). This failure can be at least partially ascribed to the fact that policy-makers have only a limited understanding of how farmers conceptualize their farming systems and, consequently, of why farmers adopt certain pesticide use practices. Such a limited understanding on the part of policy-makers does not translate into effective pesticide use policies (Wyckhuys and O'Neill 2007).

Furthermore, policy-makers mostly rely on reductionist approaches to pesticide use in agriculture, understanding a phenomenon by identifying and addressing individual components of the phenomenon separately and each discipline coming to an understanding from its own perspective. This chapter, in contrast, contends that a more integrated methodological approach is necessary, that is, one inspired by a holistic paradigm for properly understanding and addressing pesticide use in agriculture as a real-world subject of research which is embedded in the societal context in which pesticide use occurs. This chapter originates from the premise that there may be significant differences between farmers' perspectives and scientific and policy communities' perspectives on such issues, not least because of each communities' different mental models. In this chapter, reductionist approaches to study pesticide use practices are briefly reviewed, and their limitations in providing a realistic and thorough understanding of pesticide use briefly discussed. In contrast with these approaches, holistic approaches are described which provide a more realistic and farmer-centered understanding of pesticide use. These approaches are illustrated with three case studies from Iran, India, and Colombia, respectively.

17.2 Toward an Integrative Perspective

In contrast to conventional practice which assumes that farmers are passive adopters (Bruin and Meerman 2001), farmers' adoption of technologies reflects a dynamic decision-making process (Feola and Binder 2010a). However, policy-makers and agricultural experts do not necessarily understand a farmer's decision-making process. Kalaugher et al. (2012) highlight the existence of divergent perceptions of a farming system and different approaches to solving a particular problem between researchers and farmers. For instance, with regard to risk perception of pesticide use, Schöll and Binder (2009a) showed that the mental models of farmers and experts differed significantly from each other. Such a lack of understanding of farmers' decision-making is one of the main causes of policy failure (Feola and Binder 2010a).

The social sciences can contribute to the study of the decisions of the actors involved and the related institutional context. However, reductionist and mono-disciplinary approaches have dominated this field. This can seriously limit the contribution of the social sciences because the diverse range of factors that determine a farmer's pesticide use behavior can hardly be captured without considering multiple social science disciplines simultaneously. As Costanza and Kubiszewski (2012; p. 1) puts it: "Real-world problems do not come in disciplinary-shaped boxes (Jeffrey 2003), and neither do the solutions associated with these problems".

As argued by Atreya et al. (2012), the global knowledge on pesticide issues has been shifting from "mono-disciplinary" to "interdisciplinary" sciences as the pesticide-induced impacts are complex and interconnected in nature. But, minimal efforts are being made at the local level to move from mono-disciplinary sciences to new perspectives that are interdisciplinary in nature. Similarly, van Huis (2009) states that, in connection with challenges facing integrated pest management (IPM) in Sub-Saharan Africa, "A disciplinary entry point when dealing with subsistence farmers without a proper identification of their needs and opportunities is a wrong approach" (p. 408).

The potential of methods of study based on interdisciplinary approaches has remained largely untapped by scholarly research on pesticide use in agriculture, although calls for methods based on interdisciplinary approaches to address linked social and agro-environmental issues are not new (Evans 1951; Wohl 1955 as cited in Miller et al. 2008). For example, pesticide use studies tend to address "hard" (natural sciences) and "soft" (social sciences) aspects separately, which is mirrored by the lack of interdisciplinary journals dealing with pest management issues. Most journals dealing with pest management issues, in general, tend to cover articles that look at the subject from a natural sciences perspective as their first and most important priority and those that cover a social science perspective tend to follow conventional disciplinary boundaries.

In addition, farmers decisions on pesticide use are not made in a vacuum, but in a broader context of risks (e.g., health, economic) and livelihoods, in which trade-offs might exist between crop protection and other objectives. Understanding pesticide use, therefore, requires considering the context in which decisions are made, including contextual factors that might act as barriers or facilitating factors, and multiple and potentially competing farming or livelihood objectives (Schöll and Binder 2009a; Feola and Binder 2010a).

In sum, to fill the gap of understanding farmers' pesticide use practices, reductionist and mono-disciplinary approaches should be abandoned in favor of interdisciplinary and systemic approaches that best allow for understanding farmers' decisions in their specific context, and therefore provide a more solid basis for policy-making and interventions to promote safer pesticide use. The next three sections try to illustrate adopting such an approach through case studies from Iran, India and Colombia.

17.3 Pesticide Use and IPM in Iran

Chemical pesticide use has served as the dominant approach to pest control in Iran for over 60 years. In Iran, the estimated amount of total agrochemical pesticides used annually is 17–25 million liters. In addition, it is estimated that pests damage 42 % of agricultural products each year in Iran (Karamidehkordi and Hashemi 2010).

The use of pesticides is currently being seriously questioned as its negative impacts including pest outbreaks, pest resistance to pesticides, pesticide poisonings, and the threat to health and the environment have become evident in different parts of the country, particularly in provinces located on the southern coast of the Caspian Sea in northern Iran where about 60 % of the total pesticide consumption occurs (Heidari et al. 2007).

In general, the estimated amount of pesticides used each year in Iran is much more than is needed (Karamidehkordi and Hashemi 2010). The use of the insecticide diazinon on rice fields of Guilan Province, a Caspian Province, has been reported to be 5–10 times higher than the necessary amount (Allahyari et al. 2008). In addition, the frequency of overall pesticide applications in some fruits and vegetables may be as often as 6–12 times per season and almost 30 times per season in the Jirouft region (in the south-eastern part of the country) (Heidari et al. 2007).

