

**Impact of Integrated Pest Management
Farmer Field Schools
on health, farming systems, the
environment, and livelihoods of
cotton growers in Southern India**

2006

Promotoren:

Prof. Dr. Ir. Ariena H.C. van Bruggen
Hoogleraar in Biologische Bedrijfssystemen
Wageningen Universiteit

Co-promotoren:

Prof. Dr. Janice L.S. Jiggins
Gastmedewerker
Leerstoelgroep Communicatie- en Innovatiestudies
Wageningen Universiteit

Dr. Ir. Aad J. Termorshuizen
Universitair hoofddocent, leerstoelgroep Biologische Bedrijfssystemen
Wageningen Universiteit

Promotiecommissie:

Prof. Dr. Ir. Arnold van Huis (Wageningen Universiteit, Wageningen, The Netherlands)
Prof. Dr. Jozsef Kiss (Szent Istvan University, Godollo, Hungary)
Prof. Dr. William Settle (Food and Agriculture Organization of the United Nations, Rome, Italy)
Dr. Kees Eveleens (voorheen Food and Agriculture Organization of the United Nations, Rome, Italy)

Dit onderzoek is uitgevoerd binnen de C.T. de Wit Onderzoekschool 'Productie Ecologie en Beheer van Natuurlijke Hulpbronnen'.

Impact of Integrated Pest Management
Farmer Field Schools
on health, farming systems, the
environment, and livelihoods of
cotton growers in Southern India

FRANCESCA MANCINI

Proefschrift

Ter verkrijging van de graad van doctor
op gezag van de rector magnificus
van Wageningen Universiteit,
Prof. Dr. M. J. Kropff,
in het openbaar te verdedigen
op vrijdag 21 april 2006
des namiddags te 13.30 uur in de Aula

Francesca Mancini, 2006. Impact of IPM Farmer Field Schools on the environment, health and livelihoods of cotton growers in Southern India. Doctoral thesis, Biological Farming Systems Group, Wageningen University, The Netherlands.

ISBN 90-8504-388-3

Abstract

Crop productivity has increased worldwide since the late 1950s thanks to the modernisation of agriculture. However, many small-scale farming systems located in regions with limited access to resources have seen their profitability constrained by the intensification of input use. The rain-fed cotton farming sector in South and Central India provides an example of the crisis that affects subsistence agriculture. Marginal farmers are often burdened with debts and their health is undermined by exposure to highly toxic pesticides. In the given conditions, Integrated Pest Management (IPM) has been promoted as means to improve the sustainability of cotton cultivation. The objectives of this thesis were to assess the impact of adopting IPM in cotton farming systems and to develop or adapt rigorous impact assessment methodologies and tools for this purpose. The research was carried out where participatory season-long training, namely Farmer Field Schools (FFS) on cotton IPM had been conducted. FFSs aim to promote the spread of better practices in agriculture through human capacity building; therefore this thesis addressed the human and social gains, in addition to the environmental benefits associated with attending IPM FFSs. The research design followed the so-called Double Difference model, comparing farmer practices before and after the adoption of IPM with the practices of a control group of farmers who did not attend IPM FFSs. The acute poisoning rate among farmers exposed to pesticides was found to be 84%, being notably severe among women and poor farmers. Pesticides belonging to WHO category Ib and II (Highly Hazardous and Moderately Hazardous), were the most used products with an average application rate of 8 sprays per growing season. IPM adoption reduced pesticide use by 78% without affecting crop productivity, suggesting that a large part of the current use of pesticides is unnecessary. Those farmers who had learned more about pest and predator ecology attained the highest reductions. However, the adoption of IPM increased the demand for female labour in the family, indicating that the availability and opportunity costs of women workers might influence its adoption rate. IPM substantially reduced the ecological impact of pesticide use, but there is still scope to reduce other impacts generated by cotton cultivation such as global warming and eutrophication. Empowerment outcomes associated with attending FFSs in terms of improved collaboration and connection with outsiders as a means to achieve better village governance were reported by the farmers participating in this assessment. The gender sensitiveness of the research highlighted the relevance of educating women to pursue tangible livelihood improvements. In conclusion, it was shown that strategies based on education can be an efficient approach, provided that farmers have direct access to quality training. Further studies on a regional scale are needed to support the scaling-up of the educational programmes, which must be both economic and effective.

Abbreviations

AP	Andhra Pradesh State
AP	Acidification Potential (in Chapter 5)
EP	Eutrophication Potential
EIQ	Environmental Index Quotient
EU	European Union
FAO	Food and Agriculture Organization (of the UN)
FFS	Farmer Field School
GWP	Global Warming Potential
IPM	Integrated Pest Management
KA	Karnataka State
LCA	Life Cycle Analysis
SL(A)	Sustainable Livelihood (Analysis)
USLE	Universal Soil Loss Equation
WHO	World Health Organization (of the UN)

Acknowledgements

The threads of this work, and of nearly 5 years of my life, were woven across three worlds: rural India, home in Italy and study in Wageningen. I would like to thank the people from all three worlds, who have contributed to the realisation of this thesis.

First of all, this thesis would not have been written without the excellent and constant guidance of Ariena van Bruggen, Janice Jiggins and Aad Termorshuizen. I would like to thank Ariena and Janice also for having involved me in many activities besides the PhD programme, introduced me to a web of interesting professionals and invited me to nice social and culinary events. All this has made my stay in Wageningen a memorable experience. To Aad I would like to tell that, besides being a joyful colleague to work with, I have strongly admired his scientific rigour and ethic. I wish to learn more and more from him in the years to come.

The commitment, competence and enthusiasm of the Integrated Pest Management (IPM) “tribe”, within and outside the FAO, have made my most recent professional experience invaluable. Meeting and travelling to the project sites with Peter Kenmore always resulted in fresh inspiration. I still remember the train trip to Bangalore as a special time for the exciting conversations we had on Indian village life. Peter, thanks for having supported my interest in pursuing a PhD from day one. Listening to Peter Ooi’s talks, I have understood the value of building development on people’s capacity, this is a take-away lesson for life. However, my daily research and working tasks in the field were planned and reviewed with Palanyswamy Pachagounder. Swamy, you have showed me how to work in the Indian context with a culturally sensitive approach. What a more precious support could I have hoped for? Doris von Werner and Gerd Walter-Echols from the FAO Regional Office for Asia and the Pacific and Daniel Gustafson, FAO Representative in India, have guided me on several occasions with their wise advice. Thanks also go to the rest of the international team of the EU-FAO IPM programme for cotton in Asia for the stimulating interactions: Dai Weidong, Alma Linda Morales-Abubakar, Lim Guan Soon, Manzoor, H. Soomro, Cesar Galvan and Rikke Petersen. I would like to thank Manuela Allara, Harry van der Wulp and Kevin Gallagher from FAO Rome, who were always interested in my back-to-headquarters reports during the occasional visits to Rome and kept me informed on the developments that other IPM projects were making in the world. Among these IPM projects, the exchange with the FAO Regional Vegetable IPM Programme in South and Southeast Asia was very fruitful. A special thanks goes to the Team Leader Jan Willem Ketelaar. The national EU-FAO cotton IPM programme staff, facilitators and farmers have warmly welcomed me in India and constantly collaborated in my field work. I have learned from them the most I know today about cotton farming. I’m grateful to Balasubramanian, Venkatakrishnan, Arun, John, Daissy, Ramesh, Rajkumar, Praveen, Nagaraj, Veeriah, Selvam, Naheeda Anjum, Kandagal, Saravanan, Veerabadra Rao and to the many cotton growers I have worked with. I also would like to express my gratitude to the officers of the Indian National IPM Programme, the ex-Plant Protection Adviser of the Directorate PPQS, Dr. V. Ragonathan and the current officer in charge Dr. A.D. Pawar, the Additional Director of Agriculture, Government of Karnataka, Dr. Rajanna and the Commissioner of Agriculture, Government of Maharashtra,

Dr. S.K. Goel for having kindly facilitated the access to whatever information and service I had requested.

Many organisations were involved in the implementation of the field work, I'd like to remember in particular, the PRDIS, its director Dr. Reddy and the whole staff for the fruitful collaboration, which is still ongoing. Seema Khot, at that time a BAIF Foundation' officer in Pune and Edith van Walsum, ex-team leader of AME Foundation, Bangalore, got me started on gender analysis sharing their experience and visiting villages with me.

Even though not presented in this thesis, the work I carried out in Pakistan with rural women helped me to achieve a better understanding of the gender issues related to pesticide use in agriculture, which benefited my research in India. I express my gratitude to Dr. Iftikhar Ahmed, Dy. Director General, NARC and his staff, for supporting my role in the project.

I'm grateful to the co-authors of the papers presented in this thesis who have enormously contributed to the relevance of the research. In addition to my supervisors, a special thank goes to H. Murphy, A. Ambatipudi, J. Wessler and in particular to K. Kooistra, who carried out the ecological assessment of cotton cultivation under my supervision.

In Wageningen University, the Biological Farming Systems Group and the Communication and Innovation Studies Group provided the right expertise to elaborate the data collected in India into a scientific assessment of IPM impact. The analytical phase of the research greatly benefited from the intellectual discussions with the staff of the two groups. Also, the cultural exchange with the members of the Social Learning group enriched the thinking that went into the writing up. I'd like to express my gratitude to Wim Blok, Walter Rossing, Jeroen Groot, Eelco Franz, Alexandre Semenov Jr, Etienne van Rijn, Niels Röling, Arnold van Huis, Cees Leeuwis, Rhiannon Pyburn, Irene Guijt, Frank van Schoubroeck, Mans Lanting, Midori Yajima, Jessica Milgroom and Annemarie van Paassen. Thanks also to Wampie van Schouwenburg and Lien Uithol for providing their efficient secretarial and administrative support throughout my stay in Wageningen.

My assignment as Scientific Coordinator's assistant within the Interdisciplinary Research and Education Fund (INREF) Project 'Strengthening science-based policy-making in pest management', Wageningen University, provided additional financial support and interdisciplinary exchange. I'd like to thank the INREF Committee and in particular the Scientific Coordinator Kees Eveleens.

The Indian experience was so wonderful also thanks to the sincere friendships established with a number of people. Anelise, Chiara and Peter, thanks for the great time we always had together, for the support you gave me in difficult times and, Chiara, thanks also for your endless patience in teaching me English. I share good memories of the Indian adventure with Kareen and Rolf, Manolis, Jana, John and Khader.

An heartfelt thanks to Andre, Eelco and Sasha in Wageningen for the great conversations over lunch breaks and the many laughs we had together. Your company lightened the work burden I faced towards the end. And so did the good time spent with the many friends: Maria, Silwya, Kamila and Tomek, Monica, Costanzina, Giacomo, Flavio and Barbara, Grietse, and Axel.

Coming back to Genoa, my home town, it wouldn't have been the same without Claudia and Paola welcoming my returns. That rock on the seashore...it will always be there for us.

Caterina, Giulia and I have grown together in our profession and in our personal life. We have shared dreams, hopes and plans since the first year of the University. Today, we share a common vision of what development should bring about. Your friendship is an inextinguishable source of strength and joy.

The deepest thanks goes to Giuliana, Achille e Cristina. Mamma e papà, vi ringrazio per avermi insegnato il rispetto per la vita che guida le mie azioni, per aver sempre creduto nelle mie scelte, per avermi dato i mezzi di vivere una vita libera e felice. Cristina, senza la nostra cuffia la luce si spegnerebbe.

Table of Contents

	Abstract	v
	Abbreviations	vi
	Acknowledgements	vii
<i>Chapter 1</i>	General introduction <i>F. Mancini</i>	1
<i>Chapter 2</i>	Incidence of Acute Pesticide Poisoning Among Female and Male Cotton Growers In India <i>F. Mancini, A. H. C. van Bruggen, J. L. S. Jiggins, A. C. Ambatipudi and H. Murphy</i>	9
<i>Chapter 3</i>	Impact of Integrated Pest Management Farmer Field Schools on Pesticide Use and Farmers' Ecological Knowledge on Cotton Farming in India <i>F. Mancini, A. J. Termorshuizen and A. H. C. van Bruggen</i>	27
<i>Chapter 4</i>	The Effects of Integrated Pest Management on Labour Organization and Gender roles in Small Cotton Farms in India <i>F. Mancini, J. Wesseler and J. L. S. Jiggins</i>	41
<i>Chapter 5</i>	Environmental Impact Assessment of Cotton Cultivation in Central India <i>K. J. Kooistra, F. Mancini and A. J. Termorshuizen</i>	53
<i>Chapter 6</i>	Evaluating Cotton Integrated Pest Management (IPM) Farmer Field School Outcomes Using the Sustainable Livelihoods Approach in India <i>F. Mancini, A. H. C. van Bruggen and J. L. S. Jiggins</i>	69
<i>Chapter 7</i>	General discussion <i>F. Mancini</i>	85
	Summary	99
	Samenvatting	102
	Curriculum Vitae	105
	List of Publications	107
	PE&RC PhD Education Statement Form	109
	Pictures	111

CHAPTER 1

General Introduction

Agriculture provides the livelihoods of the majority of the population in India. However, its intensification has reduced the economic capacity and sustainability¹ of small farming systems by inducing a significant increase in the use of production inputs. Over 380 million people, mainly from rural areas, live below the poverty line (UNICEF, 2004). The country's agricultural sector is facing serious challenges posed by the degradation of natural resources, viz. deforestation, salinity, soil erosion, water contamination and depletion (Singh, 2000). The agricultural extension services of the country have been ineffective at reversing these negative trends, but are now in the process of reorienting their development strategies towards supporting farmers' empowerment. This paradigm shift from technology transfer to people-centred extension has become essential for agricultural development to play a strategic role in alleviating poverty (Röling and van de Fliert, 1994).

This thesis is concerned with the contribution of Farmer Field Schools (FFSs), a participatory approach to adult education adopted by the Indian Government since the 1990s, towards the achievement of a more ecologically sound, profitable and socially sustainable small-scale farming.

Background of the study

Cotton cultivation systems in the central and southern states of India illustrate the socio-economic crisis affecting smallholder farming in many developing countries (Choudhary and Larويا, 2001). In the world, India ranks third after USA and China for cotton production. The crop is grown on about 9 million hectares, equivalent to 5 per cent of the total cultivated land, mostly fragmented in small plots (Kooistra et al., 2006). Even though the national average yield is among the lowest in the world (300 kg/ha), the cotton commodity chain contributes 30 per cent (Morse et al., 2005) to the gross domestic product of Indian agriculture and 40 per cent to the total exports (Ramamurthy, 2000). The cotton industry overall, from land preparation to finished products, provides income to 60 million people (Herring and Grodzins, 2005). With the introduction of high yielding varieties and hybrids, which are more susceptible to attacks by pests than the traditional cotton germplasm, the use of synthetic pesticides has increased exponentially. Currently, 50-55 per cent of the national pesticide consumption is used on cotton cultivation (Shetty, 2003). Erroneous but common practices associated with the chemical control, such as prophylactic pesticide applications, sub-lethal or excessive dosages and

¹The ability to provide for the needs of the world's current population without damaging the ability of future generations to provide for themselves. When a process is sustainable, it can be carried out over and over without negative environmental effects or impossibly high costs to anyone involved (Brundtland, 1987)..

use of spurious products, have induced pest resistance and pest resurgence, reducing the efficiency of pesticides in controlling pest populations (Kranthi et al., 2002; Shetty, 2003). In response, farmers have adopted higher pesticide application frequencies, getting caught in what is known as the pesticide treadmill. This abuse of pesticides has led to serious economic, ecological and social consequences.

While cotton yields in the region have remained among the lowest in the world, the cost of cultivation, 40-50 per cent of which is determined by pesticide use, has increased and limited crop profitability. Farmers often are unable to repay the compound interest on debts contracted with money lenders or input dealers to purchase production inputs. In some cases, they have resorted to selling their most important production asset, the land, compromising the livelihood of their families. The wave of suicides among cotton growers in the Telangana region in Andhra Pradesh is, unfortunately, a social phenomenon well documented in the local and national press.

Pesticide abuse has undermined human health. Every year, an estimate of 1 million to 5 million cases of pesticide poisoning occur in the world. The majority of these cases are reported in developing countries where socio-economic and climatic conditions increase occupational risks (WHO, 1999). Children and women are disproportionately affected (UNEP, 2004). In India, more than a thousand cases of pesticide poisoning were recorded between 1999 and 2000 (Division of Medical Toxicology in India Report, 2000). However, it is well known that the official figures on the incidence of occupational pesticide poisoning are underestimates in most developing countries (Dinham, 1993) and that little is reported about the long-term effects (Kishi, 2005).

Natural resources have been polluted and exploited to the point of compromising future productivity. Contamination of water sources has become a major environmental concern in India. The Central Ground Water Board of the country has found high levels of nitrates in ground water, caused by the use of fertilizers in the many villages of the Punjab, Haryana and Karnataka, three intensively cultivated states (Singh, 2000). Pesticide residues have been found in bottled drinking water and ground water (CSE, 2003).

The situation described above represents more than just a technological failure. Farmers' lack of adequate alternatives, access to information, and educational services also accounts for these outcomes.

The Indian Department of Agriculture has recognized the need for innovation in its extension institutions and since the early 1980s has been supporting experimental approaches to meet farmers' needs. Most of the innovations promoted in the national agricultural plan, the IX Plan, have as central themes a move towards more integrated extension delivery and the adoption of participatory planning procedures for setting the research-extension agenda. In some states, farmers' institutions have been strengthened in the effort to make the extension system more farmer-driven and farmer accountable. The use of broadcasting media, group approaches, and the privatisation of services are some of the ongoing initiatives (Rasheed Sulaiman, 2003). A notable innovation introduced in the extension system on a large scale is the Farmer Field School (FFS) model.

In 1999, the five-year EU-FAO Integrated Pest Management (IPM) Programme for Cotton in Asia started in India with the objective of developing a cadre of IPM cotton facilitators from existing extension or field plant protection staff in order to educate farmers in FFSs. The programme was active mainly in four states, namely Andhra Pradesh, Karnataka, Maharashtra and Tamil Nadu. The research presented in this thesis was carried out in selected areas of the first three states.

FFSs were conceptualised between the 1970s and 1980s and first implemented in Indonesia in 1989 to deal with the widespread pest outbreaks in rice that threatened the security of Indonesia's basic food supplies (Pontius et al., 2002). The work of some entomologists showed that the massive use of pesticides, promoted by the government to control brown planthoppers, was the primary cause of the insects' outbreak (Kenmore et al., 1984; Settle et al., 1996). FFSs were therefore organised to educate rice farmers on the ecological relationships underlying IPM, and thereby to help them reduce their reliance on chemical pest controls (Kenmore, 1996). Because agroecological relationships are inherently place-dependent and time-specific it is ineffective to base decision making on universal dissemination of standard technologies and simple messages. The focus of FFSs was, and still is, on learning through discovery, experimentation and group or community actions. FFSs thus have social goals beyond mere changes in pest management techniques, that seek to promote the empowerment of farmers by building human and social capital (Gallagher, 2000). Farmers are no longer positioned as receivers of already developed technological packages, but as field experts, who collaborate with the extension staff to find solutions relevant to the local realities. FFS programmes emphasize farmers' ownership, partnership and group collaboration. During the past two decades, FFSs have been held for a large number of crops including cotton, tea, coffee, cacao, pepper, vegetables, small grains and legumes (Pontius et al., 2002). The FFS model has been extended to several other topics such as livestock production, forestry, nutrition and health (HIV prevention) (Tripp et al., 2005). In total, thirty developing countries in the world are currently experimenting with and implementing the FFS approach (van den Berg, 2004). This sixteen-year history of successes and drawbacks is now looked upon as an invaluable ground for institutional learning, as the recent proliferation of published evaluation studies attests.

Evaluations of the accomplishments of various FFS programmes agree in their main conclusion that attending an FFS strengthens farmers' ecological knowledge on pests and predators (Thiele et al., 2001; Rola et al., 2002; Feder et al., 2004a; Reddy and Suryamani, 2005; Tripp et al., 2005). In some cases, the understanding of the crop ecosystems has induced a reduction in pesticide use, as well as higher yields and profits, for instance in sweet-potatoes, potatoes and cotton production systems (Braun et al., 1995; Godtland et al., 2004; Khan et al., 2005). So, far, the long-term sustainability of the changes in pesticide use has been questioned only by two studies on vegetables and rice, which have drawn opposite conclusions (Khalid, 2002; Feder et al., 2004a). Consequently, some controversy has arisen about the cost effectiveness of the FFS approach. FFS programmes usually reach only a limited number of farmers compared to the total farming population. For instance, it has been estimated that in Indonesia, the country with the longest experience in implementing IPM FFSs,

only 2 per cent of rice growers has been trained. Thus, some authors argue that the economic feasibility of FFS programmes depend on the diffusion rate of their outcomes, from the participants to neighbouring farmers. Studies conducted to investigate such a process have led to contradictory findings, perhaps because the diffusion process of knowledge is strictly context- and content-dependent (Fliert, 1993; Thiele et al., 2001; Rola et al., 2002; Feder et al., 2004b). FFS supporters shift the focus of the economic debate to the benefits of IPM FFSs, contesting that a reduction in pesticide use is likely to have beneficial effects on people's health, livestock production, water and air quality, biodiversity and wildlife welfare at a regional level. They argue that return to investments in IPM FFS cannot be appraised until the pesticide use externalities have been taken into account and properly quantified. Further, it is claimed that FFSs are associated with gains in social and human capitals that escape conventional evaluations, such as farmers' self-development, improved skills, strengthened social ties and connections with local institutions.

In general, it is recognized that mono-disciplinary studies with pre-determined objectives alone are no more sufficient to evaluate development interventions centred on people's empowerment. Participatory methodologies have come into practice to enhance the effectiveness of development and evaluation approaches by involving users in the planning and implementation of the same (Greene, 1994; Mohr, 1999; Johnson et al., 2003). Participatory evaluations also reinforce the importance of transferring power to the local people by increasing a programme's accountability to the beneficiaries.

Justification, aims, and main research questions

The developmental issue that inspired this study was thus the evidence of the catastrophic effects of the use of synthetic chemicals for pest control in the cotton farming sector of India. The scientific inspiration was the desire to find ways to capture data and information on the aspects of FFS impacts that were hardly demonstrated in the literature, although accepted as possibly important contributions of the FFS approach to ameliorating or avoiding the negative effects of synthetic pesticide use, as well as to strengthening farmers' capacity and competence to bring about self-directed development. The methodological starting point of my studies was the recognition that assessing FFS impacts requires a mixture of approaches and disciplines (Waibel et al., 1999). This thesis thus has brought together development and academic professionals with different fields of expertise, project officers, facilitators, farmers and outsider evaluators with the aims of filling some of the existing research gaps in FFSs evaluation and of helping to resolve the controversies.

The main research questions address selected topics in the domains of health, practices, labour use, livelihoods, the environment, and – as a generic question – the methods that might be used to carry out and analyse the results of such studies.

Specifically, the questions are:

- What is the incidence and impact of acute pesticide poisoning among men and women farm-

ers in cotton producing households?

- What changes in pest management practice and ecological knowledge have been brought about by participation in the cotton IPM FFSs?
- What are the entailments of these changes on labour use and labour allocation and which households are most likely to be able to sustain these labour demands?
- What are the environmental effects of IPM practices in cotton, in comparison with conventional and organic practices?
- What impacts on their livelihoods do FFS participants themselves perceive as a result of their participation?
- What methods can be used or adapted for data capture and analysis in order to provide rigorous but also nuanced understanding of the multi-faceted effects and impacts of the cotton IPM FFSs?

Overall objectives and approach

This thesis reports an household-level evaluation of the cotton IPM FFSs carried out in twenty villages from 2002 to 2004 with respect to their contribution to more sustainable farming practices.

The study aimed: (i) to estimate the health impacts of the use of insecticides on spray operators and farm workers, (ii) to evaluate the changes in agronomic practices in cotton-based farming systems before and after IPM FFS training in relation to changes in ecological knowledge of farmers, (iii) to evaluate the changes in labour allocation in cotton-based farming systems before and after IPM FFS training, (iv) to estimate the ecological footprint of conventional, organic and IPM FFS cotton, and (v) to assess the social impacts of IPM FFS in terms of livelihoods and empowerment. Conventional and participatory methods were applied, with some innovative modifications. The research had the sub-objective to develop the range of evaluation tools available and to assess their effectiveness in relation to the FFS experience. Data were collected by means of questionnaires, interviews, focus group discussions, drawing and visual forms.

Outline of the thesis

The core of this thesis is formed by five independent evaluation studies (chapter 2-6). A concluding chapter summarises the main findings, reviews the research tools and methodologies, reflects on the implications for policy and practice, and identifies a number of further research challenges (chapter 7).

Chapter 2 describes the impact of occupational exposure to pesticides on farmers' health to set the stage for the need of IPM in cotton production. A self-reporting tool (Murphy et al.,

2002) was used by women farmers to report the signs and symptoms of acute poisoning experienced after direct exposure to highly toxic pesticides. Chapter 3 presents the changes in pesticide use attained by farmers trained in cotton IPM FFSs. These changes are explained by gains in farmers' knowledge on insect ecology and decision-making skills. Chapter 4 deals with the gender and social implications of introducing a management approach, i.e. IPM, into cotton farming systems. It reports a study on the changes that occurred in labour allocation and labour intensity as farms previously using conventional chemical pest control measures switched to IPM. Chapter 5 reports on an ecological analysis of integrated (low-input), organic and conventional farming systems using Life Cycle Analysis (LCA) (Guinee, 2002). LCA evaluates the mass balance of in- and outputs of systems and converts these into environmental categories (indicators) that relate to environmental toxicity and ecological side-effects. The indicators of environmental impacts used in the LCA in this thesis are Environmental Index Quotient, global warming, acidification, eutrophication, and soil erosion. Chapter 6 presents a Sustainable Livelihood Analysis (Chambers and Conway, 1992); using the five capitals concept - the financial, human, social, natural and physical capitals comprising a livelihood. This application of the SLA provided farmers with a framework for addressing the impact of FFSs on their livelihood in a systematic way. Chapter 7 summarises the thesis's general findings and their implication for policy development. It also sets out a critical review of the methodologies used in the impact assessment studies presented in the previous chapter. The role of participatory research in impact assessment and its synergy with conventional research is discussed. Furthermore, the importance of a gender sensitive approach to ensure effective project implementation and evaluation is analysed on the basis of the experience gained in the impact evaluation of cotton IPM FFS.

References

- Braun, A., Fliert, E.v.-d., Wheatley, C., Prain, G., Widodo, Y., 1995. Improving profits from sweetpotato by linking IPM with diversification of markets. CIP Circular 21, 8-15.
- Brundtland, G.H., 1987. Our common future. World Commission on the Environment and Development. United Nations.
- Chambers, R., Conway, G., 1992. Sustainable Rural Livelihoods. Concepts for the 21st Century. IDS Discussion Paper 296. Brighton: The Institute of Development Studies, Sussex, UK.
- Choudhary, B., Laroia, G., 2001. Technological developments and cotton production in India and China. *Current Science* 80, 925-932.
- CSE, 2003. Pesticide residues in bottled water, CSE Report. Centre for Science and Environment, New Delhi, India.
- Division of Medical Toxicology and Risk Assessment, 2000. Harmonized Pesticide Poisoning in India Database, Report 1999-2000, India.
- Dinham, B., 1993. The Pesticide Hazard, A Global Health and Environmental Audit. Zed Books, London & New Jersey, pp. 228.
- Feder, G., Murgai, R., Quizon, J.B., 2004a. The acquisition and diffusion of knowledge: the case of pest management training in Farmer Field Schools, Indonesia. *Journal of Agricultural Economics* 55, 221-243.

- Feder, G., Murgai, R., Quizon, J.B., 2004b. Sending farmers back to school: the impact of farmer field schools in Indonesia. *Review of Agricultural Economics* 26, 45-62.
- Fliert, E.v.-d., 1993. Integrated pest management: farmer field schools generate sustainable practices. In: Wageningen Agricultural University Papers. 1993; (93 3): xv + 304. Wageningen Netherlands: Landbouwniversiteit Wageningen (Wageningen Agricultural University).
- Gallagher, K.D., 2000. Community study programmes for integrated production and pest management: farmer field schools. In: Human resources in agricultural and rural development. Food and Agriculture Organization (FAO). Rome, Italy, pp. 60-67.
- Godtland, E.M., Sadoulet, E., Janvry, A.d., Murgai, R., Ortiz, O., 2004. The impact of Farmer Field Schools on knowledge and productivity: a study of potato farmers in the Peruvian Andes. *Economic Development and Cultural Change* 53, 63-92.
- Greene, J.C., 1994. Qualitative Programme Evaluation: Practice and promise. In: Denzin, N.K., Lincoln, Y.S. (Eds.), *Handbook of Qualitative Research*. Thousand Oaks, CA: Sage, pp. 530-544.
- Guinee, J.B., 2002. Life Cycle Assessment: An operational guide to the ISO standards. Ministry of Housing, Spatial planning and Environment (VROM) and the Centre of environmental Science, Leiden University (CML), The Netherlands.
- Herring R, Grodzins Gold A, 2005. Is there a case for growing cotton in India?, Indian Cotton: Biology and Utility, Meanings and Histories Workshop, Cornell University, April 29-30, 2005. A joint venture of Development, Governance and Nature and the Title VI National Resource Center for South Asia, Syracuse and Cornell Universities.
- Johnson, N.L., Lilja, N., Ashby, J.A., 2003. Measuring the impact of user participation in agricultural and natural resource management research. *Agricultural Systems* 78, 287-306.
- Kenmore, P., 1996. Integrated Pest Management in Rice. In: Persley, G. (Ed.), *Biotechnology and Integrated Pest Management*. CAB International, Wallingford, pp. 76-97.
- Kenmore, P., Carino, F.O., Perez, C.A., Dyck, V.A., Gutierrez, A.P., 1984. Population Regulation of the Rice Brown Planthopper (*Nilaparvata lugens Stal*) Within Rice Fields in the Philippines. *Journal of Plant Protection in the Tropics* 1, 19-37.
- Kooistra, K. J., Pyburn R., Termorshuizen A. J., 2006. The sustainability of cotton. Rapport 223. Science Shop Wageningen UR, The Netherlands.
- Khalid, A., 2002. Assessing the long-term impact of IPM Farmer Field Schools on farmers' knowledge, attitudes and practices. A case study from Gezira Scheme, Sudan. In: International Learning Workshop on Farmer Filed Schools (FFS): Emerging Issues and Challanges. Yogyakarta, Indonesia.
- Khan, M.A., Ahmad, I., Walter-Echols, G., 2005. Impact of an FFS-based IPM Approach on Farmer Capacity, Production Practices and Income: Evidence from Pakistan. In: Ooi, P.A.C., Praneetvatakul, S., Waibel H., Walter-Echols G. (Eds.), *The impact of the FAO EU IPM Programme for cotton in Asia*. Pesticide Policy Project Publication Series n. 9, Hannover University, Germany
- Kishi, M., 2005. The health impacts of pesticides: What Do We Know, What Can Be Done? In: Pretty, J. (Ed.), *The Pesticide Detox*. Earthscan, London, Sterling, VA, pp. 23-38.
- Kranthi, K.R., Jadhav, D.R., Kranthi, S., Wanjari, R.R., Ali, S.S., Russell, D.A., 2002. Insecticide resistance in five major insect pests of cotton in India. *Crop Protection* 21, 449-460.
- Mohr, L.B., 1999. The qualitative method of impact analysis. *American Journal of Evaluation* 20, 69-84.
- Morse, S., Bennett, R.M., Ismael, Y., 2005. Genetically modified insect resistance in cotton: some farm level economic impacts in India. *Crop Protection* 24 (5): 433-440.
- Murphy, H.H., Hoan, N.P., Matteson, P., Abubakar, A., 2002. Farmers' self-surveillance of pesticide poisoning: A 12-month pilot in Northern Vietnam. *International Journal Of Occupational And Environmental Health* 8, 201-211.
- Pontius, J., Dilts, D., Bartlett, A., 2002. From farm field schools to community IPM. Ten years of IPM training in Asia. FAO, Regional Office for Asia and the Pacific, Bangkok.
- Ramamurthy, P., 2000. The cotton commodity chain, women, work and agency in India and Japan: The ease for feminist agro-food systems research. *World Development* 28, 551-578.

- Rasheed Sulaiman, V., 2003. Innovation in agricultural extension in India. Sustainable Development Department (SD), FAO, Rome.
- Reddy, S.V., Suryamani, M., 2005. Impact of Farmer Field School Approach on Acquisition of Knowledge and Skills by Farmers about Cotton Pests and Other Crop Management Practices - Evidence from India. In: Ooi, P.A.C., Praneetvatakul, S., Waibel H., Walter-Echols G. (Eds.), *The impact of the FAO EU IPM Programme for cotton in Asia*. Pesticide Policy Project Publication Series n. 9, Hannover University, Germany
- Rola, A., Jamias, S., Quizon, J., 2002. Do Farmer Field School Graduates Retain and Share what they Learn? An Investigation in Iloilo, Philippines. *Journal of International Agricultural and Extension Education* 9, 65-76.
- Röling, N., van de Fliert, E., 1994. Transforming Extension for Sustainable Agriculture: The Case of Integrated Pest Management in Rice in Indonesia. *Agriculture and Human Values* 11, 96-108.
- Settle, W.H., Ariawan, H., Astuti, E.T., Cahyana, W., Hakim, A.L., Hindayana, D., Lestari, A.S., Pajarningsih, Sartanto, 1996. Managing tropical rice pests through conservation of generalist natural enemies and alternative prey. *Ecology* 77, 1975-1988.
- Shetty, P.K., 2003. Ecological implications of pesticide use in agro-ecosystems in India. Environmental Studies Unit, National Institute of Advanced Studies Indian Institute of Science Campus, Bangalore, India.
- Singh, R.B., 2000. Environmental consequences of agricultural development: a case study from the Green Revolution state of Haryana, India. *Agriculture Ecosystems & Environment* 82, 97-103.
- Thiele, G., Nelson, R., Ortiz, O., Sherwood, S., 2001. Participatory research and training: ten lessons from the Farmer Field Schools (FFS) in the Andes. *Currents Uppsala* 27, 4-11.
- Tripp, R., Wijeratne, M., Piyadasa, V.H., 2005. What should we expect from farmer field schools? A Sri Lanka case study. *World Development* 33, 1705-1720.
- UNEP, 2004. Childhood Pesticide Poisoning. Information for Advocacy and Action. Chemicals Programme of the United Nations Environment Programme, U.C. (Ed.).
- UNICEF, 2004. Statistics by Country. India. www.unicef.org/infobycountry/india_india_statistics.html.
- van den Berg, H., 2004. IPM Farmer Field Schools: A synthesis of 25 impact evaluations. Wageningen University, The Netherlands.
- Waibel, H., Fleischer, G., Kenmore, P.E., 1999. Evaluation of IPM programs: concepts and methodologies: papers presented at the first workshop on evaluation of IPM programs, Hannover, March 16-18, 1998. A Publication of the Pesticide Policy Project. Publication Series No. 8, Hannover University, Germany.
- WHO, 1999. Public Health Impact of Pesticides Used in Agriculture. World Health Organization, Geneva, Switzerland.

CHAPTER 2

Incidence of Acute Pesticide Poisoning Among Female and Male Cotton Growers In India

*Francesca Mancini, Ariena H. C. van Bruggen, Janice L. S. Jiggins,
Arun C. Ambatipud and Helen Murphy*

International Journal of Occupational and Environmental Health 11, 3: 221-232

Abstract

An average of 20 pesticide applications per season is a common practice among cotton growers in India. A season-long assessment of the acute pesticide poisoning among farmers was conducted in 3 villages in Andhra Pradesh, India. Fifty female cotton growers reported the adverse effects experienced after exposures to pesticide by themselves and by their male relatives (n=47). The study documented the serious consequences of pesticides use for the health of farmers, particularly for women field helpers. Typically female tasks, such as mixing concentrated chemical products and refilling spraying tanks were as hazardous as direct pesticide application.

Of 323 reported events, 83.6% were associated with signs and symptoms of mild to severe poisoning and only 16.4% were asymptomatic. 10% of the pesticide application sessions were associated with three or more neurotoxic/systemic signs and symptoms typical of poisoning by organophosphates, which were used in 47% of the applications. Although in 6% of the spray sessions the workers' neurotoxic effects were extremely serious, none sought medical care. Low-income marginal farmers more often subjected to severe poisoning than landlords.

Keywords: Pesticide acute poisoning; Cotton; India; Integrated pest management; Gender.

Introduction

Agriculture in South India is primarily a subsistence production system that involves 127 million cultivators and 107 million agricultural labours. Crop productivity in the rainfed area, which includes more than 70% of the cultivated land, is low and unpredictable (Department of Agriculture, India, 2002). The majority of the population is rural (74.3%, Census 2001) and 34.7%

live below the international poverty level (World Bank, 2003).

During the Green Revolution, high yielding varieties of various crops were introduced into the farming systems to increase productivity. These varieties were significantly more susceptible to plant pests and diseases and, subsequently, the use of pesticides became more intense, increasing from 2,330 kton during 1950-51 to 54,773 kton in 1990-91 (Directorate of Plant Protection, 2002, personal communication). Pesticides are largely applied to protect commercial crops. Cotton cultivation alone uses more than 60% of the national consumption. The consequences of such indiscriminate use of pesticides have recently become a matter of public concern in India. Following the publication of alarming information about the levels of pesticide residues in drinking water and soft drinks (CSE, 2003). Beside the consumers' risks stands the documented hazard to producers, who are directly exposed to chemical substances (Kishi, et. al, 1995; Murphy, et. al, 1999; Wesseling, et. al, 2001; Kunstadter, et. al, 2001). Agricultural labourers and farmers work in a highly unsafe occupational environment. The pesticides used largely belong to WHO category I and II (Highly Hazardous and Moderate Hazardous). Chemical products such as Aldicarb, Dieldrin and Paraquat that are banned in developed countries are still registered in India. Protective measures and equipment for safe handling and spraying of the pesticides are far from being adopted. Instead, people work bare-foot, barehanded, wearing only short-sleeved cotton tee shirts and traditional sarongs (lungi). During an average spraying session, a farmer is directly exposed to pesticides for three to four hours at a time through leaking spray equipment, dripping plants and wind drift. Concentrated chemical products are mixed with water with bare hands. Farmer risky behavior is not necessarily explained by a lack of awareness. On the contrary, farmers' level of knowledge on the health hazards of pesticides -even though partial and inexact - is in many cases higher than expected (Aragon, et. al, 2001; Clarke, et. al, 1997; Eisemon and Nyamete, 1990; Kishi, 2002). Training does little to change hazardous use of pesticides. For example, a programme conducted by Novartis to train farmers in the safe handling and use of pesticides in the Coimbatore District of Tamil Nadu, India, in 1992 failed to achieve substantial and sustainable changes in farmers' practices (Atkin, 2002). Not only is protective equipment expensive, unavailable and cumbersome to use, but in extreme hot weather conditions of the tropics protective gear is rarely used (Kishi, et al., 1995). Therefore, educating farmers about the safe use of pesticides alone does not seem to be a viable solution to eliminate occupational risks.

To date, studies have focused on the adverse health effects occurring among people applying chemical products. However the focus should also extend to those who play supportive roles in the pesticide applications: women and children. In India, the production of cotton is female-labour-intensive. Extremely time-consuming operations such as weeding are often performed by women and children during the peak of the spraying season when there are high residue levels in the fields. Other key female tasks are pesticide mixing with water and refilling the sprayers' tanks (Mancini, unpublished).

Pesticides are largely applied by low-income groups of people, marginal farmers and landless workers. Associated malnutrition and infectious diseases in these populations makes them more vulnerable to poisoning (London and Rother, 2000; WHO, 1990). The need to gen-

erate information about the social and gender implications of pesticide application has been well documented and recommended in a review of the health impacts of pesticides compiled by Kishi (2005).

This study was engendered by the need to document the serious human health consequences of the indiscriminate use of pesticides on cotton in India. The intent was to focus on less-visible, but much exposed subjects: women and marginal farmers. Women perform secondary activities that have often been neglected in studies dealing with direct exposure. Marginal farmers are often engaged in professional spraying and therefore prone to continuous exposure.

Materials and Methods

Study objectives

In 2003, the European Union-Food and Agriculture Organization, Integrated Pest Management (EU-FAO IPM) Programme for Cotton in Asia designed a participatory project that aimed to assess the frequency and severity of acute pesticide poisoning among cotton growers in Andhra Pradesh. For the last three years the programme has been operative in the state educating farmers in sustainable alternatives to pesticide use in Farmer Field Schools (FFSs). As part of the regular FFS curriculum, farmers were taught in the adverse effects of pesticides on human health and the environment. The assessment was conceived as a season-long special activity to be undertaken in three villages that had IPM¹ Farmer Field Schools². The initiative aimed to measure the health effects of pesticide exposure in real time through direct farmers' documentation. Because previous studies focused on male farmers who apply chemical products, this study concentrated on women as respondents (for themselves and for their male relatives). This surveillance activity assisted farmers in generating information on:

- The frequencies and severities of acute pesticide poisoning occurring among male and female cotton farmers
- The exposure of women performing supportive roles during spray operations
- The vulnerability of low-income groups involved in pesticide application

A second part of the assessment undertaken 2004 in the same villages measured actual changes occurring in the health of the respondents, as a result of the participation in the cotton IPM FFS. Monitoring continued for several months, using the same reporting method as the study reported here. The data will be analysed against the baseline survey collected in 2003.

This paper represents the first part of the assessment conducted to estimate the effects on cotton growers' health of a chemical-based plant protection system.

¹*Integrated Pest Management (IPM) is based on preserving natural enemies and growing healthy crops to control pests.*

²*Farmer Field School (FFS) is an adult educational approach to empower farmers developed in Indonesia in the early Nineties.*

Study Area

The study was conducted in three cotton-growing villages. They were purposely selected immediately after the commence of the FFS - on the basis of a high female (over 50%) and marginal (< 1ha) farmer (55%) participation predetermined by the FFS farmer selection process and the community' interest in the monitoring activity. The EU-FAO IPM Programme adopted the strategy of conducting one FFS each village, regardless of the village' size. Therefore, there were 25 trained farmers for village, out of which some were women. All the women who had participated in the FFS in the three villages joined the self-monitoring. Two of the villages (Sairedapalli and Srinagar) were located in Warangal District and one (Darpalli) in Mahaboobnagar District, Andhra Pradesh.

Andhra Pradesh is one of the 9 major cotton-producing states of India. The rural population is 73% of the total. Cotton is grown on 1.02 million hectares. The industrial production of cottonseed is also concentrated in the state. According to the 2001 census, Mahaboobnagar and Warangal districts have a total population of 3,077,050 and 2,818,832, respectively. Cotton is grown as the main crop during the raining season (Karif) on 121,260 ha in Warangal and 22,697 ha in Mahbubnagar.

Darpalli is a small village populated by marginal native farmers (721 inhabitants). The area under cotton was 45 hectares. The level of education among the people was found to be very low (in 1997, 70% of the rural people in the state were not literate). In contrast, migrant communities, who moved from the state coastal area in search of fertile lands to cultivate, mainly inhabited Srinigar and Sairedapalli villages. The villages had respectively 3108 and 1038 inhabitants; the area under cotton was 500 and 122 ha. Those villages could be considered better off in that they had more education and wealth

Training of enumerators and farmers

The study involved three FFS facilitators trained by the EU-FAO IPM Programme for Cotton in Asia in season-long (6 months) residential Training of Facilitators (ToF) on IPM. In addition to the technical knowledge, the ToF provides a solid background about adult non-formal education and enable facilitators to conduct Participatory Action Research with farmers. In order to coach the self-health monitoring, three FFS facilitators were also taught how to identify the signs and symptoms of acute pesticides poisoning. Emphasis was given to the need for establishing clear correlations between illness and exposure to pesticides. Minor adaptations to the specific study' requirements were made to the reporting format and method developed by Murphy et al. (1999, 2002).

During the initial FFS sessions, three facilitators trained the farmers who had volunteered to participate in the monitoring. The forms to be used were field tested with 20 respondents to correct for any potential misunderstandings of the reporting procedures as well as misconceptions about the signs and symptoms. During the four months of the assessment, the project staff provided constant coaching to the farmers and the facilitators. A mid-season review meeting was also organised two months from the start. A simple analysis of the forms was done together with the farmers at the end of the season in a final workshop.

Period and procedure

The actual reporting started at the second month of the cotton growing season when pesticides are first applied to the young plants, in August 2003, and lasted until December 2003. Women farmers (n=50) attending the FFSs organised in their respective villages filled in health-monitoring forms after potential exposure to a variety of pesticides. In addition to self-reporting their own signs and symptoms of acute poisoning, the women each interviewed one male family member (n= 47) who had applied pesticides. Respondents were asked to fill in a form after every potential pesticide exposure regardless of whether or not they had experienced an adverse effect. Forms were filled in as a result of any of the following circumstances:

- Spraying pesticides in the field
- Mixing chemical solution and re-filling spray tanks
- Working in field sprayed within the same day

Only the signs and symptoms that occurred during the working session or within 24 hours after exposure were recorded. At each FFS meeting the forms were reviewed.

Format

The reporting format was pictorial to facilitate participation among those that were not literate (Figure 1). Facilitators provided the necessary assistance to review the forms throughout the monitoring.

The form allows for the reporting of the following:

- A list of 18 signs and symptoms of acute pesticide poisoning³
- Type of chemical products used
- Quantity of chemical products used (ml formulated product/ Lt water)
- Hours spent in performing the operation
- Hours extra-respite taken due to illness
- Number of sick days not worked as a consequence of the illness
- Use of medical treatments and home-made remedies
- Operation performed.

The following socio-economic parameters were collected in separate interviews from each respondent: Age, Gender, Formal education, Landholding, Profession and Income level. A total of 97 farmers, 50 women and 47 men participated in the self-health monitoring (Table 1). All women participating in the FFSs in the 3 villages were involved in the self-monitoring. As a result of the purposive selection of the villages, the sample included 70% of small farmers (<2 ha).

Table 1. Distribution of respondents among the villages

	Women (respondents)	Men (indirect reporting)	Total
Darpalli	25	23	48
Sairedapalli	14	14	28
Srinagar	11	10	21
Total	50	47	97

³ Developed by Keifer (1996) and adopted by Murphy et al. (2002). The list is given in Table 2.

REPORTING FORMAT FOR SELF MONITORING OF ACUTE EFFECTS (SIGNS & SYMPTOMS) AS A RESULT OF EXPOSURE TO PESTICIDE SPRAYS

క్షేత్ర పాఠశాల నైపుణ్యం

పేరు _____

చిరునామా _____

తేదీ/ మాసము _____

జాతర నైపుణ్యం

క్షేత్ర గుర్తింపు ?

అంకం - సంఖ్య _____

పిచ్చికార చేసిన పంట రకము _____

పనిచేసిన సమయము _____

పని వివరణ _____

ప్రతి పిచ్చికారి అనంతరము ఈ పత్రము పూరించుము. 24 గంటలలో ఏమైనా లక్షణములు కనిపించినచో గుర్తించుము

రసాయనాలు కలుపుకు మరీయు పంట పనులు వివరణ		
కలుపుకు వెచ్చించిన సమయము		
రసాయన పేరు _____	రసాయన నిష్పత్తి _____	నిధి నిష్పత్తి _____
<input type="checkbox"/> మిశ్రమము		ఏక రసాయనం
చేప పై పిచ్చికారి _____	<input type="checkbox"/> అదే రోజు	<input type="checkbox"/> ముందు రోజు
నాణ్యత లక్షణాలు		
అదే పిచ్చికారి- పిచ్చి గంటలు _____		
జనాభాగ్రహణం ఉన్న రోజులు _____		
<input type="checkbox"/> పిచ్చికారి కార్మిక రోజు	<input type="checkbox"/> ముందు రోజు	<input type="checkbox"/> రెండవ రోజు
చికిత్స పరిచయ సైన్యము యొక్క వివరణ _____		
<input type="checkbox"/> సాంక		<input type="checkbox"/> సైన్యము

Figure 1. Reporting format in the local language, Telegu

Scoring system

The forms were assigned to 4 categories according to the signs and symptoms reported following Murphy’s method (Murphy et al., 2002). Local effects were considered consequences of mild poisoning and rated in category 1. In the same category were some systemic or neurotoxic effects that are ill-defined (headache, dizziness, difficulty breathing) and effects that could be related to confused with environmental factors such as heat exposure (excessive sweating, excessive salivation). The other neurotoxic effects such as nausea and vomiting, which might reflect cholinesterase depression, were classified in category 2 or moderate poisoning. Category 3 included loss of consciousness and seizure as effects of severe poisoning. Each form was assigned with a final value (severity class) equivalent to the highest category marked. Forms with no signs and symptoms marked were assigned with the severity class 0 and classified as an asymptomatic event. Forms containing only category 1 effects were

classified as mild acute poisoning events (Class 1). If at least one effect belonging to category 2 was included, the forms were classified as moderate poisoning events (Class 2). Finally, if one of the effects of category 3 was marked, the forms were considered an example of severe acute poisoning (Class 3). In addition to the severity class, the total sum of signs and symptoms reported in each form was also considered as an indicator of poisoning.

For each form two values were therefore entered in the database as severity indicators.

- Severity Class

- Total number of S&S reported (#S&S)

Data analysis

Linear trend analysis (frequencies analysis and chi-square test) was performed to describe pairs of variables [men versus women and small versus large]. The severity class and the #S&S were analysed in relation to the exposure variables. Multivariate analysis (multiple linear regression) was used to assess the contribution of each independent variable [Age, Gender, Formal education, Exposure Time, Pesticide Toxicity, Volume, Operation, Land Holding, Income, Profession] to the Severity values. Further analysis on the combination of signs and symptoms per spraying event will be performed on the complete data set at the end of the second season collection.

Table 2. List of signs and symptoms of acute pesticide poisoning

Signs and symptoms	Type	Category
Burning eyes	Localized	1
Burning nose/tearing	Localized	1
Difficulty breathing	Systemic/neurotoxic	1
Dizziness	Systemic/neurotoxic	1
Excess sweating	Systemic/neurotoxic	1
Excessive salivation	Systemic/neurotoxic	1
Headache	Systemic/neurotoxic	1
Runny nose	Localized	1
Skin rashes	Localized	1
Blurred vision	Systemic/neurotoxic	2
Muscle cramps	Systemic/neurotoxic	2
Nausea	Systemic/neurotoxic	2
Staggering	Systemic/neurotoxic	2
Tremors	Systemic/neurotoxic	2
Twitching of eyelids	Systemic/neurotoxic	2
Vomiting	Systemic/neurotoxic	2
Loss of consciousness	Systemic/neurotoxic	3
Seizure	Systemic/neurotoxic	3

Results

Characteristics of the Respondents

The average ages of the reporting women and interviewed men was respectively 36.5 and 37 years. The distribution by age categories is given in Table 3. Almost half of the respondents fell into the class “marginal” (< 1ha) (Table 3). Forty-one percent of the farmers lived below the national poverty level (10 rupees a day or 1\$ per 4-5 days).

Table 3. Distribution of respondents by ages and by land-holding classes

Age	<30	30-39	40-50	>50
Women (n=50)	18	15	17	0
Men (n=47)	10	15	13	9
Land (ha)	Marginal(<1)	Small (1-2)	Semimedium (2-4)	Medium/Large(>4)
Women	22	11	12	5
Men	19	13	7	8

Spraying operations

Individual spraying sessions recorded in 4 months of monitoring totaled 392. On average, farmers filled out one form per month. However, 69 forms have been discarded due to incomplete information on the pesticides used. The distribution of the discarded forms could not be analysed and therefore biases introduced by the selection cannot be excluded. The women self-reported on 165 events and reported on 158 spraying sessions that were performed by their male relatives. The total number of forms per farmer did not reflect the individual field spraying frequency, which was separately recorded. In Darpalli village the average number of sprays for the cotton season was 5.9 (range 2-15), in Sairedapalli it was 6.4 (range 1-11) and in Srinagar 11 (range 5-14).

In the case of the women, the health forms were filled in after mixing concentrated chemicals with water and filling spray tanks (47%), mixing and subsequently working in the field (24%), working in a recently sprayed field (17%), applying pesticides (9%) and others (3%). The application of pesticides referred to the spreading of phorate granules (organophosphate, WHO 1A hazard class) on maize and chilli plants.

Men's forms were filled after spraying pesticides (75%), spraying and subsequently working in the field (22 %) as well as mixing concentrated chemicals with water and filling spray tanks (4%). The average working session lasted 4 h 36 m for men and 4h 24 min for women, an average volume of respectively 238 and 242 liters, containing 212 and 190 mg of active ingredient was applied. During the study, participatory observations were conducted to better describe the gender roles of the pesticide-application task. An example is given in the specific session at the end of the article.