According to Shahbazi et al. (2012), some outlawed organochlorine pesticides (OCP) (e.g., lindane and technical endosulfan) are still illegally used in rice, other cereals, and cotton cultivation (Norouzian 2000). Also, dicofol, a significant source of dichloro-diphenyl-trichloroethane (DDT), is still used in cotton cultivation and in forestry (Norouzian 2000). In a study conducted in 12 cities of Mazandaran Province, a Caspian province, 3.2 % of the authorized pesticides used were considered to be extremely dangerous, 11.8 % of these were classified as seriously poisonous, and 24.7 % were potentially dangerous (Yousefi 2008). In a more recent study aimed at surveying pesticides commonly used in Tehran and Isfahan, Dehghani et al. (2011) reported that 9.3 % of the pesticides used were highly hazardous and the remaining 58.5 and 32.2 % were moderately and less hazardous pesticides to human health, respectively.

Since 1994, the Iranian government has started a number of programs to reduce pesticide use; however, such initiatives failed to establish sustainable plant management systems at the farm level as most of them did not fully incorporate bottom-up participatory approaches (Heidari 2006).

According to Heidari (2006), in practice, no farms in Iran adopted the principles of IPM until 1999 when the Farmer Field School (FFS) approach was first introduced as part of a pistachio IPM project in Semnan Province which resulted in successfully empowering farmers to deal with many of their own problems, reducing production costs, and increasing income during two successive seasons. This project was conducted by the Iran National Plant Protection Research Institute in response to a request for help from the Semnan agricultural organization in controlling two surging pests on the main crops of Semnan Province, that is, psylla (*Agonoscena pistaciae*) on pistachio and melon fly (*Bactrocera cucurbitae*) on summer crops. The project successfully controlled the surging pest problems (Heidari 2006). Experiences with IPM/FFS projects in different parts of the country (Figs. 17.1 and 17.2) revealed that "IPM cannot be successful without active participation of the farmers" (Fathi et al. 2012; p. 20).

In general, even about a decade after the introduction of IPM/FFS in Iran (Table 17.1) by national and international institutions (Fig. 17.3)—FAO and the Global Environment Facility (small grants program)—IPM/FFS can still be

Fig. 17.1 Participants of FAO project on IPM/FFS for apple in Damavand County, Iran (photo Hossein Heidari)

Fig. 17.2 Participants of weekly meeting of UNDP GEF/SGP project on IPM/FFS for rice in Sooleh, Mazandaran Province, Iran (photo Hossein Heidari)

described as "a pilot project idea," although currently it is becoming a mainstream approach in Iran (Fathi et al. 2012).

17.3.1 Pesticide Use in Agriculture from the Iranian Farmers' Perspective

From a review of the relevant literature about Iranian farmers' perspective of pesticide use in agriculture, we can conclude that consideration of the Iranian farmers' perspective is very rare. In particular, almost all of those studies were conducted by researchers with a background in agricultural extension, without any contribution from relevant scientists with backgrounds in sociology, psychology, anthropology, and so on. In addition, there are currently extremely few, if any, studies that consider the farmers' perspective from an interdisciplinary point of view.

Table 17.1 Iran's national IPM/FFS program. (Source: Fathi et al. 2012)

Year	Number of FFS sites	Number of provinces	Number of crops
2004	5	2	4
2005	28	8	8
2006	91	15	10
2007	172	22	27
2008	252	29	37

Fig. 17.3 UNDP GEF/SGP project on training of rice IPM facilitators in Azbaran, Mazandaran Province, Iran (photo Hossein Heidari)

17.3.1.1 Farmers' Pesticide Use: Perceptions, Knowledge, Practices, Training Needs, and Health Effects

With regard to awareness, knowledge, and competence as important variables to adopt the safe use of pesticides and IPM technologies (Hashemi et al. 2012a, 2012b), most Iranian farmers lack basic knowledge of IPM, competence on pest management practices, and safe use of pesticides, according to studies conducted in different parts of the country. In a study conducted in Karaj in 2007, authors reported that most farmers lacked an acceptable knowledge of IPM (Hashemi et al. 2008) and most of them were not competent in basic pest management practices (Hashemi et al. 2009). In another study carried out in Zanjan Province in the northwest of Iran, Karamidehkordi and Hashemi (2010) reported that farmers had little awareness of non-chemical pest control methods (i.e., mechanical and biological techniques and natural enemies).

In a study conducted in Fars Province in southwest Iran in 2008, two distinct groups of farmers were revealed. One group of farmers clearly had a positive opinion about the efficacy of the current pesticide products (i.e., they felt that both current and older pesticides used are the same in relation to the level of active ingredients they have). On the other hand, the other group had a rather negative opinion of the efficacy of the current pesticide products (i.e., they felt that current pesticides are less effective than older pesticides they had used and that their efficacy decreases annually because they felt that companies deliberately dilute pesticide products to sell more pesticides) (Hashemi and Damalas 2011). As a result, one farmer from this group stated that "nowadays, current pesticides do not show adequate efficacy to control pests, and even if I wash my hands with pesticides, there will be no danger for my health" (Hashemi and Damalas 2011; p. 76).

Accordingly, many experts in Iran believe that the limited knowledge of Iranian farmers with regard as to how to use pesticides and how much pesticide to use is the main problem with pesticide use in Iran (Karamidehkordi and Hashemi 2010).

According to a study carried out in five provinces of Iran, 68 % of the farmers surveyed used no protection devices (e.g., coveralls, mask, gloves, etc). Further, 55 % of the farmers discarded the pesticide containers with no special care (Aghilinegad et al. 2008). In research which surveyed pesticide use among farmers in 2009, the authors reported that only 13 % of the farmers disposed of empty pesticide containers according to the pesticide label and also only 7 % of them were following the safety precautions on the label during pesticide use. In addition, about 60 % of the farmers stated that they were not using any special protective equipment when spraying pesticides and almost no one had received any special training in pesticide safety (Hashemi et al. 2012b). Results of similar studies conducted in other parts of the country confirm these findings (e.g., Ghasemi and Karami 2009; Karamidehkordi and Hashemi 2010; Shafiee et al. 2012).

In a study conducted to identify farmers' needs for pest management training, farmers showed different needs for future training on pest management because of their different levels of training already received and their different backgrounds. Farmers who had never attended a training workshop showed low levels of competence and consequently high levels of need for pest management practices training with regard to IPM principles. On the other hand, farmers who had participated in a workshop for pest management showed the highest level of competence for all three areas of pest management practices studied (i.e., pest identification, pesticide management, and IPM principles) (Hashemi et al. 2009).

According to a study conducted among vegetable growers by Shafiee et al. (2012), all of respondents reported health problems after routine pesticide use, including dizziness, cough, nausea, skin problems, poor vision, and stomach aches.

17.3.1.2 Pesticide Use and Risk Perceptions Among Farmers

Karamidehkordi and Hashemi (2010) report that 70 % of the farmers reported that pesticides have negative effects on human health. In addition, about 50 % of the respondents identified reported pesticide impacts on groundwater and non-pest insects. In another study, the majority of farmers reported that they consider current pesticides to be as harmful as older types of pesticides (60 %), whereas about 30 % of the farmers stated that they consider current pesticides to be harmless to human health compared with older types of pesticides (Hashemi and Damalas 2011). Pesticide use and farmers' risk perceptions of unsafe use of pesticides were explored in 2009 (Hashemi et al. 2012b). Three groups of farmers were revealed: the first group included 30.3 % of the farmers with the lowest perceived risk of unsafe use of pesticides; the second group, 63 %, was the largest with an intermediate perceived risk of unsafe use of pesticides; and finally the last group, 16.7 % of the farmers, perceived the highest degree of risk in the unsafe use of pesticides. In addition, this study found that there was not a simple and linear relationship between risk perceptions of unsafe use of pesticides and farmers' age, but farming experience and experience of pesticide-related adverse health effects in the past were the effective factors which lead to higher levels of perceived risk associated with the unsafe use of pesticides.

17.3.1.3 Safe Use of Pesticides: Determinants and Training Needs

Farmers' knowledge, attitudes, and practices of pest management were explored in a study conducted in four Iranian cities in Mazandaran Province (Arjmandi et al. 2012). Five categories of variables were considered as determinants of pesticide consumption: education, pesticide application technology, regulations, IPM implementation, and the price of pesticides.

Other research in Iran highlighted the role of cost of each pesticide product for farmers as the farmers' final criterion for the purchase and use of a specific product (Hashemi et al. 2012b). In addition, considering the fact that in Iran the price of the biological pesticides is much higher than that of the chemical pesticides, farmers normally do not tend to use these biological alternatives (Arjmandi et al. 2012). In Iran, pesticide subsidies were cut in 2009; therefore, this new situation will probably influence the behavior of farmers toward pesticide use (Hashemi et al. 2012b).

About 80 % of Iranian farmers are not well-educated (either illiterate or undereducated) (Hashemi and Hedjazi 2011); some studies dealing with pesticide use among farmers revealed Iranian farmers' level of education as one of determinants of unsafe use of pesticides (e.g., Aghasi et al. 2010; Shafiee et al. 2012). In contrast, other studies have shown that there was no positive correlation between the farmers' level of formal education and their awareness of the side effects of the excessive use of chemical pesticides and farmers' personal safety in pesticide use (Karamidehkordi and Hashemi 2010; Arjmandi et al. 2012; Hashemi et al. 2012b).

Legislation and strong regulatory systems are necessary to ban or restrict use of dangerous chemicals and pesticides (Ecobichon 2001). The current regulations of the Iranian Plant Protection Organization go back to 1967 and do not cover components of environmental management of pesticide use in a comprehensive way. The regulations require revisions and amendments to include all environmental management of pesticide use (Arjmandi et al. 2012).

Hashemi et al. (2012a) focused on the three stages of pesticide handling (i.e., before, during, and after use) in pesticide safety training and compared the training needs of young farmers (up to 35 years old), middle-aged farmers (above 35 up to 50 years old), and old farmers (above 50 years old), according to a study conducted in 2009 (Hashemi et al. 2012a). The top training needs for the young farmers were mostly on measures or actions related to pesticide handling before use (i.e., "selecting appropriate pesticide products for a specific pest problem" and "defining the correct timing of application for a specific pest problem"). In contrast, the top training needs for middle-aged and old farmers were mostly on measures or actions related to pesticide handling during use (i.e., "providing first aid in case of sickness or poisoning by pesticides" and "discriminating degree of pesticide toxicity by the safety symbols").