Twenty-six types of chemicals (Table 4) were used. Products belonging to the organophosphate family were used in 47% of the spraying events. Endosulfan (organochlorine)

alone was used in 135 of the sprays.

Table 4. List of pesticides used by the reporting farmers in cotton cultivation in India *

Pesticide	WHO hazard class	Chemical Family	Cholinesterase Inhibitor	%of all pesticides
Parathion	1A	Organophosphate	+	0.3
Monocrotophos 36% SL	1B	Organophosphate	+	12
Phorate 10% G	1B	Organophosphate	+	3.7
Triazophos 40% EC	1B	Organophosphate	+	0.6
Chlorpyriphos 20% EC	2	Organophosphate	+	10
Cypermethrin 25% EC	2	Pyrethroid		8
Dimethoate 30% EC	2	Organophosphate	+	0.6
Endosulfan 35 EC	2	Organochlorine		13
Fipronil	2			0.6
Lambda cyhalothrin 5% EC	2	Pyrethroid		0.6
Phosalone 35 EC	2	Organophosphate	+	1.3
Profenophos 50% EC	2	Organophosphate	+	4
Quinalphos 25% EC	2	Organophosphate	+	13.7
Acephate 75% SP	3	Organophosphate	+	4.3
Acetamidiprid 70% WP	3	Chloro-nycotil		4.6
Copper oxychloride 50% WP	3	Inorganic		1.3
Dicofol 18.5%	3	Organochlorine		0.6
Fenvalerate 20% EC	3	Pyrethroid		0.3
Imidachloprid 17.8% SL	3			4.7
Malathion 50% EC	3	Organophosphate	+	0.3
Carbendazin	U	Azole		0.6
Indoxacarb 14.5% SC	U	Chloro-nycotil		4.7
Mancozeb 75% WP	U	Carbamate	+	0.3
Spinosad 45% SC	U	Macrobia		2
Sulfur 80% WP	U	Inorganic		0.6
Wafarin 0.025%	U	Coumarin		0.6
Others (botanical, inorganic, unidentified ingredient)				7.0

*The WHO hazard classification refers to the formulated chemical products. The classification of the formulations was based on toxicity data obtained on that formulation by the manufacturer: In the cases in which this was not available, the values were calculated on the basis of the LD50 oral or dermal toxicity using WHO conversion tables (IPCS, 2002). 1A = extremely hazardous, 1B = highly hazardous, 2 = moderately hazardous, 3 = slightly hazardous, u = unlikely to present acute serious hazard in normal use.

Health Effects

Reported Signs and Symptoms

Out of the 323 reported events 16.4% were asymptomatic, 39% led to mild poisoning, 38 % to moderate and 6% to severe. Participatory evaluation is sometime subjected to strategic bias introduced by the respondents themselves, who are centrally involved in the risk behaviors. In the case of this study, such bias would have led to an over-reporting of the health effects. In order to assess the validity of the respondents' reporting, 3 symptoms (excessive tearing, excessive salivation and tremor) specific to organophosphate exposure were used as dummy symptoms. Tremor was associated with OP exposure in 83% of the cases, excessive tearing in 62% and excessive salivation in 60%. According to the respondents, endosulfan (organochlorine) was responsible for 28% of the excessive tearing, 12% of excessive salivation and 8% tremor (1 case). The remaining cases were explained by exposure to chloro-nicotinyl, a relatively new chemical class of systemic insecticides that act on the central nervous system. Organochlorines do not stimulate glands and therefore are not expected to cause the above mentioned symptoms. However, the relatively high association of the symptoms with the use of endosulfan, imidachloprid and acetamiprid but not with the use of any other pesticide is striking. No association between the 3 symptoms and the use of pyrethroids, botanical and inorganic components was reported.

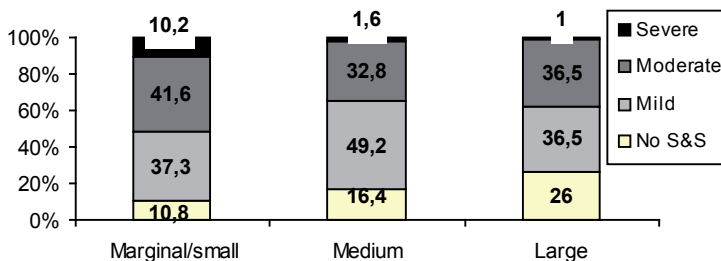


Figure 2. Distribution of acute pesticide poisoning severity classes by land-holding classes

The frequency of spray-session illness events are significantly different depending on landholding status (chi square significant at $P < 0.0001$). The incidence of severe poisoning was 10 times higher among marginal farmers than larger landholding farmers (Figure 2). Of the marginal and small landholding farmers, 10.2 % suffered major effects. The distribution in Figure 3 shows that marginal and small farmers experienced more signs and symptoms than did those who owned medium-sized and large farm. Average exposure time and pesticide toxicity were calculated for the sub-samples marginal, medium and large farmers, but the values did not explain this result. The level of formal education can partially explain the finding. Not literate farmers experienced on an average 4,8 #S&S and a severity class of 2,9 against respectively 2,4 and 2,2 of farmers educated up to the secondary school. The values for farmers educated above the secondary school were remarkably lower (0,6 #S&S and 1,3 severity class), however the sample was too small (4) farmers to be considered representative.

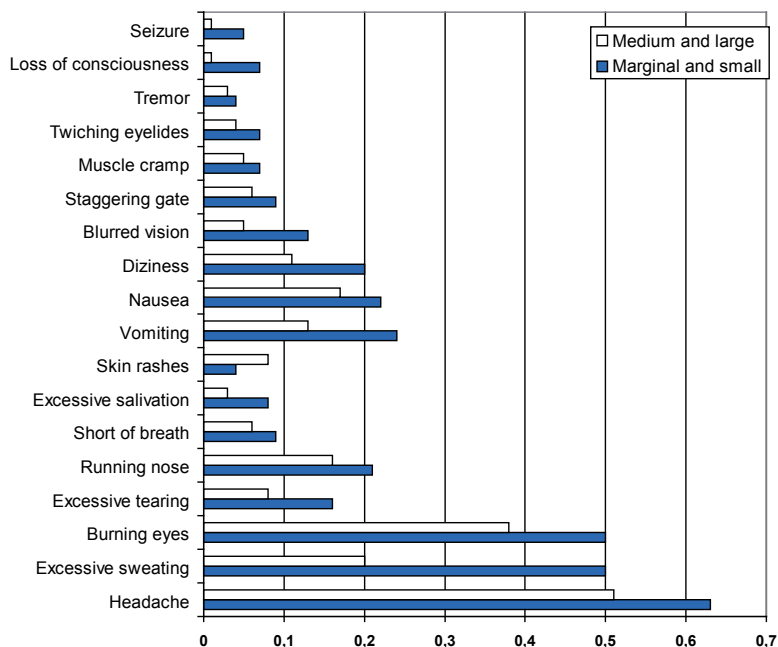


Figure 3. Distribution of acute poisoning signs and symptoms by landholding class

The higher vulnerability of small and poor farmers could also be related to their general health conditions and to a cumulative effect of prolonged occupational exposure over the years. An important factor that could have played a role in diversifying exposure among groups is the application methods, not considered in this study. Wealthier are often in the position to afford safer equipment to apply pesticides. It is worth noticing that 70% of the asymptomatic events occurred indeed among large and medium farmers. The higher incidence clearly reported calls for confirmation through an appropriate research design.

The village-wise analysis also showed a higher illness incidence among farmers in Darpalli than in the other two villages. Loss of consciousness and seizure had been recorded only among the poor community of this village. In the case of the two villages in Mahaboobnagar, the effects on the health of the reporting farmers were mild. The results of a separate on-going analysis of the labour organization within the same households might provide additional information to cross check individual exposure time to pesticides and explain some of the difference. A village effect might have been introduced in the reporting by the fact that each facilitator was operative only in one village.

The gender segregated analysis showed no significant differences in the distribution of signs and symptoms between men and women. Also, the severity class was not significantly correlated with the gender of the respondents. The health effects experienced by the women were comparable to the ones experienced by men. No significant correlation was found between severity class and age. However, the reader is reminded that children were not included

in the surveillance. These results confirm the hypothesis that women are seriously exposed to pesticide contamination.

Severity class and Total number of S&S (#S&S) versus exposure variables

Each exposure was described by four variables:

Pesticide toxicity: toxicity of the formulated chemical product classified according to the WHO Hazard classes. Pesticides belonging to the WHO class 1a (“extremely hazardous”) scored 1 point, class 1b (“highly hazardous”) points 2, class II (“moderately hazardous”) points 3 and class III (“slightly hazardous”) points 4. Pesticides unlikely to present acute hazard in normal use (class U) were assigned with a score of 5 points.

Exposure time: the duration in hours of the working session

Volume: the final volume of the spraying solution expressed in liters

Operation: the activity performed during the working session

Profession: The variable referred to whether the respondents were hired to apply pesticides in others’ fields, in addition to their own.

The mean/median of the #S&S associated with the different categories of pesticide toxicity, the severity class and the exposure time is given Table 5. The distribution of the severity class by gender across operation performed (Table 6) showed that spraying and mixing were key-exposure activities with a very similar incidence of severe poisoning. During mixing operation, the respondents prepared chemical solutions in rapid succession at close time intervals. Between mixing sessions, the respondents were present in the field. The same activities (mixing), when associated with fieldwork afterwards, led to a slight shift of the distribution towards higher degree of severity. “Mixing” and “spraying” tasks had an average duration of 3.5 and 3.8 hours respectively. The same operations combined with fieldwork lasted 6.7 hours (mixing and field work) and 7 hours (spraying and field work). Prolonged exposure led eventually to the development of more severe illness. The “field work” alone did not cause any severe or moderate poisoning. This may be explained by the absence of direct contact with the concentrated chemical. To determine the contributions of individual factors, severity class and #S&S, were regressed (Table 7) on the five exposure variables, the three social variables (Gender, Age, Formal education) and three economic variables (Land-holding, Income, Profession). The highest R^2 was found for the model that incorporated Education, Landholding, Profession, Exposure Time and Toxicity.

Table 5. Association between #S&S* and severity classes, pesticide toxicity and exposure time

Severity class	#S&S	P. Toxicity	#S&S	Exposure Time	#S&S
	Mean/Median	(WHO class)	Mean/Median	(hours)	Mean/Median
No S&S	0/0	u	0,6/0	1-2	1,8/2
Mild	1,9/2	3	1,4/1	3-4	2,0/2
Moderate	4,0/4	2	2,7/2	5-6	2,4/2
Severe	8,4/8	lb	3,0/2	7-8	4,8/5
		la	2,9/3	9 or 12	8,4/9

*Number of signs and symptoms of acute pesticide poisoning

Participant observation of a pesticide spraying session

In order to corroborate the finding on women's exposure to pesticide, the first author observed some spray sessions in Darpalli village. Table 8 refers to a typical hour of work during which wife and husband were continuously present in the field. The pesticide mixture was prepared by the woman, without any sort of protective equipment. The concentrated product was mixed bare-handed and every 7-9 minutes the tank was refilled, for a total of 6 refillings an hour. The session lasted three hours. Throughout the session the woman followed the man who was spraying the mixture. Repeated exposure of the two operators were evident. The average reporting session of the female respondents for "mixing of pesticides" was likely to include 26-28 brief exposure to the concentrated products and a prolonged air exposure to the freshly applied mixture.

Table 6. Distribution of the severity classes among operations by gender expressed in percentages and total number of events in brackets

% (No.)		Mixing	Mixing +Field work	Field work	Spraying	Spraying + field work	Total
No S&S*	Men	2(2)	0(0)	0(0)	1(1)	3(1)	1(4)
	Women	8(7)	0(0)	57(16)	19(26)	0(0)	15(49)
Mild	Men	4(3)	0(0)	0(0)	41 (55)	0(0)	18 (58)
	Women	49(42)	10 (4)	43 (12)	3(4)	19 (7)	21(69)
Moderate	Men	1(1)	0(0)	0 (0)	24 (32)	60 (21)	17(54)
	Women	31(27)	80 (31)	0(0)	8(10)	5(2)	22(70)
Severe	Men	0(0)	0(0)	0(0)	4(6)	11(4)	3(10)
	Women	5 (4)	10 (4)	0(0)	0	3(1)	3(9)
Total		100 (86)	100 (39)	100 (28)	100 (134)	100(36)	(323)

*Number of signs and symptoms of acute pesticide poisoning

Medical assistance

Regardless of the seriousness of the illness, farmers sought medical advice only in 8% of cases. Homemade treatments were taken in 70% of the cases; no action was taken in the remaining cases. In rare cases, a few hours of extra rest (1.41 for women and 1.38 for men) were necessary before resuming the work. In 7% of the cases, a full day rest was recorded - a total of 23 sick days for the all participants during the 4-months reporting period. This percentage is similar to the total number of severe cases reported (5.9%).

This suggests that the use of the sick days as an indicator might lead to an underestimation of the extent of pesticide poisoning.

Table 7. Multiple regression of the severity class on socio-economic and exposure variables

Variable	B Coefficient	Std. Error	Beta	t	Sig.
Severity Index					
Pesticide Toxicity	.295	.035	.439	8.495	.000
Exposure Time	.104	.021	.262	4.897	.000
Formal education	-.129	.063	-.128	-2.051	.041
Land holding	-1.11	.007	-.091	-1.499	.135
Profession	-.162	.120	-.076	-1.356	.176
<i>Adjusted R square = 0.292, F-value (df5, 275) = 24.1, P=0.0001</i>					
#S&S*					
Pesticide Toxicity	.654	.106	.318	6.152	.000
Exposure Time	.447	.065	.367	6.884	.000
Profession	-1.12	.367	-.171	-3.079	.002
Formal education	-.549	.193	-.177	-2.850	.005
Land holding	-3.87	.023	-.104	-1.705	.089
<i>Adjusted R square = 0.294, F-value (df5, 275) = 24.3, P=0.0001</i>					

*Number of signs and symptoms of acute pesticide poisoning

Table 8. Time schedule of one hour spraying session (participant observation)

Time	Operator*	Operation	Comments
8.00 – 8.10	W	Preparation of spray solution	Bare hand
8.10 – 8.20	M	Spraying	Bare hand and foot,
	W	Preparation of refilling	Legs and back wet
8.20 – 8.21	W	Refilling	Mixing with bare hand
8.22 – 8.29	M	Spraying	Strong smell of chemical spreads in the air
	W	Preparation of refilling	
8.30	W	Refilling	
8.30 – 8.40	M	Spraying	Both have to walk across the sprayed area to
	W	Preparation of refilling	reach unsprayed areas. Contact with solution
8.41	W	Refilling	dripping from the plants
	W	Refilling	Rinsing of the chemical measuring container with
8.41 – 8.50	W	Refilling	bare hand
	M	Spraying	Woman works in the field
8.51	W	Preparation of refilling	
	W	Refilling and moving to another field	
8.55 – 9.00	M	Spraying	
	W	Preparation of refilling	

*W= woman, M= man

Farmers' workshop

Farmers consolidated and discussed the results in a final workshop. A color-based code, suitable for a non literate population was used to score the forms following the same scoring procedure as described in this article. Participants attributed a final severity class to each form and analysed its frequency. The findings led to the farmers' realization of the serious health consequences associated with the irrational use of pesticides. The monitoring was conducted as part of the FAO Cotton IPM Programme to support the adoption of viable and socially acceptable alternatives to the pesticides.

Discussion

The study documented the serious consequences of the indiscriminate use of pesticides on farmers' health in India and specifically on women field helpers. The health surveys reviewed by Kishi in 2005 pointed out that the existing world data on poisoning refer mainly to young male subjects applying pesticides. There are also some examples that investigated the exposure of women who performed the same operations (Murphy, et al,1999; Kimani and Mwanthi, 1995; Trivelato and Wesseling,1992). However, women in developing countries are prone to other ways of exposure because through their supportive roles, they are often involved in the chemical application process (London et al, 2002). Few studies have mentioned this aspect and none have ever estimated the ill effects (Rother, 2000; London and Rother 2002; Atkin, 2002). The current survey addressed this information gap by focusing on the adverse effects developed by two target groups, women and marginal farmers, after they performed operations at risk of contamination.

The current self-monitoring has shown no differences between the degree of illness experienced by women and men. Whether this is related to the fact that women were reporting both on themselves and their husbands is not entirely clear. Nevertheless, women were reporting significant health effects. Typically female tasks, such as mixing concentrated chemical products and refilling spraying tanks, are key-exposure activities, which have been proved to be as hazardous as the direct pesticide application itself.

Ten percent of the spray sessions were associated to three or more neurotoxic/systemic signs and symptoms, which is the functional definition of acute poisoning used in Indonesia by Kishi et al. The adverse effects on the central and the peripheral nervous systems were typical of poisoning caused by organophosphates (Keifer, 1997), these products were used in 47% of the applications. Damage caused by cholinesterase-inhibitors with organophosphates can become permanent (McConnell and Magnotti, 1994 and 1999; Miranda et al, 2002; Rosenstock et al, 1991; Wesseling et al, 2002). Although 6% of the spray sessions were associated to serious neurotoxic effects none sought medical care or were hospitalized. On the contrary, farmers rarely stop working for more than a day. This finding confirms the serious underestimation of statistics based on official medical records (Keifer, 1996; Murray,1994).

Low-income marginal farmers more often subjected to severe poisoning than landlords. Small-holders and landless people often apply pesticides throughout the season as waged. Repeated exposure, in addition to malnutrition and other diseases, might explain the higher vulnerability of these groups (WHO, 1990; Repetto and Baliga, 1997). Indeed, pesticide toxicity and exposure time were positively correlated to the extent to which symptoms were experienced in this survey, while formal education and land holding were negatively correlated to this measure of ill-health. Yet, only 29% of the variation in symptom severity could be explained by these factors.

However, more research is needed on factors contributing to the health of people exposed to pesticides, in particular high-risk groups that are rarely included in health surveillance on pesticides' effects (Moses, 1993; Zham and Blair, 1993).

The survey aimed primarily to raise farmers' awareness on the seriousness of the poisoning occurring in the villages. It also aimed to quantify the problem by direct farmers' reporting. The method has some limitations. Murphy's article (Murphy et al., 2002) includes a detailed strength and weakness analysis of the method. We have reported here only those aspects which are relevant to this survey. Since signs and symptoms of acute poisoning are non-specific, the health data generated can be taken only as estimates. Whether the women over- or underreported the true extent of the problem cannot be determined without biomarkers. A gender bias related to the difference in reporting methods between women and men could also have been introduced. Self-monitoring data would need to be backed up by clinical data and blood sample analyses, such as cholinesterase depressions. Another issue is that respondents belonging to the same village had close interactions. This may have introduced a systematic bias yielding homogeneity of reporting. Finally, the method cannot appreciate the chronic consequences of prolonged exposure to pesticides. Relevant in the case of women are the long term effects on the reproductive system that can lead to abortions, still births, neonatal deaths and congenital defects (Restrepo, 1990; Taha and Gray, 1993; Zhang et al., 1992; Rojas et al., 2002). Nevertheless, a study conducted in India has shown that female cotton workers experienced the same long-term consequences of exposure to pesticides (Rupa et al., 1991). Our research concerned only adult respondents (above 18 years) and no age factor on the severity of the poisoning was found. However, the Pan American Health Organization estimated that between 10 to 20 % of all poisoning cases involve children. The cottonseed industry in India employs thousands of girl children from 7 to 14 years old to manually cross-pollinate the plants. There is need to investigate the impact on children exposed to pesticides.

The survey covered one cotton season and therefore the number of records is limited. A second data collection is however scheduled for 2004 with the same respondents to estimate changes in farmers' health induced by the cotton IPM FFS.

The extent of pesticide poisoning among farmers and workers in developing countries is worrying (Kishi, 2005). In the extreme hot weather of the tropics, protective gear does not seem to be a viable solution to eliminate occupational risks. Farmers' education on the pesticide hazard alone has not achieved significant results (Atkin, 2002). The solution seems to be in the replacement of pesticides with non- or less toxic alternatives. One example of such

alternatives can be found in the Integrated Pest Management approach.

Acknowledgements

The authors are grateful to the EU-FAO IPM Programme for cotton in Asia for providing necessary financial help in carrying out this project. They thankfully acknowledge the valuable reviews and comments of the following: Peter Ooi, Palaniswamy Pachagounder and Gerd Walter.Echols, EU-FAO IPM Programme; Peter Kenmore and Harry van der Wulp, Global IPM Facility; Add Termorshuizen, Wageningen University and Research Centre. Special recognition is due to the Indian farmers and facilitators who participated in this project.

References

- Aragon A., Aragon C., Thorn A., 2001. Pests, peasants, and pesticides on the northern Nicaraguan Pacific Plain. *International Journal of Occupational Environmental Health* 7 (4), 295-302.
- Atkin J., 2002. Safe and Effective Use of Crop Protection Products in Developing Countries. In: Lesinger KM (Ed). Wallingford, UK,CABI Publishing.
- Census 2001, <http://www.censusindia.net/rural.html>.
- Clarke E. E., Levy L.S., Surgeon A., Calvert I.A., 1997. The problems associated with the pesticide use by irrigation workers in Ghana. *Occupational Medicine (Lond)* 47 (5), 301-8.
- CSE (Centre for Science and Environment), 2003. Pesticide residues in bottled water. CSE Report, New Delhi.
- Department of Agriculture and Cooperation, 2002. Agriculture statistics at a glance. Government of India.
- Eisemon T. O., Nyamete A., 1990. School literacy and agricultural modernization in Kenya. *Comparative Education Review* 34, 161-76.
- IPCS. International Programme on Chemical Safety, 2000-2002. The WHO recommended classification of pesticides by hazard.
- Keifer M., 1996. Estimating underreported poisonings in Nicaragua. *American Journal of Industrial Medicine* 30, 195-201.
- Keifer M., 1997. Human health effects of pesticides. *Occupational Medicine: State of the Art Reviews* 12 (2).
- Kimani V. N., Mwanthi M. A., 1995. Agrochemicals exposure and health implications in Githunguri location, Kenya. *East African Medical Journal* 72 (8) 531-535.
- Kishi M., Irschhorn N., Djajadisastra M., Satterlee L.N., Strowman S., Dilts R., 1995. Relationship of pesticide spraying to signs and symptoms in Indonesian farmers. *Scandinavian Journal of Work, Environment, and Health* 21, 124-33.
- Kishi M., 2002. Indonesian farmers' perception of pesticides and resultant health problems from exposure. *International Journal of Occupational Environmental Health* 8 (3), 175-81.
- Kishi M., 2005. The health impacts of pesticides: What Do We Know, What Can Be Done?. In: J. Pretty (Ed).The Pesticide Detox. 1st ed. Earthscan, London, Sterling, VA, pp. 23-38.
- Kunstadter P., Prapamontol T., Siririjn B.O., Sontirat A., Tansuhaj A., Khamboonruang C., 2001. Pesticide exposure among Hmong farmers in Thailand. *Int J Occup Environ Health* 7, 313-25.
- London L., de Grosbois S., Wesseling C., Kisting S., Rother H. A., Mergler D., 2002. Pesticide usage and health consequences for women in developing countries: Out of sight, out of mind? *International Journal of Occupational Environmental Health* 8, 46-59.
- London L., Rother A., 2000. People, pesticides and the environment: who bears the brunt of background

- policy in South Africa? *New Solutions* 10 (4), 339-50.
- McConnell R., Magnotti R., 1994. Screening for insecticide overexposure under field conditions: a reevaluation of the tintometric cholinesterase kit. *American Journal of Public Health* 4, 479-81.
- Miranda J., Lundeberg I., McConnell R., 2002. Onset of grip- and pinch-strength impairment after acute poisonings with organophosphate insecticides. *International Journal of Occupational Environmental Health* 8(1),19-26.
- Moses M., 1993. Environmental equity and pesticide exposure. *Toxicology and Industrial Health* 9(5), 913-59.
- Murphy H., Hoan N. P., Matteson P., Morales Abubakar A. L., 2002. Farmers' Self-surveillance of Pesticide Poisoning: a 12-month Pilot in Northern Vietnam. *International Journal of Occupational Environmental Health* 8, 201-211.
- Murphy H., Sanusi A., Dilts R., Djajadisastra M., Hirschhorn N., Yuliantiningsih S., 1999. Health effects of pesticide use among women Indonesian farmers: Part I: exposure and acute effects. *Journal of Agromedicine* 6 (3), 61-85.
- Murray D.L., 1994. *Cultivation crisis: the human cost of pesticides in Latin America*. University of Texas Press, Austin.
- Repetto R., Baliga S., 1997. Pesticides and immunosuppression: the risks to public health. *Health Policy Plan* 12 (2), 97-106.
- Restrepo M., 1990. Prevalence of adverse reproductive outcomes in a population occupationally exposed to pesticides in Colombia. *Scandinavian Journal of Work, Environment & Health* 16, 232-8.
- Rojas A; Ojeda M E, Barraza X., 2002. Congenital malformations and pesticide exposure. *Rev Med Chil*. 128 (4), 399-404.
- Rosenstock L., Keifer M., Daniell W., McConnell R., Claypoole K., 1991. And the Pesticide Health Effects Study Group. Chronic central nervous system effects of acute organophosphate pesticide intoxication. *Lancet* 338, 223-7.
- Rother H. A., 2000. Influences of pesticide risk perception on the health of rural South African women and children. *African Newsletter on Occupational Health and Safety* 10, 42-6.
- Rupa D. S., Reddy P. P., Reddi O. S., 1991. Reproductive performance in population exposed to pesticides in cotton field in India. *Environmental Research* 55 (2), 123-8.
- Taha T. E., Gray R. H., 1993. Agricultural pesticide exposure and prenatal mortality in central Sudan. *Bull World Health Organization* 71 (3-4), 371-21.
- Trivelato M. D., Wesseling, 1992. Use of pesticides in non-traditional crops in Costa Rica: environmental and labor health aspects. In: Kopke U., Schulz D. G. (Eds), *Proceedings 9th International Scientific conference IFOAM*. November 16-21. Sao Paolò, Brazil.
- Wesseling C., Aragon A., Castillo Leta I., 2001. Hazardous pesticides in Central America. *International Journal of Occupational Environmental Health* 7 (1), 287-94.
- Wesseling C., Keifer M., Ahlbom A., 2002. Long-term neurobehavioral effects of mild poisonings with organophosphate and n-methyl carbamate pesticides among banana workers. *International Journal of Occupational Environmental Health* 8(1), 27-34.
- WHO, 1990. *The Public Health Impact of Pesticides Use in Agriculture*. World Health Organization, Geneva.
- World Bank, *Measuring poverty*. 2003, <http://www.worldbank.org/data/wdi2003/pdfs/table%202-6.pdf>
- Zham S. H., Blair A., 1993. Cancer among migrant and seasonal farmworkers: an epidemiologic review and research agenda. *American Journal of Industrial Medicine* 24, 753-66.
- Zhang J., Cai W. W., Lee D. J., 1992. Occupational hazard and pregnancy outcomes. *American Journal of Industrial Medicine* 21, 397-408.