17.3.1.4 Factors Affecting Farmers' Adoption of IPM

Veisi (2012) explored the determinants of farmers' adoption of IPM in the Iranian provinces of Mazandaran and Gilan, considering exogenous factors, farmer characteristics, farm characteristics, and the characteristics of innovations (IPM). The determinants with the highest effects on adoption behavior of IPM practices were "soil quality," "gender" (being male), and "level of knowledge." In Samiee et al. (2009), farmers' level of knowledge about IPM practices was found to be the most effective variable to explain the level of wheat growers' adoption of IPM practices.

17.4 Pesticide Problems and IPM in India

In India, insecticides are widely used in agriculture accounting for 64 % of the total pesticide consumption (Peshin et al. 2009a). Insecticides are the main tool of pest management in cotton, vegetable crops, and rice (Peshin and Kalra 1998; Peshin et al. 2007, 2009b; Sharma 2011). Herbicides are commonly used in wheat and rice crops. The cotton crop accounted for about 50 % of the total pesticide use before the introduction of transgenic cotton. Despite the implementation of many IPM programs in cotton, vegetable crops, and rice and widespread adoption of Bt cotton, pesticide use has increased from 37,959 tons in 2006–2007, to 55,540 tons (a.i.) in 2010–2011, corresponding to an increase of 46.31 %. Prior to 2007–2008, pesticide use in Indian agriculture had decreased between 1990–1991 and 2006–2007 from 75,033 to 37,959 tons, a reduction of 49.41 %. Pesticides continue to be the main plant protection tool in states like Punjab, Haryana, Andhra Pradesh, Maharashtra, Rajasthan, and Tamil Nadu, which consume 55 % of the total pesticide use when taken together (Peshin et al. 2009a).

Pesticide-based pest management is a complex technology for farmers to efficiently adopt (Litsinger et al. 2009). It is a mix of software (consisting of a knowledge base) and hardware (consisting of inputs) technology. Hardware in terms of pesticides, and software in terms of selection of a right pesticide against a particular pest, right dosage, right dilution, and right time of application (Peshin et al. 2012). The hardware side of technology is dominant and is adopted faster than the software side (Roger 2003). The pesticide-based pest management requires higher levels of knowledge and greater skills on the part of farmers to select the right pesticide, pesticide dosage, and dilution (spray volume). Most pesticides are only toxic to specific pests, can be washed away by rain, can drift with wind, and are required to be placed on a specific part of the plant and must be diluted correctly (Nataatmadja et al. 1979; Litsinger et al. 2009).

17.4.1 Pesticide Use and Pest Problems in Punjab, India

The state of Punjab, comprising less than 1.5% India's land area, has been "the leader of the Green Revolution" in India. The rice yield increased from 1,035 kg/ha in 1960–1961 to 3,943 kg/ha in 2004–2005, and the wheat yield increased from 1,237 to 4,221 kg/ha during the same period (Anonymous 2006a). Punjab contributes 45% of the rice and 65% of the wheat to the production of these grains in India. In addition, the state is a major producer of milk, eggs, honey, fish, sugarcane, and cotton (PAU 1998). It has earned the name of "food basket of the country" and "granary of India." Punjab produces 2% rice, 3% wheat, and 2% of cotton of the world's production (Anonymous 2006b).

Pesticide use is also high (923 g/ha) (Agnihotri 2000). In cotton production, 2.580 kg of pesticide per hectare is applied to transgenic varieties and 6.440 kg/ha to non-Bt varieties (Peshin et al. 2007). In cotton, pest problems continued to increase inexorably resulting in reduced cotton productivity. Productivity initially increased from 269 kg/ha in 1960–1961 (pre–Green Revolution period) to 371 kg/ha in 1970–1971 (Green Revolution period) to as high as 502 kg/ha in 1994–1995 (post–Green Revolution period). The increased productivity was possible through the adoption of hybrid cultivars of cotton and increased fertilizer use and pesticides (insecticide) in the early years of their adoption. In the pre–Green Revolution era, the estimates of yield losses caused by pests in cotton were 18% (Pradhan 1964), and this figure jumped to over 50% in the post–Green Revolution era (Dhaliwal et al. 2004). This was due to: (i) the emergence and development of new pests such as spotted bollworm (*Earias vittella*), American bollworm (*Helicoverpa armigera*), and tobacco caterpillar (*Spodoptera litura*), (ii) the evolution of resistance in *Helicoverpa armigera* to insecticides, (iii) the resurgence of whitefly (*Bemisia tabaci*), and (iv) pest outbreaks of *H. armigera* in 1978, 1983, 1990, 1995, 1997, 2001, *B. tabaci* in 1995, and *S. litura* in 2003 (Dhawan et al. 2004). The farmers were caught on a "pesticide treadmill." The cost percentage of insecticide to total cost of cultivation increased from 2.1% in 1974–1975, 4.6% in 1979–1980, 11.9% in 1984–1985, 15.5% in 1989–1990, and then decreased to 13% in 1994–1995 (Dhaliwal and Arora 2001). In 1997–1998, productivity decreased to 220 kg/ha, and in 1998–1999 reached an all time low of 179 kg/ha. At the same time, the cost of insecticides as a percentage of the cost of cotton production increased to 21.21% in 1998–1999 (Sen and Bhatia 2004), reaching an all time high (50%) in the "pesticide hotspots" of Punjab (Bhathinda district) (Shetty 2004). The development of pest resistance to insecticides resulted in crop failures, with the cost of insecticides exceeding the other costs of production in 1998–1999.

The overuse of pesticides in Punjab has resulted in a change in the pest scenario, as up to 1970, the major pests of cotton were jassid (*Amrasca biguttula*) and pink bollworm (*Pectinophora gossypiella*). There were no pest outbreaks at that time. In 2001–2003, the major pests reported were jassid (*Amrasca biguttula*), whitefly (*Bemisia* tabaci), American bollworm (*Helicoverpa armigera*), and spotted bollworm (*Earias vitella*). Outbreak of American bollworm was reported in 1978, 1983, 1990, 1995, 1997, 1998, and 2001 (Dhawan et al. 2004).

17.4.2 Integrated Pest Management in Cotton

To overcome the negative effects of pesticide overuse in Indian agriculture, especially in the high productivity zone of the Northwest and the coastal regions covering 103 districts, numerous IPM programs were initiated, especially in rice and cotton, which accounted for 67 % of total pesticide use prior to the introduction of Bt cotton. The Central Institute for Cotton Research (CICR), Nagpur, India, implemented an insecticide resistance management–based IPM (IRMIPM) program in 10 cotton-growing states (including Punjab) of India. The IRM approach is based on the premise that unless full-fledged efforts to understand all aspects of the resistance phenomenon are made, any attempt to implement IPM at field level would not bear results (Bambawale et al. 2004). The main focus of IRM program is on rationalizing insecticide use in cotton in the absence of availability of any effective bio-agents; this is presented within the full IPM context.

But the use of pesticides by farmers in cotton according to correct dosages, right timing, and application technology is not up to the accepted norms (farmers either apply an under-dosage or over-dosage) (Table 17.2). The farmers also did not apply the same dosage of a particular insecticide throughout the cropping season of cotton crop; they varied the dosage according to the crop stage and used a lower concentration for controlling young larvae of American bollworm (*H. armigera*) and increased the dosage for grown-up larvae. Under the Insecticide Resistance Management (IRM) program to prevent the build-up of resistance against insecticides, endosulfan was the recommended insecticide against jassid (*Amrasca biguttula*) but the farmers were reluctant to use it, as they felt intoxicated after its spray application (Peshin 2009). The Excel pesticide company was selling endosulfan as an IPM-compatible pesticide. The farmers were ahead of the scientists, because they had real-life experiences of the adverse effects with the use of endosulfan. In May 2011, the Supreme Court of India banned the production and sale of endolsulfan in the country. From their experiences with excessive use of insecticides in cotton, the farmers were knowledgeable about the resistance in insect pests. In local language (Punjabi) they termed it *Amli* (meaning pests having got inured to pesticides). The reasons cited by the farmers for the reduced pesticide use efficacy in cotton were development of resistance in insect pests (57 %), excessive use of insecticide (36 %), over/under dosage of insecticides (21 %), tank mixing of different insecticides (13 %), climate change (13 %), spray equipment and spray technique (1 %), and higher *H. armigera* infestation (3 %) (Peshin et al. 2007).

Table 17.2 The adoption of correct and incorrect dosages of insecticides in cotton in Punjab. (Source: Peshin 2009)

Insecticide	IRMIPM villages (% farmers)	Non-IRMIPM villages (% farmers)
Alphamethrin 10EC		
i. Correct dosage (250 ml/ha)	29[a]	9[a]
ii. Higher dosage	81[a]	100[a]
*N**	*83*	*54*
Cypermethrin 10EC		
i. Lower dosage	15[a]	0
ii. Correct dosage (500 ml/ha)	80[a]	100
iii. Higher dosage	9[a]	0
N	*46*	*20*
Cypermethrin 25EC		
i. Lower dosage	15	0
ii. Correct dosage (200 ml/ha)	8	0
iii. Higher dosage	77	100
N	*13*	*12*
Deltamethrin 2.8EC		
i. Correct dosage (400 ml/ha)	55	83
ii. Higher dosage	45	17
N	*11*	*6*
Fenvalerate 20EC		
i. Correct dosage (250 ml/ha)	10[a]	0
ii. Higher dosage	93[a]	100
N	*41*	*14*
β-cyfluthrin 0.25EC		
i. Correct dosage (500 ml/ha)	0	–
ii. Higher dosage	100	–
N	*2*	*0*
Lambda cyhalothrin 5EC[b]		
i. 1.200 ml/ha	100	100
N	*3*	*1*
Acephate 75SP		
i. Lower dosage	31[a]	52[a]
ii. Correct dosage (2 l/ha)	76[a]	57[a]
iii. Higher dosage	3[a]	5[a]
N	*86*	*21*
Chlorpyriphos 20EC		
i. Lower dosage	53[a]	54
ii. Correct dosage (5 l/ha)	51[a]	46
N	*89*	*37*
Dimethoate 30EC		
i. Correct dosage (625 ml/ha)	0	0
ii. Higher dosage	100	100
N	*3*	*4*
Ethion 50EC		
i. Lower dosage	40[a]	38[a]
ii. Correct dosage (2 l/ha)	67[a]	64[a]
iii. Higher dosage	5[a]	2[a]
N	*92*	*55*

Table 17.2 (continued)