CHAPTER 3

Impact of Integrated Pest Management Farmer Field Schools on Pesticide Use and Farmers' Ecological Knowledge on Cotton Farming in India

Francesca Mancini, Aad. J. Termorshuizen and Ariena. H. C. van Bruggen

Submitted to Pest Management Science

Abstract

Integrated Pest Management (IPM) has been introduced in India to reduce the serious impact caused by the use of highly toxic pesticides on people's health and the environment. However, IPM diffusion has been slow, likely due to the inherent complexity of the method that is based on extensive ecological knowledge. IPM Farmer Field Schools (IPM FFS), conducted for cotton growers in Central and South India, have shown in this study to be an effective educational approach to build the essential knowledge and decision-making skills among farmers to adopt IPM. The agronomic practices of 73 IPM FFS trained farmers and 64 control farmers were compared before and after the training had been conducted. Trained farmers drastically reduced the use of highly toxic pesticides as a result of increased knowledge on insect ecology. Crop productivity was not affected by this reduction, showing that part of the current use of pesticides in cotton cultivation is superfluous.

Keywords: Integrated Pest Management, Farmer Field Schools, Cotton, Pesticides, Farmer Education, India

Introduction

The use of synthetic pesticides in agriculture has increased exponentially after the introduction of high-yielding varieties and hybrids in the late 1940s. At the beginning of the current millennium the world pesticide use exceeded 2.5 million tons and the world pesticide expenditures were around \$ 32.0 billion (EPA, 2002). The negative consequences on human health, water quality, biodiversity and wild life associated with the release of large quantities of toxic products in the environment has increasingly become a matter of concern (Harper and Zilberman, 1989; Agne et al., 1995). The use of pesticides is concentrated in few cash crops and

cotton alone is estimated to receive some 20% of all global insecticides applied each year. In developing countries this share rises to 50% (Caldas, 1997). India is the third largest cotton producing country in the world with an area fluctuating between 8-9 million ha. Around 10% of the national acreage under cotton is located in Andhra Pradesh, Central India (ICAC, 2005), where cotton is the main crop for millions of small-holders. Yet, the average yields in Andhra Pradesh are as low as 483 kg/ha (1994-2003 average, CAB, 2005) and the incomes generated are unsteady (Herring and Grodzins, 2005). The pest control strategy largely relies on highly toxic organophosphate and pyrethroid products, namely monocrotophos, quinalphos, chlorpyrifos, dimethoate, and cypermethrin. However, even some very persistent organochlorines are used, particularly endosulfan. The organophosphates and –chlorines belong to WHO toxicity class Ib and II (WHO, 2005; ICAC, 2005). Repeated applications of insecticides (up to 19 times a season, PRDIS, 2003) have caused the development of cotton pest resistance and the resurgence of pest outbreaks (Kranthi et al., 2002).

Integrated Pest Management (IPM) is an approach to plant protection that was designed to reduce the need for chemical control. It is a complex, knowledge-based technology (Hall and Duncan, 1984) that combines biological, cultural and chemical control to keep pests below economically acceptable levels (USDA, 1993). Since 1981, the Government of India has been promoting IPM to address the crisis faced by the cotton growers. However, until 1994 no significant, large-scale changes in the management of farming systems were observed (Directorate of Plant Protection, 2003). The low adoption rate of IPM compared to the target of 75% of farmland by 2000, as reported for the USA (Fernandez-Cornejo, 1998), may be due to IPM's inherent complexity (Fernandez-Cornejo et al., 1994). Unlike traditional chemical control, IPM does not provide precise recommendations; but it requires in-depth ecological knowledge, analytical ability and practical experience from the farmer's side. In order to enhance the uptake of IPM, the Government of India introduced a new training approach to deliver IPM to the farmers, namely Farmer Field Schools (FFS) in the late 1990s, in collaboration with the Food and Agriculture Organization (FAO).

FFSs are participatory training courses conducted in the villages for small (25-30) groups of farmers (Kenmore, 1996). They differ from the previous Training-and-Visit system (T&V) (Picciotto and Anderson 1997), which was based on short field demonstrations of already developed technical packages, in providing farmers with continued opportunities to experiment in their own fields and find locally-relevant pest management solutions. The IPM principles are explored in hands-on, discovery-earning processes coached by expert IPM facilitators. Farmers are expected to strengthen their ecological knowledge, to take informed decisions on plant production and protection and to escape from the so-called pesticide treadmill (Bingen, 2004).

A decline in pesticide use has become visible in India since 2000, particularly in Andhra Pradesh, where the annual consumption dropped from 4000 tons in the 2000/2001 growing season to 2034 tons in the 2003/04 season (CIBRC, 2005). Empirical evidence on the role of IPM in reducing pesticide use while sustaining yields has been provided in a number of cases, e.g. rice farmers in Indonesia (Fliert, 1993), Vietnam (Huan et al., 1999), and pistachio

farmers in Iran (Heidari, 2003). Some studies have also established a positive relation between the reduction in pesticide use and increased knowledge on bio-control principles (Godtland et al., 2004, Reddy and Suryamani, 2005, Feder et al., 2004b). However, it still questionable whether an intensive training approach, oriented towards the development of human capital, is an effective way to promote the adoption of IPM.

This paper presents an evaluation of the FFSs' outcomes in Andhra Pradesh in terms of changed practices. The curriculum adopted in the FFSs went beyond plant protection to cover all agronomic practices that enhance plant health and resistance to adverse biotic factors as well as increase crop productivity. Thus, the objective of the study was to analyze changes not only in input use (fertilizers and pesticides), but also in agronomic practices induced by the adoption of IPM. Additionally, the study aimed to explain the changes in pesticide use by the extent of farmers' ecological knowledge and the way management decisions are made. The study formed part of a larger Monitoring and Evaluation (M&E) effort (2003-2005) conducted in the same geographical districts that assessed the impacts on the environment (Kooistra et al., 2006, submitted), farmers' health (Mancini et al., 2005), and the social capital of farmers (Mancini et al., 2006a, submitted).

Material and Methods

Study area and sampling

The study was conducted in 5 villages located in two districts of Andhra Pradesh, Warangal and Mahaboobnagar districts. Cotton was grown as the main crop during the rainy season on 121,260 ha and 22,697 ha, respectively. A total of 137 households were selected, out of which 73 were headed by farmers trained in cotton IPM FFS in 2003 and 64 by farmers who lived in villages where no FFS had ever been conducted (Table 1).

Farmers attending IPM FFSs did not constitute a random selection of the cotton growers' population, because IPM FFS programmes are preferentially located in areas with high use of pesticides. Even though no selection criteria are explicitly applied to enrol participants, socio-economic factors might favour the participation of the more progressive, wealthier and educated farmers in the village. To address the bias introduced by a non-random (purposive) sampling procedure, recent impact studies on IPM FFS effects have adopted a Double Difference (DD) model (Feder et al., 2004a). This model compares the farming systems of a treatment group (IPM FFS trained farmers) against a control group, before and after the training is conducted. The analyses of the changes in performance over time of the treatment group in relation to those of the control group, rather than the simple comparison of treatment and control groups' behaviour at one point in time, allows for the isolation of the training effects from external or seasonal effects.

Data collection

Data were collected by means of interviews the year before (2002) and the year after (2004) the IPM FFSs were conducted. The same household members were interviewed in both years using a standardised questionnaire, which included questions on agronomic practices, farmers' ecological knowledge on cotton insects and farmers' criteria to decide about the application of pesticides.

The questionnaire included the following operations: irrigation (number of operations per crop cycle); weeding (number of weeding operations per crop cycle), organic as well as inorganic fertilization (rates in kg of commercial products/ha) and pesticide application (toxicity class, rates and number of applications of the formulated products per crop cycle/ha). The rates of commercial fertilizers were converted into kg/ha of nitrogen, phosphorous and potassium and the rates of formulated pesticides were converted into ml of active ingredients (a.i.)/ha. The use of pesticides was expressed by three variables: PEST: ml of a.i. belonging to WHO toxicity classes I and II, PEST3: ml of a.i. belonging to WHO class III and U (WHO, 2005) and SPRAY: total number of applications, including all products.

The questions on knowledge focused on cotton insect ecology. Three scores were derived from the farmers' ability to: 1-List the names of the insects commonly found in cotton fields (Identification Score, IS), 2-Define whether the listed insects were pests or predators (Functional Score, FS), 3-Describe the feeding habits of the insects, the plant damages in the case of pests and the predatory capacity in the case of beneficial insects (Ecology Score, ES). The number of right answers determined the values assigned to each score.

Finally, the criteria used to take decisions on the application of pesticides were asked through a multiple-choice question. Farmers could choose their answer among the following options: 1-Consulting with dealers, 2-Consulting with neighbour farmers, 3-Observing pests in field, 4-Performing an agro-ecosystem analysis in own field. The first two options refer to decisions taken without observing the local field situations and therefore based on pre-fixed application schedules, e.g. calendar-based applications. The third option is based on the evidence of plant damage and/or presence of insects in the field without a systematic assessment of the risk of losses. The last type of decision implies an analytical process that takes into consideration biotic and abiotic factors determining losses due to pests' attacks.

Data analysis

The analysis was carried out using two analytical units: the farm and the village to isolate potential "village effects" due to the different geographical regions and the different people organising the training. Pre and post means of the variables for the five villages and for the total IPM and control sample were compared using the paired t-test. Means of scores were compared using the non-parametric Wilcoxon Matched-Pairs Signed-Ranks Test (van der Waerden, 1969). Wherever findings relative to the total sample were consistent with the village-wise findings, the discussion focused on the former.

A canonical correspondence analysis (sensu Ter Braak et al., 2002) was performed

to determine whether the 5 villages were overall different in respect of the changes undergone and which of the changes contributed most to the distinction between IPM villages and control villages. The data were log-transformed to obtain normality, and subsequently were standardised, and then processed using the software program Canoco (Canonical Variate Analysis; Ter Braak et al., 2002) with villages as 'samples', and cases (pre-FFS, pre-Control, post-FFS, post-Control) as 'species'. Best linear combinations to discriminate among the villages were based on the variables that proved to be relevant in the previous analysis: PEST; PEST3; SPRAY; ES and YIELD, and two uncorrelated axes were calculated.

Results

FFS participants were significantly (4.8 yr; $P < 0.05$) younger than control farmers and more educated (more people had completed the primary school; $P < 0.01$). There were no significant differences in terms of average total land-holding (2.7 and 3.2 ha for IPM and control farmers respectively) and area under cotton cultivation (1.2 and 1.3 ha for IPM and control farmers respectively) (Table 1).

Table 1. Descriptive Statistics of the IPM and control farmers and farms in 2002 and the significance levels of the differences between IPM and control cases

	Village code					All farms		Sign. ^b
	IPM1	IPM2	IPM3	C1	C2	IPM	Control	
N	29	19	25	31	33	73	64	
District ^c	W	M	M	W	M			
Age	34.9 (10.8) ^a	34.6 (9.8)	38.5 (11.0)	45.3 (11.0)	36.6 (12.7)	36.0 (10.6)	40.8 (12.5)	0.05
Education ^d	1.4 (0.7)	2.5 (0.6)	3.0 (0.8)	1.7 (1.0)	1.7 (1.0)	2.2 (1.0)	1.7 (1.0)	0.01
Land-holding (ha)	2.4 (2.8)	2.7 (1.4)	3.0 (1.7)	3.5 (2.9)	2.9 (2.8)	2.7 (2.2)	3.2 (2.8)	n.s.
Cotton area (ha)	0.8 (0.4)	1.1 (0.6)	2.1 (1.5)	1.3 (0.8)	1.1 (0.6)	1.3 (1.5)	1.2 (0.7)	n.s.

^a Standard deviation in brackets.

^b Significance level, of differences between IPM and control villages tested with t-student paired test, n.s. = not significant.

^c District name, W=Warangal; M=Mahaboobnagar.

^d Education level 1= Not literate; 2=Primary School; 3= Secondary school.

The use of highly toxic pesticides decreased the year after the IPM FFS in the five villages. However, the reduction in the case of IPM FFS farmers was very drastic from 1085.7 to 252.3 ml a.i./ha, equivalent to 74.8%, whereas control farmers reduced the use of pesticides by 28.0%, from 2128 to 1533 ml a.i./ha (Table 2). The usage of less harmful or not likely to be harmful products (WHO toxicity class III and U) was also remarkably lower (73.7%) for IPM FFS farmers, and no significant changes were reported by control farmers. Likewise, the total

number of pesticide applications including less toxic products, which was around 8 for the two groups in the pre survey, was significantly reduced in the case of IPM FFS farmers from 7.9 to 1.7, but no significant differences were recorded in control villages (Table 2).

Table 2. Pesticide use at the IPM and control farms before (2002) and after (2004) the IPM FFS training per village and for all IPM or control villages together

Village code	Pesticides class I and II (ml a.i./ha)		Pesticides class III and U (ml a.i./ha)		Sprays (no.)/ha	
	2002	2004	2002	2004	2002	2004
IPM1	1671*** ^a	316	375***	58	10.2***	1.5
IPM2	731***	256	301*	71	5.8***	2.6
IPM3	855***	185	366***	97	7.6***	1.0
C1	2535***	1664	496ns	689	9.7ns	8.5
C2	1722ns	1382	863ns	707	6.7ns	5.9
Avg IPM	1086***	252	347***	75	7.9***	1.7
Avg C	2128***	1533	679ns	698	8.2ns	7.2

^a Significance level between 2002 and 2004 in adjacent columns.

* P < 0.05, ** P < 0.01, *** P < 0.001, ns = not significant.

Table 3. Agronomic practices (a) and fertilizer use (b) at the IPM and control farms before (2002) and after (2004) the IPM FFS training per village and for all IPM or control villages together

(a)									
Village code	Irrigation (no.)		Weeding (no.)						
	2002	2004	2002	2004					
IPM1	8.3ns ^a	7.3	3.4ns	2.6					
IPM2	6.1ns	8.1	3.1ns	2.9					
IPM3	11.9ns	7.6	3.8ns	2.9					
C1	8.9***	6.7	5.1***	4.0					
C2	2.7ns	4.0	3.2ns	3.4					
Avg IPM	8.8ns	7.7	3.6**	2.8					
Avg C	5.8ns	5.4	4.1*	3.7					

(b)										
Village code	Org. fertilizer (kg/ha)		N (kg/ha)		P (kg/ha)		K (kg/ha)		Yield (Kg/ha)	
	2002	2004	2002	2004	2002	2004	2002	2004	2002	2004
IPM1	1037***	124	31.6	72.5	22.9ns	25.5	20.9***	73.8	569***	756
IPM2	2607ns	1384	72.2n	62.4	33.1ns	24.5	27.0ns	19.3	926***	1200
IPM3	2157ns	1288	69.0***	29.7	46.1ns	33.8	27.2**	12.1	967ns	988
C1	2016***	229	105.0*	75.0	144.0***	22.5	95.1*	65.7	841*	953
C2	1447ns	1745	144.5ns	139.8	78.6ns	67.4	28.1ns	41.3	477*	567
Avg IPM	1934***	932	57.6ns	54.9	34.0ns	41.9	25.0**	35.0	820**	981
Avg C	1732**	987	124.8ns	107.4	111.3***	45.0	61.6ns	53.5	659**	760

^a Significance level between 2002 and 2004 in adjacent columns.

* P < 0.05, ** P < 0.01, *** P < 0.001, ns = not significant

There were no significant changes in the number of irrigation and weeding operations, nor in the use of synthetic and organic fertilizers that could be attributed to a clear training effect. Irrigation and weeding operations were reduced in the post survey for both groups (Table 3).

Organic fertilization was radically reduced in the C1 and FFS1 villages in the post-survey in Warangal district as a result of unknown local factors, whereas no significant changes were recorded in the villages in Mahaboobnagar district. The use of inorganic nitrogen decreased in the control village C1 and the IPM village IPM3, while it increased in IPM1, but no significant changes were recorded in the other villages. Also, the use of inorganic phosphorus and potassium did not follow a clear pattern. The yields increased in IPM villages by 19.7% and in control villages by 15.3% (Table 3); however the two percentages were not significantly different (Table 4). Table 4 reports the significance levels of the differences for the variables between the IPM and the control villages.

The two groups of farmers were homogeneous in terms of ecological knowledge in the pre-survey. FFS farmers significantly improved their ability to identify cotton insects (IS) to describe whether the insects were pests or predators (FS), to describe the damage caused by the pest insects, and the predatory habits of beneficial insects (ES) after the IPM FFS training, whereas no significant changes were recorded for control group (Table 5).

Table 4. Changes (% of the 2002 values) in agronomic practices and input use after the IPM training (2004) per village and for all IPM or control villages together

Village code	Pest.1 (ml a.i./ha) ¹	Pest.2 (ml a.i./ha)	Sprays (no./ha)	Yield (Kg/ha)	Irrigation (no.)	Weeding (no.)	Org fertilizer (kg/ha)	N (kg/ha)	P (kg/ha)	K (kg/ha)
IPM1	-81.0	-84.5	-85.3	32.9	-12.0	-23.5	-88.0	129.4	11.3	253.1
IPM2	-65.0	-76.4	-55.2	29.6	-32.8	-6.5	-46.9	-13.6	-7.5	-28.5
IPM3	-78.3	-73.5	-86.8	2.1	-36.1	-23.7	-40.3	-56.9	-12.3	-55.5
C1	-34.3	-38.9	-12.4	13.3	-24.7	-17.7	-88.6	-28.6	-26.7	-30.9
C2	-77.6	-18.0	-11.8	14.7	48.1	-6.2	20.6	-56.4	-40.7	-46.9
Avg IPM	-76.6*	-78.2***	-78.5***	19.6ns	-12.5ns ^a	-22.2ns	-51.8ns	-4.7ns	23.2***	40.0ns
Avg C	-28.0	-2.7	-12.2	17.9	-6.9	-9.7	-43.0	-44.5	-82.0	-24.3

¹ Pest.1 includes pesticides belonging to class I and II and Pest.2 pesticides belonging to class III and U
a Significance level between all IPM and control villages in the same columns.

* = 0.05, ** = 0.01, *** = 0.001, ns = not significant.

IPMFFS as well as control farmers decided to apply pesticides if pests were present in the field. In the post-survey, half of the IPM FFS farmers decided to apply pesticides on the basis of the results of an agro-ecosystem analysis. No significant changes were recorded for the control farmers (Table 5).

The results of the canonical correspondence analysis (Figure 1) confirm that the three IPM villages had remarkably changed with respect to the pesticide variables (PEST; PEST3 and SPRAY) the year after the training, while the changes in the case of the control villages were very small. It also shows that the use of pesticides was not correlated to the yields. There was a negative correlation between ecological knowledge and pesticide use (Figure 2). Figure

3 illustrates that at higher values of the Ecological Score corresponded to lower usages of highly and moderately toxic pesticides.

Table 5. Knowledge and decision-making score of IPM and control farmers before (2002) and after (2004) the IPM FFS training per village and for all IPM or control villages together

Village code	Identification Score		Functional Score		Ecological Score		Decision criteria	
	2002	2004	2002	2004	2002	2004	2002	2004
IPM1	4.0*** ^a	7.7	3.3***	7.3	2.3***	7.0	3.4*	4.0
IPM2	5.4***	7.2	5.2***	7.3	4.0***	7.3	2.5ns	3.2
IPM3	4.6***	5.5	3.7***	5.4	2.5***	4.4	3.2*	3.5
C1	5.4***	3.9	4.4ns	3.9	4.2***	3.1	3.1ns	3.0
C2	3.3ns	3.4	3.2ns	3.1	3.2ns	3.1	2.9ns	2.9
Avg IPM	4.7***	6.8	4.0***	6.7	2.9***	7.0	3.0*	3.6
Avg C	4.4*	3.7	3.8ns	3.5	3.1ns	4.7	3.0ns	2.9

^a Significance level between 2002 and 2004 in adjacent columns.

* P < 0.05, ** P < 0.01, *** P < 0.001, ns = not significant.

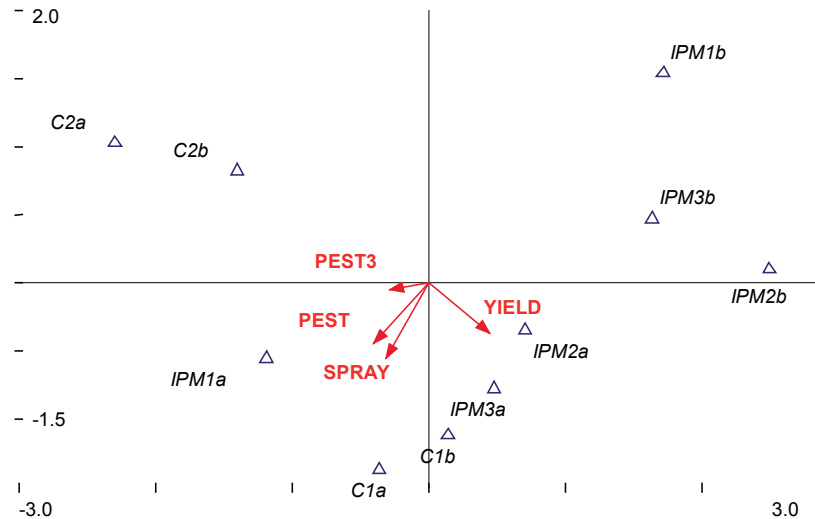


Figure 1. Canonical Correspondence Analysis of the five villages before (a, 2002) and after (b, 2004) the IPM FFS training based on ml a.i./ha of WHO I and II pesticides (PEST), ml a.i./ha of WHO III and U (PEST3), total number of pesticide applications (SPRAY) and Kg/ha of cotton harvested (YIELD). The letters a refer to the village coordinates for 2002 data, before the IPM training, and the letters b refer to the coordinates of the same village for 2004, after the IPM training.

Discussion

The study shows that the adoption of Integrated Pest Management (IPM) by Farmer Field Schools (FFS) can very significantly reduce the current overuse of pesticides. Given that the reduction in pesticide use attained in all the villages never affected cotton yield, it can also be concluded that the current use of pesticides on cotton is in excess. The scope for reduction is large, as shown by the IPM FFS farmers, who used only one sixth of the volume of highly toxic pesticides used by the control farmers, achieving the same yield level. The diffusion of IPM through FFS on a large scale is expected to mitigate the serious consequences that the heavy use of pesticides has caused on people's health (Mancini et al., 2005), biodiversity (Walter-Echols et al., 2005) and water quality (CSE, 2003) in India.

The strong correlation between knowledge level and reduction in pesticide use proved that a skill-oriented, knowledge-intensive and hands-on education approach, as used during FFSs, is an efficient system to deliver the complex IPM principles to farmers. Graduates of IPM FFS significantly gained in ecological knowledge concerning pest and beneficial insects of cotton fields. These were anticipated impacts of the FFSs, where the training is structured around weekly field visits to perform crop ecosystem analysis. Farmers attending the schools learn to sample plants in the field and leaves on the plants according to a cross-trasect design, to record the number of insects visible and to predict insect population dynamics looking at the climate conditions and food availability for pests. Ultimately, farmers take joint and informed decisions based on the relations among all these factors. This finding is in agreement with all previous literature on knowledge gains associated with the participation in FFS (Rola et al., 2002; Sinzogan et al., 2004; Feder et al., 2004b; Reddy and Suryamani., 2005). FFSs seem to be an appropriate strategy to overcome constrains to IPM adoption identified in the lack of farmers' biological and ecological knowledge, because it allows farmers to develop a deeper understanding of the crop systems and a stronger confidence in the method. In the case of this study, such a confidence was expressed in the decision to take fewer but likely more targeted pesticide applications.

The FFS approach focuses on the importance to judge the necessity for plant protection interventions on the basis of actual field needs, which is essential to achieve a more sustainable agriculture. In this light, a replacement of toxic pesticides by other less harmful products is considered an improvement only if the need for these products has also been established through an ecological field assessment. Substituting pesticides with biocontrol agents or other technologies such as transgenic cotton is unlikely to become a definitive solution to sustain agricultural productivity, if these new technologies are not paired with educational programmes (Yang et al., 2005).

Although the use of Bt-cotton in China is accompanied by a significant reduction in number of pesticide sprays, pesticide use is considerably lower if the Bt technology is associated with adequate training (Pemsl et al., 2005). The current study shows that IPM farmers changed their practices as a result of a change in their decision-making process, unlike the control group that continued to apply synthetic pesticides and biocontrol agents at the same

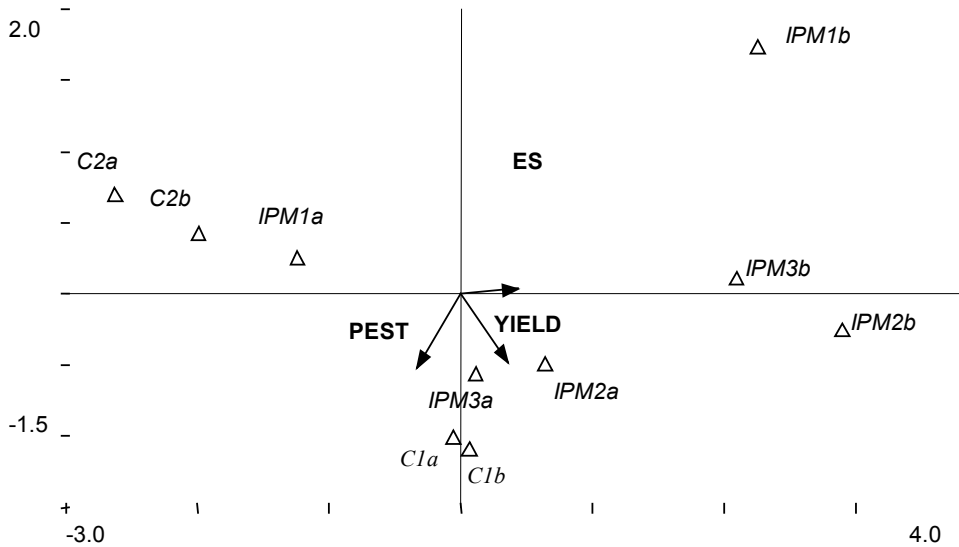


Figure 2. Canonical Correspondence Analysis of the five villages before (a, 20002) and after (b, 2004) the IPM FFS training based on ml a.i./ha of WHO I and II pesticides (PEST), ml a.i./ha, Kg/ha of cotton harvested (YIELD) and Ecological Score (ES). The letters a refer to the village coordinates for 2002 data, before the IPM training, and the letters b refer to the coordinates of the same village for 2004, after the IPM training.