Insecticide	IRMIPM villages (% farmers)	Non-IRMIPM villages (% farmers)
Monocrotophos 36SL[c]		
i. Lower dosage	22[a]	27
ii. Correct dosage (1.5 l/ha)	78[a]	46
iii. Higher dosage	11[a]	27
N	*9*	*11*
Profenophos 50EC		
i. Lower dosage	5	0
ii. Correct dosage (1.25 l/ha)	75	50[a]
iii. Higher dosage	20	67[a]
N	*20*	*6*
Quinalphos 25EC		
i. Lower dosage	16	0
ii. Correct dosage (2 l/ha)	75	100
iii. Higher dosage	9	0
N	*32*	*5*
Triazophos 40EC		
i. Lower dosage	40[a]	51[a]
ii. Correct dosage (1.5 l/ha)	64[a]	53[a]
iii. Higher dosage	18[a]	20[a]
N	*121*	*59*
Thiodicarb 75WP		
i. Correct dosage (625 ml/ha)	0	–
ii. Higher dosage	100	–
N	*4*	*0*
Endosulfan 35EC		
i. Lower dosage	35	20
ii. Correct dosage (2.5 l/ha)	58	60
iii. Higher dosage	7	20
N	*57*	*15*
Imidacloprid 17.8SL		
i. Correct dosage (100 ml/ha)	58[a]	63
ii. Higher dosage	50[a]	37
N	*117*	*48*
Acetamiprid 20SP		
i. Correct dosage (50 gm/ha)	11	7
ii. Higher dosage	89	93
N	*46*	*15*
Thiomethoxam 25WSC		
i. Lower dosage	4	0
ii. Correct dosage (100 gm/ha)	46	53
iii. Higher dosagne	50	47
N	*24*	*19*
Indoxacarb 15SC		
i. Lower dosage	4	6
ii. Correct dosage (500 ml/ha)	95	94
iii. Higher dosage	1	0
N	*74*	*31*

Table 17.2 (continued)

Insecticide	IRMIPM villages (% farmers)	Non-IRMIPM villages (% farmers)
Spinosad 48SC		
i. Lower dosage	8[a]	0
ii. Correct dosage (150 ml/ha)	33[a]	9
iii. Higher dosage	63[a]	91
N	*52*	*22*

– Decimals have been rounded up to nearest whole number
[a] Farmer applied different dosage of a particular insecticide for spraying on different occasions
[b] Not recommended by the Punjab Agricultural University
[c] Not recommended under IRM strategy
[*] N = The number of farmers out of a sample of 210 who have used a particular insecticide

17.5 Pesticide Use in the Colombian Andes[1]

17.5.1 Background and Research Problem

Human health and environmental effects of pesticide use are serious concerns among smallholder potato farmers in the Colombian Andes. Potato is one of the crops with the highest demand for fungicides and insecticides in Colombia (MADR 2006). The cultivation of potato is mainly concentrated in the Andean regions of Boyacá, Cundinamarca, and Nariño and is carried out by smallholders (MADR 2006). Smallholders in the region achieve an average yield of 14–15 t/ha, which has stayed constant in the last few decades (MADR 2006; Feola and Binder 2010c). Similar to many rural areas in the less developed countries, smallholders apply pesticides by means of a lever-operated knapsack sprayer and often wear inadequate personal protective equipment (PPE) (Cardenas et al. 2005; Ospina et al. 2008). Mostly carbamates (Carbofuran, Mancozeb, Methomyl), organophosphates (Metamidophos, Malathion), and pyrethroids (Cypermethrin) insecticides and fungicides are applied to the crop (details in Feola and Binder 2010c). In addition, smallholders in these regions were reported to overuse pesticides. Several studies showed that, as a consequence of such pesticide use practices, farmers in Boyacá and their environment are at risk because of exposure to pesticides (Leuenberger 2005; Cardenas et al. 2005; Ospina et al. 2008). Moreover, the negative economic consequences attracted the concern of governmental agencies; crop protection represents a significant share of the production costs for smallholders in this region (MADR 2001) and therefore more efficient pesticide use may not only reduce environmental and health risks, but also contribute to a more viable livelihood strategy.

Intervention programs in Boyacá often failed to achieve a durable and self-sustaining change from current pesticide use toward sustainable pesticide practices (e.g., Ospina et al. 2009). This is consistent with what has been observed in many

[1] An earlier and more extensive account of this research can be found in Feola and Binder 2010a, 2010b, 2010c, and Feola et al. 2012.

other contexts in poor countries (e.g., Orr 2003; Wyckhuys and O'Neill 2007)., and similar to those other contexts, this failure can be at least partially ascribed to the fact that policy-makers have only a limited understanding of how farmers conceptualize their SES and, consequently, of why farmers adopt certain pesticide use practices. Schöll and Binder (2009a, 2009b), for example, by using the structured mental model approach (Binder and Schoell 2010), showed that farmers and experts in Boyaca had divergent understandings of agricultural systems including the definition and importance of different capitals (i.e., human, physical, social, natural, and financial). Such a limited understanding does not translate into effective policies (Wyckhuys and O'Neill 2007). Therefore, sound knowledge was urgently needed to develop effective interventions for a transition toward a more sustainable pesticide use in Boyacá.

17.5.2 Goals

With reference to the study area of Vereda La Hoya in the region of Boyacá, this research aimed to: (i) uncover the behavioral dynamics underlying unsustainable pesticide use practices of smallholder potato farmers, and (ii) on this basis provide policy recommendations to foster a transition toward more sustainable pesticide use in this region.

17.5.3 Methods

The research was structured in three phases. Firstly, a theoretical framework was developed (see below) to allow for the understanding of farmers' behaviors as embedded in their specific SES (Feola and Binder 2010a). Secondly, data were collected through a survey ($N=210$) and statistical and econometric models of PPE and chemical pesticide use developed to identify influential factors and social dynamics (Feola and Binder 2010b, 2010c). Two practices were studied: PPE use and the chemical pesticide use. Finally, a dynamic behavioral model was developed and used to simulate alternative policies to achieve higher PPE use rates. This model was employed as a learning tool with local agriculture experts and policy-makers (Feola et al. 2012).