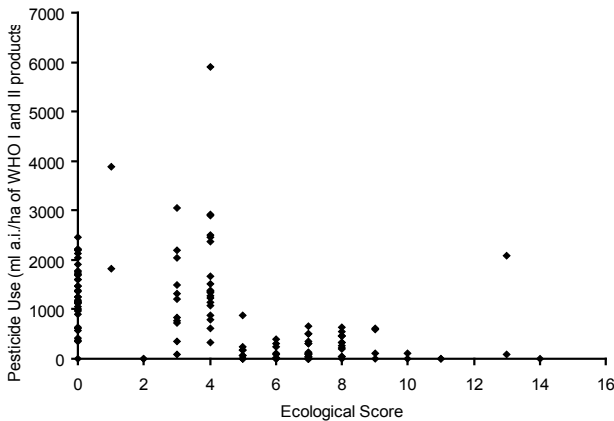


Figure 3. Dosages of pesticides belonging to WHO I and II hazard classes per hectare used by the farmers and their Ecological Score values for year 2004

rate in terms of number of applications. A similar behavioral difference was observed by Khan et al., (2005) in Pakistan where trained farmers reduced the frequency and rates of pesticide applications as a result of increased decision-making and field observational scores. Yang (2005) reported that in China IPM FFS trained farmers decided on the basis of a cotton ecosystem analysis, whereas control farmers followed a pre-fixed schedule or neighbors' and dealers' advice in the early stages of the crop and decided on the evidence of plant damage in the later stages.

The negative correlation between pesticide use and knowledge indicates that those farmers, who learned more about insect ecology, were able to manage the largest decrements in pesticide usage. Cotton yield was not correlated with the ecological knowledge. It should be noted that the knowledge investigated by this survey concerned insect ecology, and not other agronomic topics. It can therefore be inferred that, at the farms sampled, better plant protection practices led to a lower input use, and likely to a higher profitability, but not to an increase in productivity.

The use of fertilizers, of particular interest for its consequences on the environment and crop productivity, was not changed by the IPM FFS training even though addressed by the curriculum. Similar conclusions were drawn by a complementary environmental assessment of cotton cultivation carried out in the same area (Kooistra et al., 2006, submitted) and in Pakistan (Khan et al., 2005). This result can be explained by the relatively higher emphasis given to plant protection measures in comparison with other topics. Reducing the use of highly toxic pesticides was an urgent need determined by the serious impacts reported on human health. In addition to IPM field trials, farmers experimented with insect zoos throughout the cropping season and spent the majority of the FFS sessions' time in discussing pest ecology. The difference in the training achievements between pesticide and fertilizer use can also be interpreted as a confirmation that intensive training investments are required in order to induce appreciable changes in farmers' practices. Nutrient management is another important area that could enhance the impact of IPM FFS in India.

Acknowledgements

The financial support provided by the EU-FAO IPM Programme for Cotton in Asia and the constant technical guidance provided by P. Kenmore, P. Ooi, G. Walter-Echols, D. von Werner, P. Pachagounder and the local staff during the fieldwork is gratefully acknowledged. Janice L. S. Jiggins provided invaluable support in designing and planning this research study. A special thank is due to the farmers, who collaborated with this survey for letting us visit their farms and dedicating their valuable time to the survey.

References

- Agne S., Waibel H., Jungbluth F., Fleischer G., 1995. Guidelines for Pesticide Policy Studies. A Framework for Analyzing Economic and Political Factors of Pesticide Use in Developing Countries. Institute of Horticultural Economics, Hannover.
- Bingen J., 2004. Pesticides, politics and pest management: toward a political ecology of cotton in Sub-Saharan Africa in African environment and development: rhetoric, programs and realities, In: Moseley W.G. Logan B.I. (Eds), African Environment and Development: Rhetoric, Programs, Realities. King's SOAS Studies in Development Geography. Ashgate Publishing Ltd., Aldershot, UK, pp. 111-126.
- CAB (Cotton Advisory Board), 2005. Cotton and Man-made Fibre Filament Yarn industry. Annual Report 2004/2005. Ministry of Textile, India.
- Caldas T., 1997. Organic Cotton: Not Just A Matter of Fibre, in Ecology and Farming, IFOAM.
- CIBRC (Central Insecticides Board & Registration Committee), 2005. Consumption of pesticides in various states during 2000-01 to 2004-05, in Central Insecticides Board and Registration Committee, India.
- CSE (Centre for Science and Environment), 2003. Pesticide residues in bottled water, CSE Report. New Delhi, India.
- Directorate of Plant Protection, 2003. Integrated Pest Management Package for Cotton. In IPM Package no.25. Government of India, Ministry of Agriculture, Faridabad, India.
- EPA, 2002. Pesticides Industry Sales and Usage 2000 and 2001 Market Estimates, U.S. Environmental Protection Agency, Kiely T., Donaldson D., Grube A., (Eds.), Washington, DC, USA.
- Feder G., Murgai R., Quizon J.B., 2004a. Sending farmers back to school: The impact of farmer field schools in Indonesia. *Review Of Agricultural Economics* 26 314-314.
- Feder G., Murgai R., Quizon J.B., 2004b. The acquisition and diffusion of knowledge: the case of pest management training in Farmer Field Schools, Indonesia. *Journal of Agricultural Economics* 55, 221-243.
- Fernandez-Cornejo J., 1998. Environmental and economic consequences of technology adoption: IPM in viticulture. *Agricultural Economics* 18, 145-155.
- Fernandez-Cornejo J., Douglas Beach E., Huang W.Y., 1994. The Adoption of IPM Techniques By Vegetables Growers in Florida, Michigan and Texas. *Journal of Agricultural and Applied Economics* 26 158-172.
- Fliert E. v.-d., 1993. Integrated pest management: farmer field schools generate sustainable practices, Wageningen Agricultural University Papers. Wageningen Netherlands: Landbouwniversiteit Wageningen (Wageningen Agricultural University) (93 3): xv + 304.
- Godtland E.M., Sadoulet E., Janvry A.D., Murgai R., Ortiz O., 2004. The impact of farmer field schools on knowledge and productivity: a study of potato farmers in the Peruvian Andes. *Economic Development and Cultural Change* 53, 63-92.
- Hall D. C., Duncan G.M., 1984. Econometric Evaluation of New Technology with an Application to Integrated Pest-Management. *American Journal of Agricultural Economics* 66, 624-633.
- Harper C.R., Zilberman D., 1989. Pest Externalities from Agricultural inputs. *American Journal of Agricultural Economics* 71, 692-702.
- Heidari H., 2003. Farmer Field Schools slash pesticide use and exposure in Iran. *Pesticides News*. 59: 12-14. London UK: Pesticide Action Network, UK.
- Herring R., Grodzins Gold A., 2005. Is there a case for growing cotton in India?, Indian Cotton: Biology and Utility, Meanings and Histories Workshop, Cornell University, April 29-30, 2005. A joint venture of Development, Governance and Nature and the Title VI National Resource Center for South Asia, Syracuse and Cornell Universities.
- Huan N.H., Mai V., Escalada M.M., Heong K.L., 1999. Changes in rice farmers' pest management in the Mekong Delta, Vietnam. *Crop Protection* 8, 557-563.
- ICAC (International Cotton Advisory Committee), 2005. Cotton Production Practices. Technical Information

- Session. 64th Plenary Meeting. International Cotton Advisory Committee. Liverpool, UK.
- Kenmore P., 1996. Integrated Pest Management in Rice. In Persley G. (Ed.), *Biotechnology and Integrated Pest Management*, CAB International, Wallingford, pp. 76-97.
- Khan M.A., Ahmad I., Walter-Echols G., 2005. Impact of an FFS-based IPM Approach on Farmer Capacity, Production Practices and Income: Evidence from Pakistan. In: Ooi P.A.C., Praneetvatakul S., Waibel H., Walter-Echols G. (Eds.), *The impact of the FAO EU IPM Programme for cotton in Asia*, Pesticide Policy Project Publication Series n. 9, Hannover University.
- Kranthi K.R., Jadhav D.R., Kranthi S., Wanjari R.R., Ali S.S., Russell D.A., 2002. Insecticide resistance in five major insect pests of cotton in India. *Crop Protection* 21, 449-460.
- Mancini F., van Bruggen A. H. C., Jiggins J.L.S., Ambatipudi A., Murphy H., 2005. Incidence of Acute Pesticide Poisoning Among Female and Male Cotton Growers In India. *International Journal of Occupational and Environmental Health* 11, 221-232.
- Pemsl D., Waibel H., Gutierrez A.P., 2005. Why Do Some Bt-Cotton Farmers in China Continue to Use High Levels of Pesticides? *International Journal of Agricultural Sustainability* 3, 44-56.
- Piccio R., Anderson J.R., 1997. Reconsidering agricultural extension. *World Bank Research Observer* 12, 249-259.
- PRDIS, 2003. Impact Assessment of Cotton Integrated Pest Management Training Through Farmer Field School Approach. Report for the FAO-EU IPM Programme for cotton in Asia. FAO, Bangkok.
- Reddy S.V., Suryamani M., 2005. Impact of Farmer Field School Approach on Acquisition of Knowledge and Skills by Farmers about Cotton Pests and Other Crop Management Practices - Evidence from India. In: Ooi P.A.C., Praneetvatakul S., Waibel H., Walter-Echols G. (Eds.), *The impact of the FAO EU IPM Programme for cotton in Asia*, Pesticide Policy Project Publication Series n. 9, Hannover University.
- Rola A., Jamias S., Quizon J., 2002. Do Farmer Field School Graduates Retain and Share what they Learn? An Investigation in Iloilo, Philippines. *Journal of International Agricultural and Extension Education* 9, 65-76.
- Sinzogan A.A.C., Van Huis A., Kossou D.K., Jiggins J., Vodouhe S., 2004. Farmers' knowledge and perception of cotton pests and pest control practices in Benin: results of a diagnostic study. *NJAS-Wagen. Journal of Life Science* 52, 285-303.
- Ter Braak C.J.F., Smilauer P., 2002. *Canoco reference manual and canodraw for windows user's guide*. Wageningen University, The Netherlands.
- USDA, 1993. *USDA Programs related to integrated pest management*. USDA Program Aid 1506, Agricultural Research Service, Washington, DC.
- van der Waerden BL, 1969. *Mathematical Statistics*, Springer-Verlag, New York.
- Walter-Echols G., Soomro M.H., 2005. Impact of FFS Training of the FAO-EU IPM Programme for Cotton in Asia on the Environment. In: Ooi P.A.C., Praneetvatakul S., Waibel H., Walter-Echols G., *The impact of the FAO EU IPM Programme for cotton in Asia*, Pesticide Policy Project Publication Series n. 9, Hannover University.
- WHO, 2005. *The WHO recommended classification of pesticides by hazard and guideline to classification to 2004*. International Programme in Chemical Safety.
- Yang P, Li K, Shi S, Xia J, Guo R, Li S, Wang L, 2005. Impacts of transgenic Bt cotton and integrated pest management education on smallholder cotton farmers, *International Journal of Pest Management* 51, 231-244.

CHAPTER 4

The Effects of Integrated Pest Management on Labour Organization and Gender Roles in Small Cotton Farms in India

Francesca Mancini, Justus Wesseler and Janice L. S Jiggins

Submitted to Agricultural Systems

Abstract

The introduction of new technologies and management approaches in agriculture induce changes in the labour organization of farming systems. Such changes often are gender differentiated, particularly in countries like India with a sharp gender division of roles. The organization of labour in turn influences the uptake and diffusion of innovations. The adoption of Integrated Pest Management (IPM) on a large-scale similarly could be expected to bring about differential change for female and male workers. This study shows that the adoption of IPM in conventional small-scale cotton farms in South India does not lead to an increase in the overall labour requirement, nor in the total time spent on plant protection. However, it causes a replacement of the time spent in applying pesticides with plant protection tasks performed mainly by women. The availability and opportunity costs of female workers were found to be a potential limiting factor to the rate of IPM adoption.

Keywords: Integrated Pest Management, Farmer Field Schools, Labour, Gender, Cotton

Introduction

Integrated Pest Management (IPM) aims to preserve enemies of insect pests in the field and crop in order to avoid or reduce the need for chemical control. In India, IPM has been promoted by national plant protection policies for the last two decades in order to address the abuse of pesticide use that has occurred in the small-scale farming sector.

Cotton accounts for over 50% of the pesticide consumption in India. India is the third cotton producing country in the world with nearly 9 million hectares under cotton cultivation, equivalent to 25% of the world cotton growing area. Yet the national average productivity (429 kg/ha) is considerably lower than the world average (603 kg/ha). In the central states of India

yields are among the lowest in the world (221 kg/ha, ICAC, 2005). The high-yielding cotton varieties and hybrids released with high expectations have not achieved the anticipated yield levels because of a number of constraints, primarily associated with lack of irrigation and pest control. The spread of improved seeds has been associated with a large increase in the use of production inputs and in the cultivation cost. Serious consequences resulting from the use of pesticides have been reported for the environment and water quality (CSE, 2003). A recent study in Andhra Pradesh showed that cotton growers experience economic losses (PRDIS, 2003). Cotton farming has become a risky, non-remunerative, and occupationally unsafe activity, particularly for small-scale producers (Herring et al., 2005).

Despite the government's efforts, the adoption of IPM in the country did not reach a significant coverage till the end of the 1990s; of the 2.4 Mtons of cotton produced in 1998, only 0.3% was produced using IPM (Stolton et al., 1999). In 1995, the government then invested in a new educational approach, Farmer Field Schools (FFSs), in order to increase the uptake of IPM. FFSs are based on season-long, experiential learning curricula aiming to improve farmers' ecological knowledge and confidence to make informed management decisions, based on systematic observation of their own fields. They were first developed in 1989 to solve a similar crisis in rice cultivation in Indonesia (Kenmore, 1996; Gallagher, 1992; van den Berg, 2004).

Cotton is one of the most labour-intensive crops in southern India; its labour requirement ranges between 190 and 225 working days/ha (PRDIS, 2003), compared to 29-84 days/ha for maize and 195 days/ha for rice (FAO, 2002). Therefore, the first issue to address is whether the adoption of IPM requires more labour and whether this is gender-characterised. Bennet (1992), argues that there has been an increase in women's labour share in agriculture since 1961 as a result of the significant technical changes introduced by the spread of high-yielding varieties and hybrids, particularly with respect to certain operations such as weeding and harvesting that are performed almost exclusively by women. Duvvury (1989), showed that the increase in female labour share in India was particularly significant in areas where cash crops were grown. Hunter (1969) already had observed that male rather than female tasks get modernised first and that when female tasks do get modernised, they are likely to be taken over by men. Consequently women perform always rather time-consuming and manual tasks, whereas men are typically engaged in performing tasks that involve the use of technical equipment. In the IPM context, it could be expected that the share of female labour in plant protection would increase if IPM techniques are not mechanised and if the opportunity costs of female household members are less than the opportunity costs of male household members. Such would be the case if, for instance, IPM requires handpicking of cotton bollworms larvae, which normally is delegated to children and adult female household members.

That labour organisation has effects on the adoption rate of IPM was already pointed out by Beckmann and Wessler (2003) and the first empirical results were presented by Beckmann et al., (2005). Specifically, if IPM imposes a demand for tasks differentiated by gender or by labour class (i.e. hired versus family labour), then the adoption rate would be influenced by the availability and opportunity costs of the workers belonging to that gender or labour class. However, currently little is known about the actual changes in labour allocation and labour in-

tensity as farms using conventional chemical pest control measures convert to IPM. This study attempts to partially fill this gap by analyzing 3 years' labour data from 95 small-scale cotton farms in Central India in terms of:

1. Gender division of roles and labour contribution (expressed in working hours) before and after the introduction of IPM,
2. Influence of labour organization on the adoption of IPM.

In the following chapter we present the study area and a descriptive analysis of the data followed by the presentation and discussion of the results before the conclusions are presented in the final section.

Material and Methods

Study area and sampling

The study was conducted in two districts of Andhra Pradesh, namely Warangal and Mahaboobnagar. Cotton was grown as the main crop during the rainy season (*Karif*) on 121,260 ha in Warangal and 22,697 ha in Mahaboobnagar. In 2002, season-long Integrated Pest Management Farmer Field Schools (IPM FFSs) in cotton were organised in the study districts by the FAO in collaboration with the Department of Agriculture, Government of India. Participant farmers were selected before the cotton season started on the basis of the area under cotton cultivation and the pesticide use in each district. A labour survey was carried out for 42 IPM FFS farms (20 in Mahaboobnagar and 23 in Warangal) and for 52 (26 in each district) control farms located in the same agro-ecological zone but in villages where no IPM FFS had ever been conducted. However, three records were excluded from the IPM FFS sample on the basis of their non adoption of IPM, the year after the FFS the three trained farmers spent no time on IPM practices and had increased the time spent in applying pesticides. The analysed sample, therefore, included 39 IPM FFS practitioners.

Data

Data on labour use were gathered for two periods, pre (2002) and post (2004) IPM FFSs, by interviewing farmers using a standardised questionnaire. The questionnaire included the total land-holding, the area under cotton, and a list of agricultural operations (which had been identified previously in collaboration with the local farmers). The final number of operations that were commonly practised was 24. The pre-IPM FFS information was retrieved from farm records or collected on a recall basis at the end of 2002. A second round of interviews was conducted in year 2004 at the end of the cropping season. The hours of labour required to perform each operation were recorded under four headings: family female labour, family male labour, hired female labour, and hired male labour. Exchange labour is not a common practice in the area and was excluded from the questionnaire.

Data analysis

This study compared the pre/post changes of the treatment (IPM FFS) group to the pre/post changes of the control group. It used a two-factor design with a repeated measure of one factor. The design had the advantage of allowing control of any built-in, systematic, or seasonal, pre/post change resulting from causes other than the IPM FFS treatment. This is particularly necessary when evaluating FFS impact because FFS participants cannot be considered a random sample of the farming population. Even though the IPM FFS programme did not use explicit criteria to select IPM FFS participants, social and economic factors might have privileged certain groups in the selection process.

The data were analysed by a two-way ANOVA with time as the repeated measure, using the PROCGLM procedure in the statistical analysis system SAS version 6 (SAS Institute, 1994).

Canonical discriminant analysis was performed for the four cases (pre-IPM FFS, post-IPM FFS, pre-Control, post-Control) after appropriate transformations to determine the magnitude and direction of the association of individual variables (i.e. farm operations) for each of the cases (Afifi and Clark, 1984). The operations were pooled according to their affinity to mechanised tasks (ploughing, cultivating, furrows making, intercultivation); to non-mechanised tasks (stubble removal, sowing, gap filling, intercropping, thinning of the crop, unearthing plants, weeding, fetching water for pesticide applications, de-topping, labour supervision, harvesting of crop and inter-crop and cotton grading); and to IPM practices (application of traditional botanical preparations, hand-picking of larvae, and installing pheromone traps). The term mechanised in this context is extended to manual operations that require the use of equipment or simple tools. The operations that were expected to change as a consequence of IPM FFSs in addition were analysed separately i.e. irrigation, fertilizer application, preparation and application of pesticides.

Finally the econometric model described in Beckmann et al., (2005) was used to measure IPM adoption by the amount of time spent on total crop protection. We used the sub-sample of the IPM FFS farmers for the year 2004 and included a number of endogenous variables. The ratio of female over total labour time spent in plant protection before the FFSs was included to see if this had an effect on adoption because our previous results indicated this was a relevant variable. Also, we included the squared ratio, which gives a higher weight to farms with a high female labour share and linearises the effect of female labour on total labour. We further included the ratio of hired labour to total labour for plant protection in the year 2002 to control for the effect of hired labour on IPM adoption. The age of the household head was included as a proxy for learning ability. Further we included the size of the cotton farm and village as blocks (dummy variables) to control for unobserved factors. As the explanatory variable is censored on the lower side by zero and on the upper side by one, the OLS regression model would result in biased and inconsistent estimates. One way to address this problem is to use a two-sided censored Tobit model (Greene, 2003). The Tobit model was developed by Tobin (1958) and it hypothesises the existence of a latent variable, sometimes called an 'index function', which is not actually observed.

Results

The respondents were small-holders, whose primary occupation was self-employment on their own land but who also hired in paid labour at peak periods and hired out their labour services for wages at times of need. There were no significant differences in age (around 35 years) among the respondents. The average land-holding was 1.5 and 2.6 ha, and the area under cotton 0.7 and 1.0 ha, for the IPM FFS and the control group respectively ($P < 0.01$).

Gender division of labour in cotton farming

The currently in-use gender division of labour is described below using the 2002 subset of data. The total time required to cultivate one hectare of cotton was on average 2294 hours, equivalent to 287 8-hour days (Figure 1), of which 74% was provided by women (23% female family labour and 51% waged female labour) and 26% by men (22% male family labour and 4% male waged labour). A high share of waged work was provided by women at peak times, namely at weeding and harvest (Figure 2). In terms of gender roles, the study confirmed that men performed mostly tasks that involved the use of tools and machines, such as preparing the land for cultivation (ploughing and furrow making), while women were in charge of selecting and sowing seeds, removing stalks, ensuring proper plant populations by thinning the crop or filling the gaps, weeding the field and harvesting the lint. The application of fertilizers and pesticides involved both men and women. However, in the case of pesticide application, there was a sharp gender division between men, who carried out the actual spraying, and women, who prepared the chemical mixture and re-filled the tanks. Fetching water was a predominantly female task (requiring 18 h labour /ha); in the analysis this task was included under the non-mechanised operations (Figure 2).

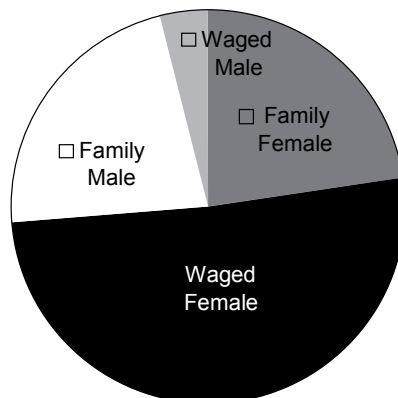


Figure 1. Percentages of family and waged, male and female work, in cotton cultivation, in 2002 in India

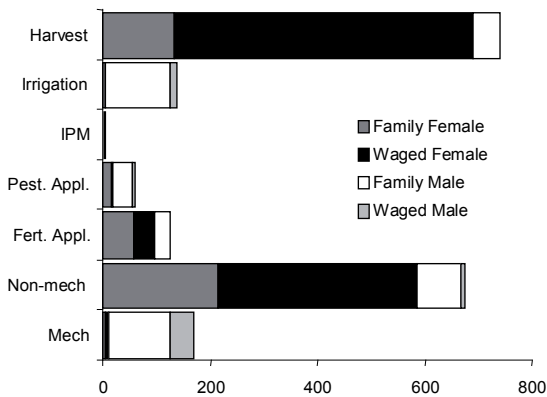


Figure 2. Gender analysis of the labour input in conventional cotton farming (hours/ha) in 2002, India

Changes in the labour pattern induced by the adoption of IPM

Overall, the total labour requirement was not significantly different for the IPM FFS farms (1875.5 and 1666.3 h/ha for the pre and post survey respectively), and the control farms (1951.7 and 1784.2 h/ha for the pre and post survey respectively) (Table 1). The post survey recorded a 11.2-8.6% decrease in the total labour requirement of both farm types as a result of less time being invested in weeding and harvesting. Time spent in fertilizer application increased 14.4% for the IPM FFS and 59.5% for the control group. Both farmers' groups spent significantly less time (29.7 and 52.5% for the IPM FFS and control group respectively) on irrigation in the post survey. The changes in fertilizer application and irrigation can be explained by the fact that in 2002 both districts were declared drought prone, while in 2003 they both received good rainfall, which would have reduced the need for irrigation and also allowed for higher fertilization levels. Control farms also seem to have had better access to irrigation facilities than the IPM FFS farms. The total time spent on plant protection measures (pesticide application and integrated pest management) was around 3.3% of the total in 2002 and 5.2% in 2004, for both IPM FFS and control farms. There were no significant differences between the groups before and after in terms of time spent in plant protection, but there were differences in terms of specific plant protection practices. The control group increased the time spent on applying pesticides by 42.6% and no significant time was spent on IPM practices in either year. The IPM FFS group reduced the time spent on pesticide application by 48.4% and increased the time spent on IPM nearly 11-fold (from 4.8 to 56.3 hours) during the post year.

The ratios of female to total work before and after IPM FFSs for the control group and the IPM FFS group were analysed to investigate eventual changes in the gender roles (Table 2). The only ratios that significantly differed pertained to the plant protection measures and specifically the adoption of IPM. Women contributed 40% of the total work required for chemical control, including time required to fetch water (8-10%) (Table 2). On the contrary, the adoption of IPM shifted the female to total ratio of the time spent in plant protection from 0.31-0.33 to 0.49 i.e. the adoption of IPM resulted in a higher time demand on women. This reliance of IPM on time-demanding and unmechanised tasks explains this shift in labour time allocation.

Hand-picking of larvae to control the bollworm population and to prepare the natural bio-agent Nucleus Polyhedrosis Virus (NPV), the installation of pheromone traps, and the application of herbal extracts had become 'typically' female tasks. The analysis carried out so far evaluates the effects of IPM FFSs regardless of the degree of IPM adoption. The analysis was repeated to exclude from the IPM FFS group eleven farmers who made use of IPM practices but also increased their use of chemical controls (Table 3). In this case the reduction in time spent by the IPM FFS group on pesticide application was larger, from 66.2 to 19.5 hours.

Table 1. Labour use (hours/ha) in the control and IPM FFS farms before and after the IPM FFSs

		Total	Mech ¹	Non-Mech ²	Pesticide	Fertiliser	Irrigation	IPM ³	Plant Prot. ⁴
IPM -FFS	Pre	1875.5 ^{A*}	149.5 ^A	1391.5 ^A	57.8 ^A	168.3 ^A	86.5 ^A	4.8 ^A	62.5 ^A
	Post	1666.3 ^B	108.3 ^B	1199.3 ^B	29.8 ^B	192.5 ^B	60.8 ^B	56.3 ^B	86.3 ^B
Control	Pre	1951.7 ^A	141.0 ^A	1411.0 ^A	64.5 ^A	144.5 ^A	183.5 ^C	0.5 ^C	65.45 ^A
	Post	1784.2 ^B	141.5 ^C	1226.7 ^B	92.0 ^C	230.5 ^B	87.2 ^D	0.0 ^D	92.0 ^B

*Means with the same letter do not significantly differ among them according to the Duncan test. Different letters indicates differences at a significance level of $p < 0.001$.

¹Mechanised tasks: ploughing, cultivating, furrows making, inter-row cultivation.

² Non-mechanised tasks: stubble removal, sowing, gap filling, intercropping, thinning of the crop, unearthing plants, weeding, fetching water for pesticide applications, de-topping, labour supervision and cotton grading.

³ IPM tasks: application of traditional botanical preparations, hand-picking of larvae, and installing pheromone traps.

Table 2. Changes in the ratios female to total work in cotton cultivation before and after the IPM FFS

		Total	Mech	Non-Mech	Pesticide	Fertiliser	Irrigation	IPM	Plant Prot.
IPM FFS	Pre	3.40 ^A	0.018 ^A	0.87 ^A	0.30 ^A	0.54 ^A	0.00 ^A	0.14 ^A	0.33 ^A
	Post	4.00 ^A	0.019 ^A	0.89 ^A	0.22 ^A	0.67 ^A	0.02 ^A	0.50 ^B	0.49 ^B
Control	Pre	3.21 ^A	0.020 ^A	0.89 ^A	0.31 ^A	0.70 ^A	0.06 ^A	0.02 ^C	0.31 ^C
	Post	3.29 ^A	0.005 ^A	0.90 ^A	0.32 ^A	0.68 ^A	0.03 ^A	0.00 ^D	0.32 ^D

*Means with the same letter do not significantly differ from other means in the same column according to the Duncan test. Different letters indicates differences at a significance level of $p < 0.001$.

Combined operations

Stepwise and canonical discriminant analyses showed that IPM FFS and control farms were similar at the time of the pre-survey. However, in the post-survey IPM FFS farms were significantly different ($P < 0.001$) from the control farms (Figure 3). The factors contributing most to the separation between the control and IPM FFS were the time spent on IPM practices, the application of pesticides and fertilizers and irrigation ($P < 0.001$). The time spent on applying fertilizers was positively correlated in all cases with the time spent on irrigating the field (0.33, $p < 0.001$). The use of pesticides was also positively correlated with irrigation in 2002 (0.30; $P < 0.05$), but the correlation turned negative in IPM-converted farms (-0.32; $P < 0.05$). A negative correlation was found also between time spent in applying pesticides and time spent on IPM practices (-0.30; $P < 0.05$).

Table 3. Labour use (hours/ha) in the "practitioners" sub-set of IPM FFS farms before and after the IPM FFS

IPM FFS	Total	Mech	Non-Mech	Pesticide	Fertiliser	Irrigation	IPM	Plant Prot.
Pre	1865.0 ^{A*}	158 ^A	1327.7 ^A	66.2 ^A	195.0 ^A	85.1 ^A	6.5 ^A	72.75 ^A
Post	1599.8 ^B	111.0 ^B	1100.5 ^B	19.5 ^B	224.2 ^B	70.5 ^B	52.3 ^B	71.75 ^A

*Control values are the same as reported in Table 1.

Factors explaining the adoption of IPM

The results indicate that there is an important village effect, which could be explained by the different people organising the IPM FFSs in each village. Two of the three village dummies are highly significant ($P < 0.015$), and so is the age variable at $P < 0.10$, (Table 4). The female labour ratio shows a positive sign and the squared ratio a negative sign, as expected. The ratio of hired labour over total labour for plant protection shows, again as expected, a negative sign. This indicates that the division of plant protection tasks between female and male workers, when measured as a ratio before the IPM training, has a positive impact on IPM adoption in cotton in India. The negative sign of the squared ratio indicates that on farms with an initially high female labour contribution to plant protection (applying pesticides plus time spent on IPM) the adoption of IPM does decrease. Also, the results indicate that the higher the share of hired labour the lower the adoption of IPM (which implies that households with higher recourse to family labour are more likely to adopt IPM). The size of land allocated to cotton was not significantly different.

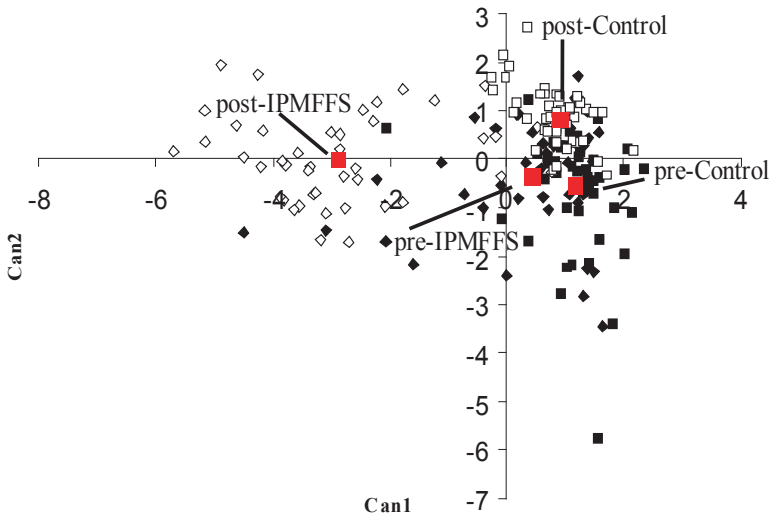


Figure 3. Plot of canonical discriminant variable 2 versus canonical discriminant variable 1 for the four cases (pre-IPM FFS, pre-control, post-IPM FFS and post-control) showing the overall changes in labour patterns

Discussion

The study shows that cultivating cotton is a labour-intensive activity, requiring 287 days/ha, that in small-holding involves a high share of female family work. Even though there is a sharp gender division of labour, plant protection measures involve both men and women, as already observed by (Upadhyay, 2005).

The adoption of IPM did not lead to an increase in the total labour requirement, nor in the time allotted to plant protection measures, which together accounted for 3-5% of the total time for both IPM and control groups. However, significant changes in terms of time allotted to different practices in plant protection were measured. The time spent on applying pesticides increased for the control group in the post survey, whereas it decreased for the IPM FFS group, which led to a 3-fold higher time allotment to pesticides in the control farms. This change could be expected to have beneficial effects on the workers' health (Antle and Pingali, 1994; Kishi et al., 1995; Murphy et al., 1999; Kunstadter et al., 2001). Female and male cotton growers in Andhra Pradesh have reported severe acute poisoning in 10% of pesticide exposure cases (Mancini et al., 2005). In developing tropical countries the replacement of pesticides by non- or less toxic alternatives seems to be the only viable solution to protect farmers' health (Kishi, 2005).

In the case of chemical control, women worked besides men, but after the adoption of IPM the average ratio female to total work for plant protection increased from 0.3 to 0.5, indicating that the operations performed under the umbrella of IPM are considered mainly female tasks. Creating female employment in an occupationally and legally safe environment might be seen as a positive effect considering that most of the women belonging to poor households rely on agricultural wages to meet daily basic needs. However, greater female employment has not always enhanced women' empowerment, particularly in the villages of Andhra Pradesh where women have replaced men in the bonded (unfree) agricultural workforce (Da Corta and Venkatesharlu, 1999). In the labour class analysed by this study, the highest share of work was provided by female family members, who are likely to be burdened with extra, unremunerated work. The only general conclusion on the effects of generating demand for female workers on women's livelihood that can be drawn is the importance of evaluating cases in relation to the socio-economic context.

The adoption rate of IPM was also negatively influenced by the age of the respondent. Godtland (2004) found that the impact of FFS on knowledge decreased with the age of the household head, indicating that management approaches based on "new knowledge" are less likely to be adopted by older farmers. The results of the analysis of the changes in labour time in combination with the results of the model used to explore the adoption of IPM, provide important insights for future IPM programs. They indicate that on average the higher the labour contribution of females in plant protection the higher the adoption of IPM. In the context of this study this implies that the availability of female family labour increases the likelihood that IPM will be adopted. Further, the share of hired labour seems to decrease the adoption of IPM. This confirms the observation by Beckmann et al. (2005) and the general conclusion by Beckmann and Wesseler (2003) that the adoption of IPM to a large extent depends on labour organisa-

tion.

The study does not take into account the time spent by farmers in field observation. An initial attempt to include this aspect in the operations list was made; however, the data collected were discarded because of their poor quality. Farmers visited their fields on a regular basis before and after the IPM FFS, also in the control group, but an accurate quantification in hours was not possible. Tripp et al., (2005) reported similar difficulties in using the time devoted to field monitoring as an indicator of the time spent in monitoring pest populations in his survey of FFSs in Sri Lanka. This is an important gap in that the effectiveness of IPM relies in part on regular and accurate field observation, and thus deserves further investigation using more adequate tools for data capture.

Table 4. IPM adoption measured as the time spent for IPM on the total time spent for plant protection (Tobit Estimates)

Dependent variable	IPM adoption		
	Coefficient (Standard Error)	t	P > t
Hired labour share in plant protection, 2002, %	-0.7421 (0.4278)	-1.73	0.092
Female labour share in plant protection, 2002, %	1.3252 (0.9576)	1.38	0.175
Female labour share in plant protection, 2002, %, squared	-2.7548 (1.6241)	-1.70	0.099
Age of household head in years	-0.1554 (0.0064)	-2.44	0.020
Cotton acreage (ha)	0.0624 (0.0505)	1.24	0.224
Village 2 ¹	-0.2578 (0.1930)	-1.34	0.191
Village 3	-0.6311 (0.1341)	-4.71	0.000
Village 4	-0.8675 (0.1721)	-5.04	0.000
Constant	1.3748 (0.2689)	5.11	0.000
LRChi ²		53.97	
Pseudo R ²		0.6861	
Observations		42	

¹Village 1 corresponds to the base case.

Conclusions

The analysis of the substitution processes between the different tasks in plant protection measures, and the consequences of this for farm-household welfare, are beyond the scope of this study and are left for future research on the topic. However, this study emphasises the importance of analysing gender disaggregated data to better understand these consequences. It would be interesting to know if the observations in this specific case will prove to be a general result for IPM in cotton and for IPM on other crops. If indeed this proves to be a general result than the consequences for farm-household welfare need further investigation.

Acknowledgements

The financial support provided by the EU-FAO IPM Programme for Cotton in Asia and the technical guidance provided by P. Kenmore, P. Ooi, G. Walter-Echols, D. von Werner, P. Pachagounder and the local staff during the fieldwork is gratefully acknowledged. A special thanks is owing to the farmers who collaborated in this survey. We are grateful to the constructive comments from Ariena van Bruggen and Aad Termorshuizen, which helped us to improve the manuscript.

References

- Afifi, A.A., Clark, V., 1984. *Computer-aided Multivariate Analysis*. Van Nostrand Reinhold, New York, USA.
- Antle, J.M., Pingali, P.L., 1994. Pesticides, Productivity, and Farmer Health - a Philippine Case-Study. *American Journal of Agricultural Economics* 76, 418-430.
- Beckmann, V., Wesseler, J., 2003. How labour organization may affect technology adoption: an analytical framework analysing the case of integrated pest management. *Environment and Development Economics* 8, 437-450.
- Beckmann, V., Irawan, E., Wesseler, J., 2005. Does Farm Labour Organization Affect IPM Adoption? Poster paper presented at the Tropentag The Global Food & Product Chain—Dynamics, Innovations, Conflicts, Strategies, October 11 - 13, 2005, University of Hohenheim, Stuttgart, Germany.
- Bennet, L., 1992. *Women Poverty and Productivity in India*. World Bank, Washington, DC, USA. Economic Development Institute Seminar Paper 43.
- CSE (Centre for Science and Environment), 2003. *Pesticide residues in bottled water*, CSE Report. New Delhi, India.
- Da Corta, L., Venkatesharlu, D., 1999. Unfree Relation and the Feminization of Agricultural Labour in Andhra Pradesh, 1970-75. In: Byres T.J., Kapadia, K., Lerche, J. (Eds.), *Rural Labour Relations in India*. Frank Cass Publishers, London, UK, pp. 71-139.
- Duvvury, N., 1989. Work Participation of Women in India: A Study with Special Reference to Female Agricultural Labourers, 1961-1981. In: *Asian Employment Programme, A. (Ed.), Limited Options: Women Workers in Rural India*. International Labour Organization, New Delhi, India.
- FAO (Food and Agriculture Organization), 2002. *Issues and challenges in rice technological development for sustainable food security*. In: *The International Rice Commission*. Bangkok, Thailand.

- Gallagher, K.D., 1992. IPM development in the Indonesian National IPM Program. In: Kadir, A.A.S.A., Barlow, H.S. (Eds.), *Pest management and the environment in 2000*. CAB International, Wallingford, UK, pp. 82-98.
- Greene, W.H., 2003. *Econometric Analysis* 5th Ed., New Jersey: Prentice Hall, USA.
- Godtland, E.M., Sadoulet, E., Janvry, A.d., Murgai, R., Ortiz, O., 2004. The impact of farmer field schools on knowledge and productivity: a study of potato farmers in the Peruvian Andes. *Economic Development and Cultural Change* 53, 63-92.
- Hunter, G., 1969. *Modernizing Peasant Societies: a Comparative Study in Asia and Africa*. New York, Oxford University Press, USA.
- Herring, R., Grodzins Gold, A., 2005. Is there a case for growing cotton in India?, *Indian Cotton: Biology and Utility, Meanings and Histories Workshop*, Cornell University, April 29-30, 2005. A joint venture of Development, Governance and Nature and the Title VI National Resource Center for South Asia, Syracuse and Cornell Universities, USA.
- ICAC (International Cotton Advisory Committee), 2005. *Cotton Production Practices. Technical Information Session*. In: 64TH Plenary Meeting. International Cotton Advisory Committee Liverpool, UK.
- Kenmore, P., 1996. *Integrated Pest Management in Rice*. In: Persley, G. (Ed.), *Biotechnology and Integrated Pest Management*. CAB International, Wallingford, pp. 76-97.
- Kishi, M., 2005. The health impacts of pesticides: What Do We Know, What Can Be Done? In: Pretty, J. (Ed.), *The Pesticide Detox*. Earthscan, London, Sterling, VA, pp. 23-38.
- Kishi, M., Irschhorn, N., Djajadisastra, M., Satterlee, L.N., Strowman, S., Dilts, R., 1995. Relationship of pesticide spraying to signs and symptoms in Indonesian farmers. *Scandinavian Journal of Work, Environment & Health* 21, 124-133.
- Kunstadter, P., Prapamontol, T., Siririjn, B.O., Sontirat, A., Tansuhaj, A., Khamboonruang, C., 2001. Pesticide exposure among Hmong farmers in Thailand. *International Journal of Occupational Environmental Health* 7, 313-325.
- Mancini F., van Bruggen A. H. C., Jiggins J.L.S., Ambatipudi A., Murphy H., 2005. Incidence of Acute Pesticide Poisoning Among Female and Male Cotton Growers In India. *International Journal of Occupational and Environmental Health* 11, 221-232.
- Murphy, H., Sanusi, A., Dilts, R., Djajadisastra, M., Hirschhorn, N., Yuliantiningsih, S., 1999. Health effects of pesticide use among women Indonesian farmers: Part I: Exposure and acute effects. *Journal of Agromedicine* 6, 61-85.
- PRDIS, 2003. *Impact Assessment of Cotton Integrated Pest Management Training Through Farmer Field School Approach*. Report for the FAO-EU IPM Programme for cotton in Asia, FAO Regional Office, Bangkok, Thailand.
- SAS Institute, 1994. *SAS/STAT User's Guide for Personal Computers, Version 6* Cary, NC: SAS Institute.
- Stolton, S., Meyer, D., 1999. *Organic Cotton – From Field to Final Product*. ITDG Publishing, Warwickshire, UK.
- Tobin, J., 1958. Estimation of Relationships for Limited Dependent Variables. *Econometrica* 26, 24-36.
- Tripp, R., Wijeratne, M., Piyadasa, V.H., 2005. What should we expect from farmer field schools? A Sri Lanka case study. *World Development* 33, 1705-1720.
- Upadhyay, B., 2005. Women and natural resource management: Illustration from India and Nepal. *Natural Resources Forum* 29, 224-232.
- van den Berg, H., 2004. *IPM Farmer Field Schools: A synthesis of 25 impact evaluations*. Wageningen University, The Netherlands.

CHAPTER 5

Environmental Impact Assessment of Cotton Cultivation in Central India

Karst J. Kooistra, Francesca Mancini and Aad J. Termorshuizen

Submitted to Agriculture, Ecosystems and Environment

Abstract

To estimate environmental impact of rain-fed cotton production systems in Central and South India, a Life Cycle Assessment (LCA) of 15 conventional, 10 Integrated Pest Management (IPM), and 12 organic cotton-growing farms was carried out. Five indicators - the Environmental Index Quotient (EIQ), Global Warming Potential, Acidification Potential, Eutrophication Potential, and Erosion Potential - were selected to perform the LCA. In conventional farming, extremely and highly hazardous pesticides (WHO toxicity classes I and II) were largely used to control pests. In IPM systems, less toxic pesticides were used and applications were dependent on agro-ecosystem analysis performed by farmers. With respect to the use of artificial fertilisers, IPM had slightly less negative environmental impact than conventional farming. In the IPM and conventional systems the organic matter was burned in the fields, but this practice was omitted at the organic farms, resulting in considerably lower Global Warming Potential in the organic systems. The nitrogen requirements in organic systems were met by cropping leguminous plants in rotation and by applying farmyard manure applications. The EIQ values - which accounted for the impact generated by the pesticide use - were 257, 62, and 0 per tonne of raw cotton for conventional, IPM and organic systems respectively. Global Warming Potential was 1839, 1962, and 2 CO₂- equivalents per tonne - of cotton, for conventional, IPM and organic farms respectively. N₂O, which is formed during the production of artificial fertilisers and during open-air burning of organic residues, is the main factor contributing to the Global Warming Potential, accounting for 61% at conventional and 71% at IPM farming systems. Acidification was low for all farming systems. Eutrophication was higher for conventional systems (3.1 kg PO₄-equivalent per tonne of cotton with NH₃ accounting for 46%) than for IPM systems (1.0 kg PO₄-equivalent per tonne NH₃ 15%) and organic systems (1.2 kg PO₄-equivalent per tonne NH₃ 93%). The conventional farms had an estimated average annual soil loss of 804 kg tonne⁻¹ of cotton. IPM and organic farms led to significantly lower loss of soil, equivalent to 495 kg tonne⁻¹ for IPM farms, 422 kg tonne⁻¹ for organic farms. Soil loss occurs

mainly due to sloping of the field and lack of conservation measures (e.g. ridging, terraces). In conclusion, organic systems have a lower environmental impact per tonne of cotton and per tonne per unit of area, which is mainly caused by the use of synthetic fertilisers and the burning of organic residues in conventional and IPM systems. The 20-50% lower yield in organic systems however requires a larger area for the cotton to be produced.

Keywords: LCA; Cotton; Environmental Impact; Conventional; Integrated Pest Management; Organic; India

Introduction

There is a growing concern about the sustainability of modern agriculture in the past 40 years, since it appears to bring about chemical contamination, global warming, eutrophication, acidification and erosion (European Environment Agency, 1998). Cotton is one of the crops known to have a notably severe impact on the environment, due to its high water demand as well as the intensive use of pesticides and fertilisers. In many cotton-growing areas water and pesticide use is not strictly regulated, and the use of pesticides is less restricted than is the case of food crops. It has been estimated that 10% of world's pesticides are being used for cotton cultivation (PAN UK, 2001), while cotton is cropped only on 2.5% of the world's agricultural area (FAO, 2003).

India is one of the countries increasingly suffering from the negative side-effects of cotton cultivation, mainly due to the combination of an enhanced production (0.6 Mtonne in 1950 to 2.5 Mtonne in 2002, NIRD, 2003) and indiscriminate use of chemical inputs paired with ineffective extension of farmers about sustainable farm management (Krishna et al., 2002). Depletion and pollution of natural resources has become a major environmental concern in the country. In states with intensive cotton cultivation, high levels of nitrates are found in the ground water. Pesticide residues – up to hundred times higher than the European Economic Community's directives permit – have been found in 14 brands of bottled drinking water and soft drinks. Of the 2.4 Mtonne of cotton produced in 1998, only 0.3% was produced according to Integrated Pest Management (IPM) and 0.05% according to organic management (Stolton and Meyer, 1999).

At the beginning of the millennium, the national agricultural policy of the Government of India issued an urgent plea to adopt technologies which are economically viable, environmentally friendly and socially acceptable. Ever since, the Food and Agriculture Organisation (FAO) of the United Nations has collaborated with the Government to promote sustainable, pesticide-free cotton cultivation through farmers' education in Farmer Field Schools (FFS). IPM FFS are field-based training courses that aim to preserve natural resources and sustain small-scale agriculture profitability (Kenmore, 1996; van den Berg, 2004).

This study presents a comparative analysis of three types of cotton production – conventional, integrated, and organic - on the basis of their impact on the environment using Life

Cycle Assessment (LCA) methods. LCA evaluates the mass balance of in- and outputs of systems converting them into environmental categories that relate to human health and ecological effects. It embraces all elements involved in the production of the item under study (ISO, 2001). A number of indicators namely Environmental Index Quotient (EIQ), Global Warming Potential, Acidification Potential, Eutrophication Potential and Erosion Potential were used to perform the LCA. The EIQ accounts for effects of pesticides on water resources and partially on biodiversity. The consequences of pesticide use for human health were explored in a parallel survey conducted in the same area (Mancini et al., 2005). The emissions from a selection of conventional, integrated, and certified organic farms were quantified and the environmental impact of these emissions calculated. To the best of the authors' knowledge, except for an LCA study focussing on irrigation systems in cotton cultivation (Tobler and Schaerer, 2002), no other comparative LCA has been done on cotton production. The results generated by the current LCA and similar studies might support policy-makers in designing production strategies that promote a more sustainable agriculture and stimulate cotton traders to further develop their sustainability targets.

Material and Methods

Types of farm management

Three types of cotton production systems were distinguished: (1) conventional management, characterised by the use of pesticides, mineral fertiliser, the use of modern cotton hybrids and varieties, and only occasionally crop rotation; (2) Integrated Pest Management (IPM), promoted by the Indian government in collaboration with FAO (FAO, 2000), characterized by limited pesticide applications and alternative crop protection measures based on monitoring pests, diseases and weeds, regular mineral fertiliser use, and crop rotation; (3) certified organic management, which excludes the use of synthetic inputs and relies on organic fertilizers while striving for (near-) closed nutrient cycles. The most resistant available cotton varieties are generally used and crop rotation is applied in organic production.

Selection of farms

The study was conducted in three districts in Central India: Warangal, Amravati, and Yavatmal. These are the few areas where cotton is produced certified organically according to the European export standards. The districts receive respectively 800, 700, and 800 mm of rainfall annually and the average temperatures during the growing season range between 18-41°C (daily minima and maxima respectively, NIRD, 2003). Despite the low rainfall, agriculture is primarily rain-fed and this is a major factor limiting productivity. The traditional, small mix-cropped cotton farms (< 2 ha) cover approximately 56%, the mid-sized ones (2-6 ha) 32% and the large (> 6 ha), mostly mono-cropped cotton farms, 13% of the cotton area (ICAC, 2005). Fifteen conventional, 10 IPM and 12 organic farms with similar agronomic characteristics were selected

for this study. All farms were situated on Black Cotton soils (Vertisols), except 5 conventional farms, which were on Red Soils (Alfisols and Mixed-Laterite).

Life Cycle Assessment

The impact of the three management types on the environment was assessed using the Life Cycle Assessment (LCA) tool (ISO, 2001; Guinee, 2000). The system investigated in this study was an arable farming system with the main function of cotton production. The geographical coverage was limited to the area of the farm. Production inputs were only considered for pesticides, fuel and mineral fertilisers. Impacts caused by the construction of the farm, machinery, tools and roads were excluded since they were considered to be equal for all the participating farms. Further, side effects of veterinary medicines for cattle, soil runoff to surface water due to erosion, increased cost of cleaning drinking water, and the slurry and silage effluent of livestock were not considered in this study. The processing of the cotton fiber after harvest is also beyond the scope of this paper. Two functional units are used: one tonne of raw seedcotton and one hectare. It is assumed that denitrification does not take place (thus no production of N_2O from soil), since the soil is quite dry and denitrification usually takes place under wet soil conditions.

Data collection and questionnaire

Data were gathered during the cotton-growing season 2003/2004. The questionnaire included general data about the farmer and his/her family, composition of the farm (crops, labour), cultural measures (mechanised labour, pesticide types and quantities, mineral fertiliser types and quantities, fuel use, etc.) and harvested yields. A summary of the farms characteristics is given in Table 1. All questionnaires were executed by the first author, in co-operation with an experienced interpreter specialised in agriculture. All fields were inspected by the first author for an estimation of crop cover, slopes and soil type.

Indicators

To evaluate the inventory data, the different in- and outputs were summarised into environmental effects, the indicators. Classical product LCA's and farm level LCA's differ in the selection of indicators. For instance, solid waste and photo-oxidants are applied in classical LCA's (Klöppfer and Klöppfer, 1994 and 2003), but not necessarily at the farm level (Geier, 2000), because they are not the central issues in the environmental impact of agriculture (Haber and Salzwedel, 1992; Hellweg and Geisler, 2003; Finnveden and Ekvall, 1998; Finnveden and Potting, 1999). Instead, at the farm level, Haas et al. (2000) considered resource consumption, Global Warming Potential, soil function (acidification, erosion), water quality (eutrophication), human toxicity, ecotoxicity, biodiversity, landscape image and animal husbandry as key indicators. Based on the time frame of the research and the availability of information, the Environmental Index Quotient (EIQ), Global Warming Potential (GWP), Acidification Potential (AP), Eutrofication Potential (EP) and Universal Soil Loss Equation (USLE) were chosen as indicators (EPA, 2001).