17.5.4 Theoretical Background

Most socio-psychological approaches to study farmers' behavior and decision-making fall short with respect to at least one of the following: (i) an explicit and well-motivated behavioral theory, (ii) an integrative approach, and (iii) understanding feedback processes and dynamics (Feola and Binder 2010a). The integrative agent-centered (IAC) framework (Feola and Binder 2010a), which was developed and ap-

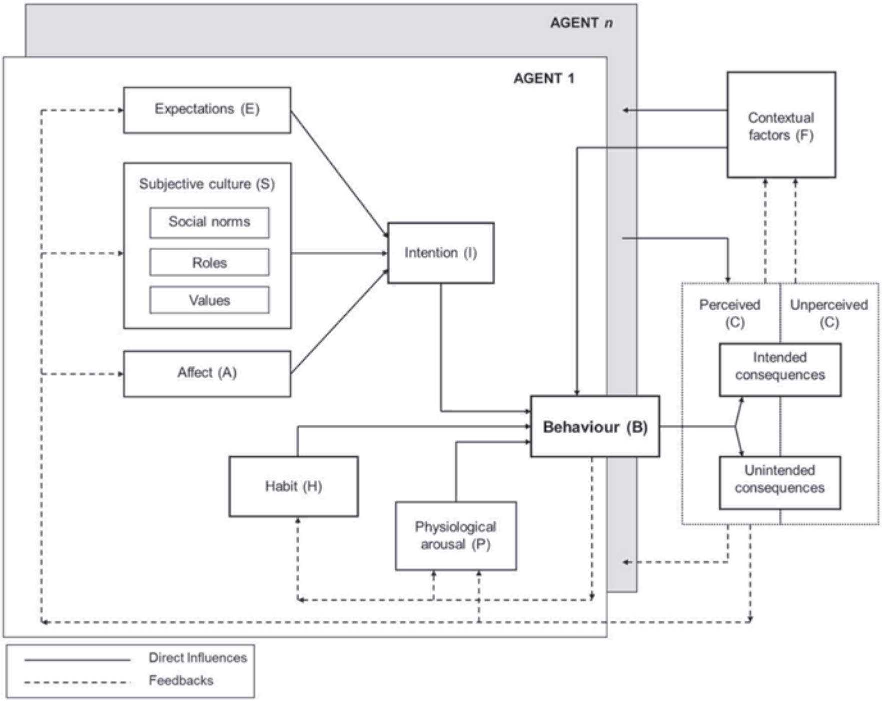

Fig. 17.4 The integrative agent centered (IAC) framework. The IAC framework provides a conceptual structure to understand social agents' behavior in their social–ecological systems by combining different behavioral drivers. It entails feedbacks and focuses on behavioral dynamics more than states and on the feedbacks among the determinants of a given behavior. (Source: Feola and Binder 2010a, with permission from Elsevier)

plied in this study, addresses simultaneously these three points and was developed to fill this gap. The IAC framework provides a conceptual structure to understand social agents' (i.e., farmers') behavior in their SES (i.e., agricultural systems).

The IAC framework is agent centered. It integrates and adapts Giddens' Structuration Theory (Giddens 1984) and Triandis' Theory of Interpersonal Behavior (Triandis 1980) to provide an understanding of farmers' behavior consistent with the perspective of agricultural systems as complex SES. It combines different behavioral drivers (i.e., rational expectations, subjective culture, affect, habit, and external factors) and, therefore, depicts a complex and potentially varied model of human behavior. It entails feedbacks, according to a circular, that is, systemic, conceptualization of human behavior. In addition, the IAC framework focuses on behavioral dynamics more than states and on the feedbacks among the determinants of a given behavior, and in particular between individual behavior and that of the system (Fig. 17.4).

In the framework (Fig. 17.1), an agent's (i.e., farmer) decision to enact a specific behavior (e.g., PPE use) is influenced by external and internal drivers. The former consists of contextual factors (i.e., facilitating conditions or barriers), whereas the latter includes habit (the frequency of past behavior), physiological arousal (the physiological state of the individual), and intention (Feola and Binder 2010a). The latter is determined by: (i) expectations (the beliefs about the outcomes, their probability, and their value), (ii) subjective culture (social norms, roles, and values), and (iii) affect (the feelings associated with the act). The behavior can have intended or unintended and perceived or unperceived consequences, which can feed back to the farmers. Only the perceived consequences, which are re-interpreted by the agent, feedback directly to farmers by influencing intention, affect, habit, and physiological arousal. The feedback processes can reinforce the current state or trigger change and can occur at different temporal levels (i.e., short- or long-term). Agents' interactions happen either directly or indirectly. The former depends on the agents' social network. The latter happens through the consequences of behavior, which can aggregate at the next highest hierarchical level, being perceived and reinterpreted by individual agents (Feola and Binder 2010a).