Environmental Index Quotient (EIQ)

Pesticides are evaluated for the mode of action, the half-life residues on plant surface, the toxicity to fish, birds, bees and beneficial insects, the long-term health effects and ground water and runoff potential (Kovach et al., 1996). Individual EIQ values are calculated on the basis of the pesticide type and quantity used for each application and individual values are then summed to determine the final EIQ value of each farm. For two of the pesticides a value had to be estimated since no value is yet determined. The following equation has been used:

$$EIQt \times qt \times at,$$

where EIQt = EIQ of pesticide t according to Kovach et al. (1996), qt = quantity of pesticide t applied ha⁻¹ or tonne⁻¹ cotton and at = the area (ha) pesticide t has been applied to.

Global Warming Potential (GWP)

GWP represents the contribution of gaseous emissions to climate change for the coming 100 years. To estimate the GWP the emission of CO₂, CH₄ and N₂O, the burning of organic material, the burning of fuel and the application of fertilisers was estimated (Table 1). Emissions generated by pesticide production were negligible. The CH₄ production by the cattle providing the traction has not been included, as it is considered on an average similar for the three cases. The function of agricultural fields acting as a sink for CO₂ has not been taken into account. For the calculation of the GWP the following equation is used:

$$MF + FYM + BOM + FUEL + NU,$$

where MF = Mineral fertilizers (kg ha⁻¹ or tonne⁻¹ cotton), FYM = Farm-Yard Manure (kg ha⁻¹ or tonne⁻¹ cotton), BOM = Burned Organic Material (kg ha⁻¹ or tonne⁻¹ cotton), FUEL = Fuel Use (kg ha⁻¹ or tonne⁻¹ cotton), NU = Nitrogen use (kg ha⁻¹ or tonne⁻¹ cotton).

Each factor is calculated by multiplying a component (e.g. SO₂ released during artificial fertilizer production) by its corresponding emission factor and classification factor, divided by hectare and production ha⁻¹ (Eurostat, 1991; France and Thompson 1993; IPCC, 1997; Bouwman, 1995; CORINNAIR, 1996; Kroeze and Vis., 1997; Barker et al., 2002).

Acidification Potential (AP)

AP represents the effects of cotton production on acidification of natural ecosystems (Audsley et al., 1997). For the estimation of the AP the emission of SO₂, NH₃ and NO₂ were taken into account, and the emitted quantities derived from the use of mineral fertilisers, diesel, pesticides, farm-yard manure and the burning of organic material (Hoogenkamp, 1992; France and Thompson 1993; Frischknecht et al., 1994; RIVM-EDGAR, 1995; IPCC, 1997).

$$MF + FYM + BOM$$

Eutrophication Potential (EP)

EP is usually subdivided in terrestrial and aquatic eutrophication. In this case terrestrial data are taken into account only due the lack of aquatic data. To estimate EP, the emissions of NO_3 , P, PO_4 , NH_3 and NO_2 were taken into account. The emitted quantities were derived from the used amounts of mineral fertiliser, diesel, pesticides, farmyard manure, the burnt organic material and the estimated quantity of leaching

$$\text{MF} + \text{FYM} + \text{BOM} + \text{LE},$$

where LE = Leaching (kg ha^{-1} or tonne^{-1} cotton).

The emission factors used were reported in Bøckman et al., 1990; Hoogenkamp, 1992; France and Thompson 1993; Frischknecht et al., 1994; RIVM-EDGAR, 1995; IPCC, 1996; Hanegraaf et al., 1998.

Universal Soil Loss Equation (USLE)

The USLE (Wishmeier and Smith, 1978) method to estimate the erosion potential of a field includes rainfall, soil erodibility, a topographic factor including slope (%) and slope length, cultural measures, and conservation practices. All these factors are indexed and multiplied to obtain the Erosion Potential, expressed in $\text{tonne ha}^{-1} \text{ yr}^{-1}$. Rainfall is based on a heterogeneous rainfall pattern over the year. Soil erodibility is directly derived from soil type (Wishmeier and Smith, 1978). The cropping and management factor represents an indexed value for the type of crop (cover of soil) and the duration of coverage. Finally, the conservation factor represents the measures taken to prevent erosion, like erosion stopping hills and direction of the ridges on the field. The equation is:

$$A = R \times K \times LS \times C \times P,$$

where A = Computed average annual soil erosion loss (tonnes ha^{-1}), R = Rainfall factor [-], K = Soil erodibility factor [-], LS = Topographic Factor [-], C = Cropping and management factor [-], P = Conservation practices factor [-].

Aggregation of inventory data

To calculate GWP, AP and EP indicators inventory data (fertiliser and pesticide use, labour, agronomic practices) are translated in data that can be compared among farms. E.g. for GWP, the emissions of CO_2 , N_2O , and CH_4 are aggregated by defining CO_2 equivalents by multiplying the original value by the classification factors 1, 270, and 21 respectively. The reason for this is that the impact on GWP of N_2O and CH_4 is respectively 270 and 21 times more severe than the impact of CO_2 . The classification factors used are given in Table 1.

Canoco analysis

A Discriminant Analysis (*sensu* ter Braak and Smilauer, 2002) was carried out using the software program Canoco (Canonical Variate Analysis; ter Braak and Smilauer, 2002) with farms as 'samples', and type of farm (organic, conventional, IPM) as 'species'. Best linear combinations to discriminate between the types of farms were based on the Environmental Index Quotient, Global Warming Potential, Acidification Potential, Eutrophication Potential and Erosion Potential and two uncorrelated axes were calculated.

Table 1. Classification factors used to translate emissions into CO₂ equivalents

Global Warming		Acidification		Eutrophication	
	CO ₂ eq (1 kg)		SO ₂ eq (1 kg)		PO ₄ eq (1 kg)
CO ₂	1	SO ₂	1	PO ₄	1
CH ₄	21	NH ₃	0.462	NO ₃	0.1
N ₂ O	270	NO ₂	1.147	P	0.09
				NH ₃	0.11
				NO ₂	0.05

Results

Description of the agronomic practices

Rotation cycles including pigeon pea (*Cajanus cajan*), green gram (*Vigna radiata*), horse gram (*Dolichos biflorus*), and black gram (*Vigna mungo*) were common for all three management systems, but 8 conventional farms and 5 IPM farm were growing cotton continuously and in monoculture. Except for one conventional (#1) and one IPM farm (#21) (Table 2), all others were rain-fed.

All farms used animal traction for the field labour, except for one conventional, which used a tractor. Conventional and IPM farms used mineral fertiliser, pesticides and power sprayers (gasoline engine) for pesticide application. Weeds and old cotton stalks were burnt to clean up the fields in conventional and IPM systems, whereas this practice was not allowed for the organic farms, here, all organic material was left on the field.

Individual indicator values for the three farm types: organic, IPM and conventional

Environmental Impact Quotient

The EIQ values were 257, 62 and 0 tonne⁻¹ of raw cotton for conventional, IPM, and organic management systems respectively (Figure 1, A I and II). In conventionally managed farming systems the insecticide Monocrotophos (WHO toxicity class IB) contributes on average 37% to the total EIQ value. Next are the insecticides Chlorpyrifos (WHO toxicity class 2; 14%) and Endosulfan (WHO toxicity class 2, 12%). The impact of the IPM system was mainly due to

Table 2. Location, size, practices and yields of the three farm types, organic, IPm and conventional, surveyed

	Farm No.	Region ¹	Farm size (ha)	Rotation ²	N ³	P ³	FYM ⁴	Org. ⁵	Pesticide spray /year	Soil type ⁶	Yield kg/ha
C	1*	W	7.2	R	0	0	0	0		B	1198
o	2	W	2	C	151	59	2500	10	0	B	593
n	3	W	2	R	116	70	3750	12	5	B	519
v	4	W	0.8	C	45	59	0	16	7	B	1186
e	5	W	4	C	95	40	0	12	9	B	655
n	6	W	1.6	C	177	97	2813	20	5	B	704
t	7	W	3.2	C	94	78	0	10	3	B	931
i	8	W	0.6	C	60	28	1875	10	3	B	531
o	9	W	2	C	107	52	0	20	3	B	642
n	10	W	3.2	R	83	60	0	12	6	B	741
a	11	A	9.6	R	23	0	750	0	4	R	716
l	12	A	8	R	0	0	1125	0	3	R	766
	13	A	4.8	R	0	0	1000	12.5	7	R	741
	14	A	8	R	0	0	1000	21	3	R	543
	15	A	3.4	C	0	0	83	52.5	2	R	716
I	16	W	3.2	C	0	0	0	20	3	B	1556
P	17	W	2.4	C	108	50	0	0	2	B	976
M	18	W	4.8	R	130	108	1500	15	6	B	2668
	19	W	3.2	R	94	54	0	0	2	B	766
	20	W	2.4	R	115	93	320	12	2	B	1334
	21*	W	2.8	R	76	83	0	6	2	B	1198
	22	W	3.2	R	110	41	0	6	3	B	679
	23	W	1.6	C	156	84	0	11	1	B	889
	24	W	2.4	C	111	25	0	15	5	B	600
O	25	W	2.4	C	80	58	0	7	0	B	272
r	26	A	40	R	0	0	500	0	0	B	618
g	27	A	14	R	0	0	500	0	0	B	494
a	28	A	8	R	0	0	0	0	0	B	469
n	29	A	18	R	0	0	1000	0	0	B	692
i	30	A	15.2	R	0	0	469	0	0	B	395
c	31	A	16	R	0	0	500	0	0	B	519
	32	A	10.4	R	0	0	375	0	0	B	543
	33	A	17.2	R	0	0	500	0	0	B	593
	34	A	19.2	R	0	0	1000	0	0	B	741
	35	A	22	R	0	0	1000	0	0	B	679
	36	Y	8	R	0	0	125	0	0	B	632
	37	Y	104	R	0	0	500	0	0	B	593

* Irrigated farms #1 and #21; ¹ w = Warangal, a = Amravati, y = Yavatmal.

² r = rotation present, c = continuous cotton, no rotation present.

³ N and P applied as artificial fertilizers (kg ha⁻¹) respectively.

⁴ FYM = farm-yard manure (kg ha⁻¹).

⁵ = Organic residue burnt 10⁻² Kg/ha.

⁶ b = black cotton soils (Vertisols), r = red cotton soils (Mixed Laterite Soils).

the application of insecticides belonging to lower hazard classes such as Imidacloprid (WHO toxicity class 3; 23%), Acephate (WHO toxicity class 3; 18%), Chlorpyrifos (WHO toxicity class 2; 10%), and Spinosad (unlikely to present acute hazard in normal use, commonly called WHO Class U; 8%). The organic systems have no impact in this category since no pesticides were applied. Locally-produced plant extracts (like neem oil) may have been used, although the first author did not notice it during his visits. Neem-based biopesticides are classified under the green colour according to the National colour code, which is likely to correspond to WHO class U.

Global Warming Potential

GWP was 1232, 1559, and 1.23 kg CO₂-equivalents ha⁻¹ or 1839, 1962, and 2.05 kg tonne kg⁻¹ of cotton, for the conventional, IPM and organic farms respectively (Figure 1, B I and II). N₂O is the main component responsible for the contribution of the conventional (61%) and IPM (71%) management systems and it is not relevant for the organic systems. CO₂ is responsible for 23% of the contribution of the conventional farms, 21% for the IPM and not relevant for the organic farms. CH₄ is responsible for 16% of the contribution of the conventional farms, 7% for the IPM farms and 100% for the organic farms. In conventional farms on average 53% of the impact on GWP is caused by the consequences of the use of mineral fertiliser, the remaining part is caused by the burning of stalks and weeds (32%), fuel use (8%) and use of manure (7%). For IPM farms 72% of the impact on GWP is caused by the use of artificial fertiliser, burning of organic material contributes 26% and fuel use 2%. Finally, the impact of organic farms is fully caused by the application of FYM, which results in formation of methane.

Acidification Potential

The AP amounts to 15, 10, and 1.4 kg SO₂-equivalents ha⁻¹ or 22, 12 and 2.2 kg⁻¹ tonne cotton- (Figure 1, C I and II). -NO₂ is the main responsible factor in the conventional (71%) and IPM (79%) management systems, but it is not relevant for the organic farms. SO₂ is responsible for 6% of the contribution in the conventional, 17% in the IPM and is again not relevant for the organic farms. Finally NH₃ contributes 23% to the total of the impact of conventional, 4% for IPM and 100% for the organic systems. For conventional systems, 55% of the impact is caused by the consequences of burning organic material, the remaining part is caused by the use of manure (20%), artificial fertilisers (16%), fuel use (8%) and the use of pesticides (1%). For IPM systems, these figures are 54, 2, 39, 5, and 1% respectively. The IPM farms are not using manure. Since organic farms do not burn organic material nor apply artificial fertiliser the value remains low. Also 3 conventional and 2 IPM farms apply the same practices and have therefore a low Acidification Potential.

Eutrophication Potential

The EP was 1.9, 0.9 and 0.7 kg PO₄-equivalents ha⁻¹ or 3.1, 1.0 and 1.2 kg⁻¹ tonne raw cotton (Figure. D, I and II). NO₂ contributes 39% to the impact of conventional, 38% for IPM and zero to the organic management systems.

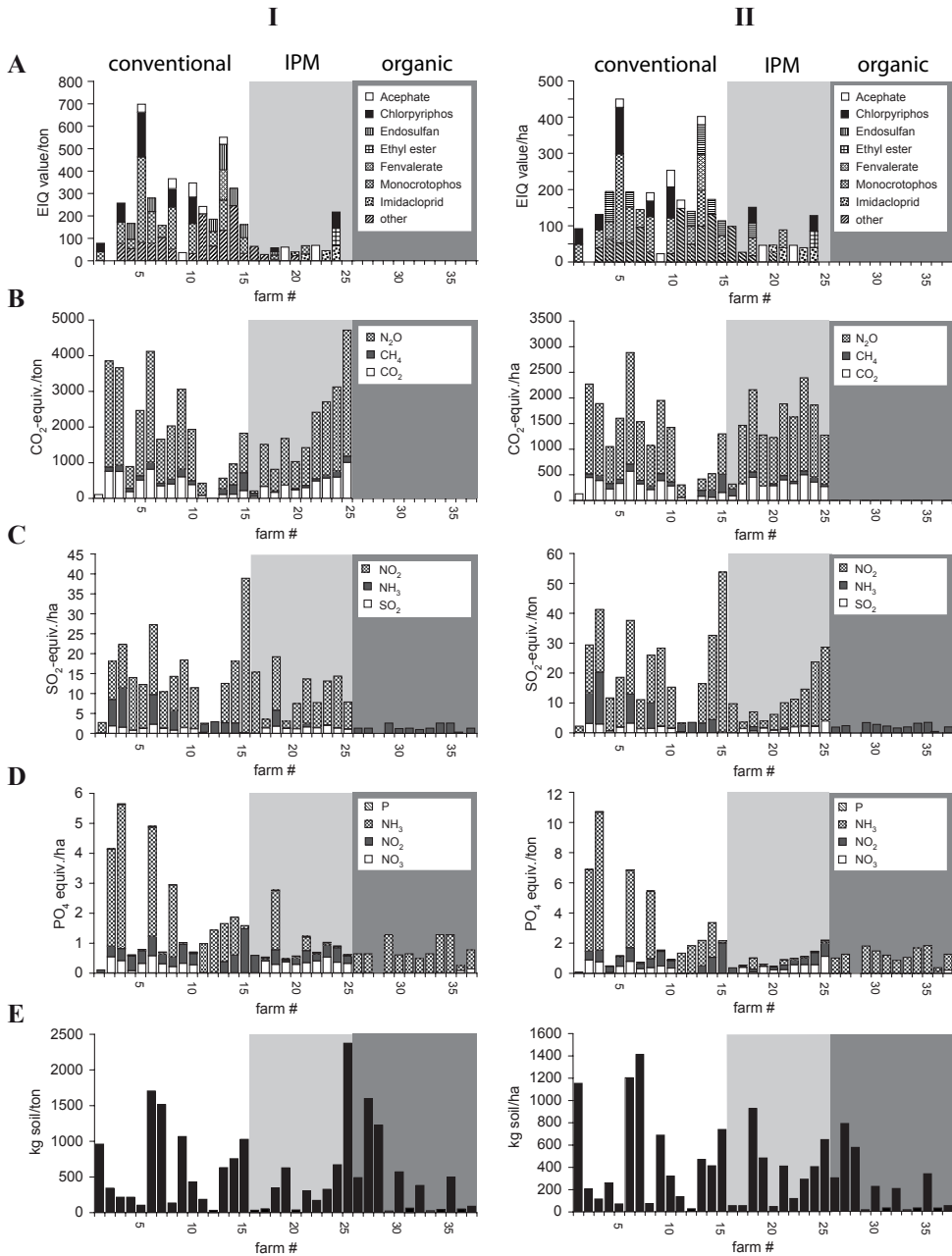


Figure 1. Environmental impact indicators expressed per farm and system (conventional, IPM and organic). Rows represent the indicators (A= EIQ-value, B= Global Warming, CO_2 -equivalents, C= Acidification, SO_2 -equivalents, D= Eutrophication, kg PO_4 -equivalents, and E= erosion, kg), columns distinguish between expression per tonne (I) and hectare (II)

NO₃ is responsible for 14% of the potential impact of the conventional management system, for IPM it is 44% and for organic 7%. NH₃ is responsible for 46% of the conventional impact, 15% of the IPM impact and 93% of the organic impact. Finally the contribution of P to the Eutrophication Potential is 1.1% for the conventional, 2.6 for the IPM and 0.0 for the organic systems. The impact of conventional systems is for 41% due to the use of farm-yard manure, 30% due to the burning of organic material, 7% to the use of fuel, 5% to the use of artificial fertiliser and 1% to pesticide production. For IPM systems these figures are 9, 30, 2, 14 and 1% respectively.

Erosion Potential

Organic matter content and soil fraction distribution were estimated based on samples from nearby farms. The conventional farms had an average annual soil loss of 591 kg ha⁻¹ or 804 kg tonne⁻¹ of raw cotton, compared to 351 or 495 kg for IPM farms 218 and 422 for organic farms (Figure 1, E I and II). IPM and organic farmers adopted cultural measures to contain erosion.

Combined effects of the five indicators

The Discriminant Analysis confirms the results of the separate indicators in that the organic systems are well-separated from the other two systems (Figure 2). The variation in EIQ and GWP contributes most to this separation. IPM and conventional systems are most separation by the Eutrophication index, which is higher for the conventional systems.

Discussion

Much is being claimed about the environmental sustainability of organic cotton production and about the environmental pollution incited by conventional cotton production, but quantitative data underpinning the claims have not been described in the scientific literature. Here, we clearly show that the organic farming systems in the area studied have a far lower impact on the environment than the other cotton farming systems. The indicators that contributed the most to the differentiation of the systems were the EIQ and the Eutrophication. The major reason for this difference can be ascribed to the use of mineral fertilisers and pesticides and the burning of organic material in conventional and IPM systems. IPM had a comparatively lower environmental impact than conventional systems on the basis of the reduced pesticide use. Considerable differences were found among farms, but the differences between farm management systems predominated.

Organic farming had EIQ values equal to zero as no pesticides, including biopesticides, were used in the farms. The EIQ values in IPM farms were <75% compared to those found for conventional farms. This is likely due to the IPM FFS training organised to train farmers on preserving natural enemies and strengthening plant health to control pests and diseases. As a result, pesticide use was cut down to minimum levels, whereas mineral fertilisers were still used. The impact of pesticides shows a particularly high EIQ value for farm #5 which

is caused by the use of monocrotophos (WHO toxicity class IB). Because of its potential hazards (toxicity to humans, including carcinogenicity, reproductive and developmental toxicity, neurotoxicity, and acute toxicity), it has officially been banned in 18 countries and the import is not legal in 46 countries, but it is still legally and widely used in cotton production in India.

For the Eutrophication Potential (EP) the difference among the systems was less evident. The impact of organic farms is per tonne of cotton higher than that of IPM farms, and more than three times lower than for conventional systems, since NH_3 by farmyard manure and NO_3 (N-content soil/legumes) have an important contribution to EP. The conventional and IPM systems could reduce by 5 and 14% respectively their EP values, if artificial fertiliser were not used. However, the use of inorganic nitrogen in the conventional farms in India (63 kg ha^{-1}) is already low compared to cotton fertilization in other countries: 200 kg ha^{-1} in Turkey; 150 in Australia; 112 in Pakistan; 100 in China and USA (ICAC, 2005) and the replacement of artificial fertilizers with farm-yard manure to lower the Eutrophication Potential is not an option, as the former has a similar polluting potential. Therefore, increasing intercropping and widening the rotation is recommended to reduce the EP potential and maintain soil fertility for the three systems.

The Acidification Potential (AP) of conventional and IPM cotton farms were around 10, resp. 5 times higher than that of organic cotton production systems. The AP was largely due to the burning of stalks. Burning of organic residues on the field after harvest, which occurred on almost all IPM and conventional farms, was carried out to destroy weeds and their seeds and clearing the land for the next crop. Burning organic matter is not allowed in organic farming systems. The high AP value for conventional farm #15 is caused by the burning of excessive quantities of weeds on the field. Renouncing the burning of organic materials on the field would lower the AP of conventional and IPM farming systems by 56 and 54% respectively, but also the GWP by 32 and 26% respectively, and the EP by 30% for both these farming systems.

The Global Warming Potential (GWP) was negligible in organic farms. In conventional and IPM farms the GWP could be further reduced by at least 50%, if artificial fertilisers were not used. However, this measure could not be implemented without compromising the crop productivity unless care is taken to regenerate the natural soil fertility, as already discussed. Erosion turns out to be at an acceptably low level (Webster, 2001) for most farms. However, since the slope length is a topographic factor in the estimation of potential soil erosion, this environmental impact factor can hardly be changed by farm management. In terms of minimising environmental impact, the best practices would be to avoid the removal of organic matter from the field, increase green manuring and replace the use of pesticides with IPM practices such as planting of flowering strips around the fields.

LCA findings can be extrapolated from farm to regional level by adopting a farm classification system, assuming uniformity of farmer practices and production systems within a class (Dalgaard et al., 2004). Farms with a similar production scale in the country cover 87% of the land under cotton, but a great diversity can be found in terms of practices within the group. Passing to an evaluation at regional level would require more than adding up the evalu-

ations of single farms (von Wiren-Lehr, 2001). At regional scale, interactions between farms on emissions of pollutants due to exchanges of products, by-products or waste material and on the consumption of resources need to be explored (Nielsen, 1999). Additional studies are therefore required to bridge the integration levels providing information on farm classifications and using new indicators for farms' interactions. Scaling up to country level would be even more dangerous. Nevertheless, countries such as Pakistan, parts of China, Benin or Mali have farm types with an input use level comparable to the Indian farms sampled in the study and may have similar environmental impacts.

The methodology has a number of limitations. The method used to calculate Global Warming Potential (GWP) is somewhat disputable since all emission factors are fixed and comply with a theoretical farm system (Wegener Sleeswijk et al, 1996). It is, however, not known what the precise effect of local circumstances is on GWP-related emission factors, but it is not unlikely that e.g. local production methods for mineral fertiliser affects total emission. Furthermore, emissions are likely to be affected by manure management, by the method of burning organic material, the quality of the diesel and efficiency of the tractor engine on the emission during combustion. Since all these influences are assumed to be the same for all farms, potential differences do not become apparent here. Similar approaches in other studies (e.g. Haas et al., 2001) make it plausible that these factors do not influence the final result significantly, but they may influence conclusions if comparisons are made with other regions in the world. Some environmental aspects such as pesticide use, impact on biodiversity, drinking water quality, human and animal health as well as water consumption were only partially or not at all addressed due to the unavailability of reliable data in the study area. In a more extended study, soil tillage activities should be taken into account in more detail, since they likely affect the nutrient flow and energy balance of the cotton production system. Finally, a monthly monitoring of the farms would increase the accuracy of the data.

Despite these limitations, this study provided important insight in how to contain the pollution generated by cotton production. Therefore, it would be useful to carry out similar studies to compare different systems not covered by the current survey, such as rain fed versus large scale (irrigated and intensive) farms.

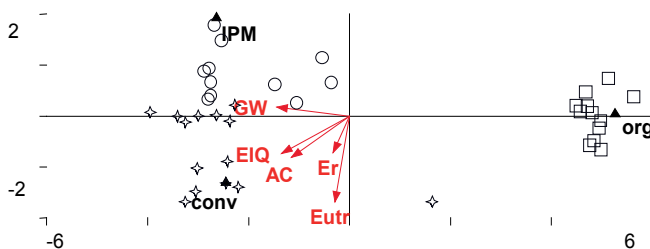


Figure 2. Plot of canonical discriminant variable 1 versus canonical discriminant variable 2 for the conventional systems (stars), IPM systems (circles) and organic farming systems (squares), with the weights of the LCA indicators given (EQ = Environmental Impact Quotient, GW = Global Warming AC = Acidification index, Eutri = Eutrophication index, Er = Erosion index). Closed triangles are the centroids of the three farming systems

Conclusions

The use of artificial fertilisers and the burning of organic matter, together with the application of chemical pesticides, contribute most significantly to the environmental impact of cotton cultivation systems assessed in this study. The organic management systems had by far the lowest potential impact due to the fact that artificial inputs were not used nor were organic materials burned. However, there were considerable differences in the yields: organic fields (580 kg ha^{-1}) produced on an average nearly 50% less than fields in IPM farms (1093 kg ha^{-1}) and 20% less than those in conventional farms (745 kg ha^{-1}). Even though the cost of cultivation was most likely lower in organic farms than in the other two systems studied, organic growers have to pay the costs of certifying their production method and only an economical analysis can establish the profitability of organic production for the farmers. Yields under rain fed conditions are constrained by the erratic distribution of rainfall (Mandal et al., 2005), the inherent poor soil fertility (Blaise and Ravindran, 2003), and pest severity. These factors are likely to have played a greater role in organic farms than in the other systems. There is a need to reduce the impact of agriculture, and particularly of cash crops like cotton, on the environment without compromising on farmers' economical livelihood.

We conclude that the LCA method used in this study is an efficient method to analyse the environmental problems related to farming systems. Organic systems score much better than conventional and IPM systems, but the yields of organic systems are too low. The variation between farms within conventional and IPM systems is large. The most urgent issue in the conventional systems is the use of hazardous pesticides.

Acknowledgements

Among all the people who helped realising this study, the authors would like to thank the staff of the EU-FAO IPM Programme for Cotton in Asia who kindly assisted with the field survey. Special thanks are due to the late Sha Shank Deshpande. The authors are also very grateful to Goede Waar & Co., a critical consumers organization in Amsterdam, The Netherlands, and especially to Jan-Willem Mulder for the assistance and financial support provided.