17.5.5 Results

With respect to the use of personal protective equipment (PPE), among the factors that influence this behavior, such as the cost of PPE and the ability to understand pesticide safety labels, there were two particularly important dynamics. Firstly, farmers tended to conform to the descriptive social norm, that is, the most common behavior observed in the peer group, thus reproducing the norm itself (reinforcing feedback; social level). Secondly, farmers tended to intermittently react to short-term pesticide-related adverse health effects by using more pieces of PPE more frequently, but disregarding PPE as the health effects loses relevance with time (balancing feedback; individual level). These behavioral dynamics were rendered, together with static factors, in the dynamic behavioral model that was used to simulate the effect of different combinations of policies on PPE use (Feola et al. 2012). The most effective simulated strategy was one that combined diversification of policies, long-term implementation, and intervention on structural aspects (i.e., descriptive social norm). Moreover, PPE use is influenced by the level of pesticide application (see below), farmers reacting to adverse health effects more frequently under more intense application levels.

Regarding the use of chemical pesticides, the results show that it is possible for smallholders in the region to achieve satisfactory productivity (average 13.6 t/ha) while applying insecticides and fungicides effectively, and consequently minimizing health and adverse environmental effects, and containing production costs (Feola and Binder 2010c). The analysis of the factors that influence farmers' pesticide use choices explains why the technical fix and approaches traditionally adopted by development agencies in the region might be bound to fail in Boyacá. These approaches focus on the short-term and assume the unsustainable practices are caused by a lack of knowledge. They do not address the specific social dynamics that induce ineffective pesticide use in the region, among which are conformity to social norms, market pressure for farmers to grow pest-vulnerable varieties, small parcels that hamper resource management, and the influence of pesticide producers and sellers on smallholders. Instead, the results suggest that a different approach is needed, in particular one that: (i) engages pesticide producers and sellers, (ii) facilitates new institutional settings such as farmer cooperatives, which support more efficient and less hazardous practices, and (iii) exploits social conformity in developing campaigns for sustainable practices (Feola and Binder 2010c).

17.6 Conclusions

We reviewed the potentials and limitations of different methodologies and approaches used in the literature to study pesticide use from the farmers' perspective. We contended that the reductionist paradigm's assumptions prevail in the current approaches and methodologies. This can result in creating an "unreal picture" of the farmers' perspective. In contrast with the narrow disciplinary approaches, we suggest adopting a more interdisciplinary approach with more potential to create a realistic and farmer-centered understanding of pesticide use.

Using three case studies from Iran, India, and Colombia, this approach was illustrated. In particular, drawing on studies currently available in the literature that look at pesticide use in agriculture from Iranian farmers' perspective, we found this area of scholarly research in nascent stages with a need for contributions from all relevant social scientists in an interdisciplinary and integrative way.

In addition, although there have been many efforts from both national and international supporters to encourage Iranian farmers to adopt safe use of pesticides and IPM practices, in practice many obstacles still prevent IPM from being a mainstream strategy for pest control in Iran. According to many studies currently available in the literature, Iranian farmers' attendance in educational courses on pesticide issues is highlighted as a critical need. Since such insights come from studies that are confined within narrow disciplinary boundaries, their recommendations may not be realistic enough when seen from a farmer's perspective. As such, other studies argue that Iranian farmers continue to use pesticides excessively and in an unsafe way even though they may be educated and aware of the hazardous effects of chemical pesticides. Their economic considerations and limited access to appropriate alternatives contribute crucially to choosing between pesticide products. Furthermore, farmers may not be interested in attending the classes provided by Iran's Ministry of Agriculture since they perceive that there is a wide gap between the "prescriptions" of the classes and the reality of their daily life. Even in cases where learning opportunities for farmers were provided in a more participatory and experiential way (FFS), some authors reported that Iranian farmers faced many obstacles such as lack of access to spraying tools and/or specific equipment needed to go through the pest management steps that they learned. The conclusion here is that there is a need to educate Iranian farmers about safe use of pesticides and other alternatives to pest control. We wish to suggest that this is not the only recommendation that needs to be made in every situation. This is consistent with results revealed in the case study conducted in the Colombian Andes which showed that more sustainable pesticide practices might result from diversified strategies.

The Indian case study showed that the farmers that have hands-on experience with pest management act rationally given their grasp of the relationship between cause and effect. Any IPM program and IPM technologies need to be modified by making farmers "partners" at the technology testing phase. Farmers' use of pesticides according to good agricultural practices is a complex technology. Researchers need to take into consideration farmers' perceptions about the technological attributes during the technology development process, rather than the technologists' predicting the adoptability in order to overcome innovation biases.

Finally, the Colombian case study illustrated how the IAC framework can be adopted to understand farmers' pesticide use practices, and thus help to define a policy agenda for triggering a transition toward a more sustainable pesticide use that goes beyond the search of "silver bullets" such as education. The IAC framework helps to understand the causes and meanings associated by farmers to selected pesticide use practices in the specific social and environmental context (i.e., social structures and the biophysical environment in SES) in which they take place, that is, the socially and environmentally adaptive value of those actions. It therefore also helps to overcome the rationality/irrationality discourse that often frames expert assessment of farmers' practices, such as not using PPE while applying chemical pesticides. It is on the basis of such a theory-based and integrative understanding that effective strategies and policies for a transition towards sustainable practices can be based.

Overall, this case study showed that while education and technological innovation are commonly claimed to be the way forward, more sustainable pesticide practices might result from different strategies. These include: (i) targeting the systemic processes which determine the actual social behavioral norms, (ii) diversification of measures to address different factors and processes co-influencing farmers, (iii) the involvement not only of farmers, but of other actors (e.g., pesticide producers) at the different levels of the agricultural system who influence farmers in symbolic and material ways, and (iv) strengthening institutional arrangements such as farmer cooperatives that scaffold best practices at the local level.

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