References

- Audsley, A., Alber, S., Clift, R., Cowell, S., Crettaz, R., Gaillard, G., Hausheer, J., Jolliet, O., Kleijn, R., Mortensen, B., Pearce, D., Roger, E., Teulon, H., Weidema, B., Zeijts, H. van, 1997. Harmonisation of Life Cycle assessment for Agriculture. Final Report, action AIR3-CT94-2028, European commission DGVI, Brussels, Belgium.
- Barker, J.C., Hodges, S.C., Walls, F.R., 2002. Livestock manure production rates and nitrogen content. North Carolina Department of Agriculture and Consumer Services. Available at: <http://ipm.ncsu.edu/agchem/chptr10/1011.pdf>.
- Berg van den, H., 2004. IPM Farmer Field Schools: A synthesis of 25 impact evaluations. Wageningen

- University, The Netherlands, prepared for the Global IPM Facility.
- Blaise, D., Ravindran, C.D., 2003. Influence of tillage and residue management on growth and yield of cotton grown on a vertisol over 5 years in a semi-arid region of India. *Soil and Tillage Research*, (70) 2:163-173.
- Bøckman, O.C., Kaarstad, O., Lie, O.H., Richards, I., 1990. Agriculture and fertilizers. Agricultural group, Norsk Hydro, Oslo, Norway.
- Bouwman A.F., 1995. Compilation of a global inventory of emissions of Nitrous oxide. Ph.D. thesis, University of Wageningen, The Netherlands.
- CORINNAIR, 1996. Atmospheric Emissions Inventory Guidebook. In: EMEP/CORINNAIR Atmospheric Emissions Inventory Guidebook, 2nd edition, 1999. Dalgaard, T., Halberg, N., Kristensen I.S., Larsen, I., 2004. An LC inventory base don representative and coherent farm types. In: Proceedings of the Fourth International Conference on Life Cycle Assessment in Agri-food sector, Bygholm, Denmark; DIAS Report no. 61, October 6-8 2003, Tjele, Denmark, pp. 98-106.
- EPA, 2001. United States Environmental Protection Agency.
- European Environment Agency. 1998. Soil Degradation, and Climate change. In: Europe's Environment: The Second Assessment, Elsevier Amsterdam, p. 293.
- EUROSTAT, 1991. Energiebilanzen-Energy Balance Sheets-Bilans de l'Énergie. Office des publications officielles des Communautés Europeennes, Luxembourg.
- FAO (Food and Agriculture Organisation of the United Nations), 2000. International Code of Conduct on the Distribution and Use of Pesticides. Hundred and Twenty-third Session of the FAO Council in November 2002.
- FAO (Food and Agriculture Organisation of the United Nations), 2003. FAOstat. Agricultural Bulletin Board on Data Collection, Dissemination and Quality of Statistics, Food and Agriculture Organisation, United Nations, Rome, Italy.
- Finnveden, G., Ekvall, T., 1998. Life Cycle Assessment as a decision support tool - The Case of Recycling vs. Incineration of Paper. *Resources. Conservation and Recycling* 24, p. 235-256.
- Finnveden, G., Potting, J., 1999. Eutrophication as an impact category. *International Journal of Life Cycle Analysis* (4) 6, 311-314.
- France, G.D., Thompson, D.C., 1993. An overview of efficient manufacturing processes. In: Proceedings of the Fertilizer Society no. 337. Greenhill House, Petersborough, UK
- Frischknecht, R., Dones, R., Bollens, U., Bosshart, S., Ciot, M., Ciseri, L., Doka, G., Hirschler, R., Martin, A., Grabner, U., 1994. Ökoinventaire von energiesystem. Bundesamt für Energiewirtschaft, Bern, CH.
- Geier, U., 2000. Anwendung der Ökobilanzmethode in der Landwirtschaft-dargestellt am beispiel einer Prozess-Ökobilanz konventioneller und organischer Bewirtschaftung. Ph.D. thesis, Institute of Organic Agriculture, University of Bonn, Germany.
- Guinee, J.B., 2000. Life Cycle Assessment: An operational guide to the ISO standards. Ministry of Housing, Spatial planning and Environment (VROM) and the Centre of environmental Science-Leiden University (CML), The Netherlands.
- Haas, G., Wetterich, F., Geier, U., 2000. Life Cycle Assessment Framework in agriculture on the Farm Level. *International Journal of Life Cycle Analysis* 5, 345-348.
- Haas, G., Wetterich, F., Kopke, U., 2001. Comparing intensive, extensified and organic grassland farming in southern Germany by process life cycle assessment. *Agriculture Ecosystems & Environment* 83, 43-53.
- Haber, W., Salzwedel, J., 1992. Umweltprobleme der Landwirtschaft. In: Der Rat von Sachverständigen für Umweltfragen (Eds.): Metzler-Pöschel, Stuttgart, Germany p. 76.
- Hanegraaf, E., Biewinga, E., Van der Bijl, G., 1998. Assessing the Ecological and Economic Sustainability of Energy crops; *Biomass and Bioenergy*, 15, 345-355.
- Hellweg, S., Geisler, G., 2003. Life Cycle Impact Assessment of Pesticides. *International Journal of Life Cycle Analysis* (8) 5
- Hoogenkamp, A.W.H.M., 1992. Productie van fosfaatmeststoffen. In SPIN (Samenwerkingsproject Projectbeschrijvingen Industrie Nederland); RIVM report. National Institute for Public Health and the

- environment, Bilthoven, The Netherlands.
- ICAC (International Cotton Advisory Committee), 2005. Cotton Production Practices. Technical Information Session. 64TH Plenary Meeting, Liverpool, UK.
- IPCC (International Panel of Climate Change), 1996. IPPC guidelines for national greenhouse gas inventories. In: Greenhouse gas inventory reference manual. IPPC, London, UK.
- IPCC (International Panel of Climate Change), 1997. Greenhouse gas inventories reference manual, revised edition 1996. Vol.3, IPPC, Bracknell, UK.
- ISO (International Organisation for Standardisation), 2001. Environmental management-Life Cycle Assessment- Principles and Framework. International Standard ISO 14040, ISO, Geneva.
- Kenmore, P., 1996. Integrated Pest Management in Rice. In: G. Persley (Eds.): Biotechnology and Integrated Pest Management, CAB International, Wallingford, pp.76-97.
- Klöppfer, W., Renner, I., 1994. A methodology of Impact Assessment within the framework of Life Cycle Assessment taking into account environmental categories which cannot (or only with difficulty) be quantified (in German). In federal Environmental Agency (Ed.) (1995); Methodik der produktbezogenen ökobalancen-Wirkungsbilanz und Bewertung. Texte 23/95, Berlin, Germany. p. 80.
- Klöppfer, W., 2003. Life-Cycle based Methods for Sustainable Product development. The International Journal of Life Cycle Assessment (8) 3, 157-159.
- Kovach, J., Petzoldt, C., Degni, J., Tette, J., 1996. A Method to Measure the Environmental Impact of Pesticides. New York's Food and Life Sciences Bulletin No. 139, New York State Agricultural Experiment Station, Geneva, NY 14456.
- Krishna, V.V., Byju, N.G., Tamizhenyan, S., 2002. Integrated pest management in Indian agriculture: a developing economy perspective Department of Agricultural Economics, University of Agricultural Sciences, Bangalore, India.
- Kroeze, J., Vis, J.C., 1997. Application of two methods for N₂O emission estimates to Bulgaria and The Netherlands. IdoJaras. Quarterly Journal of Hungarian Meteorological Service. N.101, pp 239-260.
- Mancini F., van Bruggen A.H.C., Jiggins L.S.J., Ambatipudi A., Murphy, H., 2005. Acute pesticide poisoning of cotton growers in Andhra Pradesh. International Journal of Occupational and Environmental Health; 11, 221-232.
- Mandal, D.K., Mandal, C., Venugopalan, M.V., 2005. Suitability of cotton cultivation in shrink-swell soils in central India. Agricultural Systems 84, 55-75.
- Nielsen, V., 1999. The effect of collaboration between cattle farms on the labour requirement and machinery costs. Journal of Agricultural Engineering Research 72, 2:197-203.
- NIRD (National Institute of Rural Development), 2003. Rural Development Statistics 2002-03, Hyderabad, India.
- PAN UK (Pesticide Action Network), 2001. Development House, London, United Kingdom.
- RIVM-EDGAR (Rijksinstituut voor Volksgezondheid en Milieu; Emission Database for Global Atmospheric Research), 1995. Data on emissions. Available at <http://www.mnp.nl/edgar/>.
- Stolton, S., Meyer, D., 1999. Organic Cotton – From Field to Final Product, ITDG Publishing
- Ter Braak, C.J.F., Smilauer, P., 2002. Canoco reference manual and canodraw for windows user's guide. Biometris, Wageningen.
- Tobler, M., Schaerer, S., 2002. Environmental impacts of different cotton growing regimes, Conference proceedings, International Cotton Conference, Bremen, March 2002.
- Von Wiren-Lehr S., 2001. Sustainability in agriculture – an evaluation of principal goal-oriented concepts to close the gap between theory and practice, Agriculture Ecosystems and Environment 84, 2:115-129.
- Webster, D., 2001. Soil erosion. In: Soils in our environments. Miller R.W. and Gardiner D.T. (Eds.). Prentice Hall, Upper Saddle river, New Jersey, p. 410-440.
- Wegener Sleeswijk, A., Kleijn, R., Meeusen - van Onna, M.J.G., 1996 Toepassing van LCA voor agrarische producten, CML Leiden.
- Wishmeier, W.H., Smith, D.H., 1978. Predicting rainfall erosion losses- a guide to conservation planning. Agric. Handbook, no. 537, USDA, Washington D.C.

CHAPTER 6

Evaluating Cotton Integrated Pest Management (IPM) Farmer Field School Outcomes using the Sustainable Livelihoods Approach in India

Francesca Mancini, Ariena H.C. van Bruggen and Janice L.S. Jiggins

Abstract

Farmer Field Schools (FFSs) were conducted in Southern India to reduce pesticide input and enhance sustainability of cotton production systems. This study was carried out to determine the additional benefits of FFSs in the social and economic arena, using the Sustainable Livelihoods (SL) concept to frame the evaluation. Farmers who had participated in the IPM FFSs perceived a range of impacts much beyond the adoption of IPM practices. The reduced cost of cultivation allowed for financial recovery from debt and the building of physical assets. IPM FFS households and production systems were perceived by the participants to have become more economically resilient than non-IPM FFS control groups when faced with adversity. In the participants' view, IPM FFSs also led to enhanced individual and community social well-being, a benefit valued in particular by the women participants. The study tested a new application of the SL conceptual framework as a tool for evaluation. A SWOT analysis of its strengths and limitations suggests it has considerable potential in impact evaluation that complements other evaluation approaches.

Keywords: Impact Assessment, Farmer Field Schools, Integrated Pest Management, Sustainable Livelihoods Concept

Introduction

Farmer Field Schools provide people-centred experiential learning experiences that promote the empowerment of farmers through education. They were first applied on a wide scale in 1989 in Indonesia in order to reduce reliance on pesticides in rice by enhancing farmers' understanding of crop ecology (Kenmore, 1996). In India, FFSs have been organised for a number of crops, but especially to reduce the massive use of pesticides in cotton production. The training curriculum has engaged researchers, extensionists and farmers in on-site participatory research to compare Integrated Pest Management (IPM) options with the currently-in-use farmer practices. IPM management decisions are based on the results of an

agro-ecosystem analysis of field observations and measurements carried out by the farmers. The critical thinking and dialogue encouraged among participant farmers by the analytical process are considered central to the experiential learning process. Farmers are expected to increase their knowledge but, even more, to master new management skills based on an informed understanding of what is happening in their own fields, and to develop independence from the recommendations circulated by the extension service and pesticide salesmen. These recommendations promote heavy use of agricultural inputs (fertilisers and pesticides) that result in a decline in natural enemies and resurgence of insecticide-resistant pests in rain-fed cotton fields in southern India. As farmers take out loans to pay for the inputs, they become dependent on moneylenders and continued pesticide use, which is frequently ineffective and uneconomic. Any reduction in pesticide use as a result of FFSs is seen as a desirable outcome that increases farmers' profits, but also protects people's health. The extent of pesticide poisoning occurring in the cotton farming communities as a consequence of the massive use of highly toxic products has been documented since the beginning of the 1990s.

This study took place in the context of the FAO-EU-Government of India IPM Programme for Cotton in Asia that was implemented in southern India from 1999 through 2004. The cotton IPM FFSs devoted significant time to team-building activities and emphasised participants' self-development, partnership, and collaboration. They led in many instances to local post-FFSs self-development projects following the farmers' own interests. Farmer alumni groups were formed in the villages the year after the conclusion of the schools, to continue experimenting on crop production methods but also to organise social activities for the benefit of other members of the community. The IPM FFS sessions also became, in some cases, a space for women to express their views outside the house walls, and an opportunity for them to participate in large farmers' gatherings and in official meetings with policy makers. Women farmers in a selected sample of the cotton IPM FFSs were trained to identify the signs and symptoms of acute poisoning and to analyse the consequences of unsafe pest management behaviour (Mancini et al., 2005). Women were particularly involved in assessing the safety of their households, of water sources, and food in relation to the storage of chemical products.

It follows that the impacts of the cotton IPM FFSs could be expected to go much beyond a decrease in pesticide use, to include effects on the environment, health, social organisation and human capital i.e. they could be expected to initiate a process of capacity building that leads to people's empowerment. Evaluation methods therefore are needed that go beyond a pre-determined agricultural focus to appreciate the broader effects that might result from educating farmers, and that capture farmers' own appreciation of these values. Participatory methodologies, either used in synergy with conventional methodologies (such as standard questionnaires) or on their own, have gained increasing support (Mohr, 1999; Jiggins, 2003). Some authors even consider 'independent' evaluation as contradictory to the principles of activities that support people's empowerment (Bartlett, 2005). The literature on IPM FFS evaluation offers a number of studies that have addressed specific impact categories, using either qualitative or quantitative methodologies and including participatory, conventional, and hybrid approaches (for pesticide use see Feder et al., 2004; Wu et al., 2005 for changes in

knowledge and attitude Rola et al., 2002; Reddy and Suryamani, 2004; for health effects and costs see Rola and Pingali, 1993)

This study tests an evaluation framework that guides farmers in conceptualising changes over time in their overall livelihood. It formed part of a larger monitoring and evaluation (M&E) effort (2003-2005) in the same farmer communities that has used a mix of conventional and participatory methodologies to triangulate findings. A complementary effort to capture IPM FFS participants' perception of their experience was also made, using a photo-visioning method (Mancini and Jiggins, in prep.). The framework used in this study draws on the definition of Sustainable Livelihoods (SL) formulated by Chambers and Conway (1992):

"A livelihood is held to comprise the capabilities, assets, and activities required for securing a means of living. A livelihood is considered sustainable when it can cope with and recover from stresses and shocks; maintain or enhance its capabilities and assets in the present and through time, without degrading the natural resource base."

The concept was operationalised in the early 1990s by a number of development agencies (e.g. DFID, Oxfam, CARE and UNDP) as a guide to programme development and a sizeable bibliography on this application is available in the on-line libraries of the organisations concerned (http://www.careinternational.org.uk/resource_centre/livelihoods.htm; <http://www.livelihoods.org/index.html>; <http://www.dfid.gov.uk>; <http://www.undp.org/sl/Documents/documents.htm>). The SL also has been adapted for evaluation purposes (Haan, 2002), but has never been used to assess IPM FFSs. The present study has adopted the U.K. Department for International Development's formulation. It serves as a guide to assessing SL in an holistic but flexible perspective (Haan, 2002), without using pre-defined indicators. It allows for links between changes in different capitals to be revealed. The aim of the study was to test the SL framework to document the emic perception of change in people's livelihoods since they attended IPM FFS (or over the same time period without IPM FFS for the control groups). Two cases are presented: case 1 reports farmers' perceptions of changes over time after a favourable cropping season in Warangal district, while case 2 reports farmers' perceptions of change during a severe drought. In conclusion, the article presents an analysis of the limitations and strengths of the framework.

Material and Methods

Study Area

Cotton IPM FFSs were held in 2002 in Dharwad District, Karnataka (KA) State and in 2003 in Warangal, Andhra Pradesh (AP) State. Cotton was grown as the main crop during the rainy season on 119 and 125 thousand ha, in Warangal and Dharwad, respectively. Calendar-based applications (up to 19 per season) of pesticides, including applications of highly toxic products (24% of the total quantity), are practised by the majority of growers (PRDIS, 2003). Yet yields are among the lowest in the world - 221 Kg/ha for 2004 (ICAC, 2005), against the world average of 603 kg/ha.

Sampling

Six IPM FFS villages from the pool of schools organised in the two districts, and six control villages within the same agro-ecological zone but at least 20 km apart from the IPM FFS villages, were selected for the study. A total of 95 respondents were invited to participate in the assessment. The participation was free and no incentives were provided. The following three categories were included: IPM FFS = male and female farmers trained in IPM FFS; Non-IPM FFS= farmers living in the IPM FFS villages, but not trained in IPM FFS; Control = farmers living in villages where IPM FFS have never been conducted (Table 1). The Non-IPM FFS case was included because the possibility of diffusion of the effects to farmers living in the surrounding areas has been discussed in a number of studies and has led to conflicting conclusions concerning the cost-effectiveness of IPM FFS impacts (van de Fliert, 1993).

Table 1. Sample size of participants in IPM FFS, Non-IPM FFS and control villages by gender

By gender	IPM FFS	Non-IPM FFS	Control	Total
Men	12	12	23	47
Women	13	9	26	48
Total	25	21	49	95

IPM FFS = participants in IPM FFSs, Non-IPM FFS = farmers living in IPM FFS villages, but not themselves participants, Control = farmers living in villages where IPM FFSs have never been conducted.

Rating of the capital stocks

The SL framework is constructed around the identification of capital assets that individuals can access, augment, and manage in the interplay of need and opportunity to sustain their livelihoods. The five capitals are in brief described below, with the entities where IPM FFSs might be expected to have a direct impact indicated in italic font:

Natural capital: natural resource stocks from which resource flows are derived, including land, water, biodiversity, landscapes etc.;

Social capital: social assets, such as networks, memberships in groups, relationships, and the wider institutions of society;

Human capital: assets such as skills, knowledge, ability to work, good health, creativity etc.;

Physical capital: basic built infrastructure (roads, wells, hospitals, energy, communications etc.), tools and equipment;

Financial capital: financial assets (savings, loans, credit, remittances, pensions and other transfers).

The framework assumes that a stronger and more sustainable capital base is inherently empowering (Bartlett, 2004). It is content-led; it does not address asset functions or functioning (Dorward et al., 2001).

In order to visualise the five capitals and aid analysis, recourse was made to 'spider diagram ming'. The participatory assessment consisted of the following steps. First each respondent was questioned to elicit the meaning to the respondent of each of the capitals, and the most valued assets in each capital stock, during an interview conducted by trained facilita-

tors. An outline diagram was drawn on a poster sheet and the meanings elicited for each capital stock were listed by the relevant axis of the web. The questions were framed in terms of: “what do you value the most, and in which form, in your livelihood in terms of natural, human, social, physical and financial capitals?” Secondly, the respondents rated the capital stocks identified, for the baseline year (2002) and for the impact year (2003), on a 0-5 scale, with the zero value (no stock) at the centre of the diagram and the value 5 at the other extreme of each of the axes, corresponding to the respondent’s full satisfaction regarding the capital stock in her or his possession. Thereafter any changes made visible between the two reference years were discussed and causes attributed to the changes were noted on the poster sheet. (The possible biases introduced by the recall process concerning estimation of stocks in the baseline year are addressed in the discussion section).

Data analysis

The initial process of generating and interpreting findings was participatory. However, the data were further processed by the authors, using parametric and non-parametric statistical analysis as detailed below, to compare changes reported by the different groups.

Analysis of the elicited meanings of the five capitals

The meanings listed by the respondents under each of the capitals were analysed to determine whether the farmers interviewed in the three sample populations in each of the two cases belong to similar epistemic communities. Subsequently, the descriptions of the capital stocks were analysed to capture farmers’ livelihoods at the two reference periods. Non-parametric statistical analysis (free-listing and consensus analysis) of the results was carried out using the software Anthropac 4 (Analytic Technologies, Harvard, MA).

Analysis of the capitals’ stocks in the baseline and the year after the IPM FFSs (spider diagrams)

The spider diagrams were instrumental to the visualisation of changes perceived over time and for making visible respondents’ perceptions of the connections between capitals. The visualisation became a dialogic tool for reflection and discussion of the attribution of the causes of the changes recorded. Quantitative analysis also was conducted on the rating values (Table 2). Median values of the capitals for the baseline and the impact year were calculated and compared for the three sample populations and both the two cases. Significant differences were determined using the Wilcoxon Matched-Pairs Signed-Ranks Test (van der Waerden, 1969), a non-parametric test alternative to the Student-t test for ordinal data that applies to two-sample designs involving repeated measures, matched pairs, or “before” and “after” measures. The data were also analysed by gender to highlight gendered perceptions of outcomes.

Secondly, stepwise and canonical discriminant analyses were performed to determine whether the three groups, within and between the cases, could be separated based on the changes in all capitals simultaneously. The analysis also established which of the changes in capitals contributed most to the distinction among groups (IPM FFS, Non-IPM FFS, control)

(Afifi and Clark, 1984). The proportions of change in each of the capital assets between years were calculated and log-transformed to obtain normality, and subsequently were standardised, a requirement for discriminant analysis, and then processed using the statistical analysis system SAS version 6 (SAS Institute, 1994).

Table 2. Median values of the five capital stocks in 2002 and 2003 for the three groups

Warangal	N	Year	Natural	Physical	Human	Social	Financial
FFS	11	2002	2	2	3	3	3
		2004	4	3	4	4	4
Non-FFS	11	2002	2	3	3	3	3
		2004	4	2	4	4	3
Control	24	2002	3	3	3	3	3
		2004	3	3	3	3	3
Dharwad							
FFS	14	2002	2	2	2	2	2
		2004	2	2	4	4	2.5
Non-FFS	10	2002	2	2	2	1	2.5
		2004	2	1	3	2.5	1
Control	25	2002	3	3	3	3	3
		2004	2	4	4	4	3

Results

The consensus among respondents in the entire sample with respect to the meaning of their capital assets was high. The pseudoreliability factor (PRF) - a measure of reliability - was 0.99 for the natural capital, 0.98 for the human capital, 0.99 for the social capital, 0.98 for the financial capital and 0.98 for the physical capital. A PRF value close to 1 indicates a high degree of consensus. The Eigenvectors - three additional factors that assess the salience of the domain - confirmed that the variability was largely explained within the same epistemic community (for further information on the analytical procedure see Ryan et al., 2000). In the authors' view, establishing the degree of consensus regarding the capitals was necessary before a comparative analysis could be carried out. The lists of meanings attributed to the capitals were categorised (Table 3) to describe the main assets perceived as comprising the livelihood of the cotton farmers. Before proceeding further with presentation of the results, the authors summarise the key qualitative aspects of the respondents' livelihood that were elicited in the discussions that resulted from the spider diagramming.

The participants had rain-fed agriculture as the first or their only source of income. Growing cotton required a high initial cash investment in seeds, fertilisers and pesticides, which was not always regenerated by the marketing of the lint. Sporadic rains, heavy pest loads, and pest outbreaks (bollworms and sucking pests), combined with fluctuating output prices meant that it was a risky activity. Nevertheless, the crop occasionally fetched good financial returns and it was in hope of this that they continued to grow the crop. Educational opportunities were highly rated, with information, knowledge and training seen as the preferred

means for pursuing personal and social growth. A good health status was seen as central to human capital. The majority of the respondents felt the need to be supported by governmental and local institutions, particularly by the officials of the department of agriculture. However, the respondents also emphasised the importance of developing a higher degree of independence from governmental institutions by strengthening their own organisations.

Table 3. Categories of responses identified under the five capitals (natural, human, social, financial, and physical) We now turn to the more detailed results of the two cases

Natural capital	Human	Social	Financial	Physical
Climate and weather	Contact with and support of others		Marriage and ceremonies	
Food	Personal features	Knowledge and information	Food	Transport
Health	Happiness	Services	Household, household goods and basic needs	Gold
	Health	Institutional support	Health	Agriculture
Land			Travel	Clothes
Landscape and nature elements	Social ties and responsibilities	Solidarity	Clothing	Communication
Pests and		Social ties	Education	Services
Water	Knowledge and information	Social work, commitment	Future needs	Household and household goods
Yields			Agriculture	Food

The same categories might appear under more than one capital according to respondents' reporting.

Case 1: Warangal District

The first case study was carried out after a favourable farming season. in Warangal district (Figure 1). In 2003, the rainfall regime was particularly favourable to cotton cultivation, which clearly was reflected in the yield, 565 kg/ha (CAB, 2005).

Natural Capital

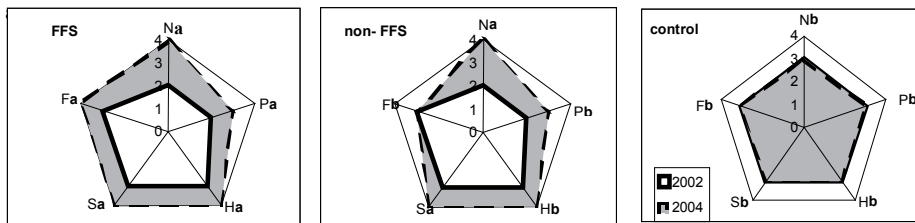
The respondents shared deep concerns about the long-lasting polluting effects caused by deforestation, industry, vehicles, and the use of chemical inputs in agriculture. Women claimed that the contamination of fodder by the use of pesticides had reduced the production of milk by cows and buffaloes qualitatively and quantitatively. In the IPM FFS villages, the respondents' environmental concern was mitigated by the reduction in pesticide use in cotton reported by a majority of the respondents, although they said they were still using pesticides in other crops. The perceived benefits of living in a cleaner environment as a result of reduced pesticide use in cotton - including gains for both human and livestock health – were indicated in the discussion of the scores of both participants and non participants in the IPM FFS villages.

Financial and Physical Capitals

The IPM FFS farmers perceived an improvement in their financial capital while the Non-IPM FFS and control farmers reported no significant change. The respondents related this finding to differences in credit exposure. Most of the Non-IPM FFS and control respondents had purchased pesticides and fertilisers on credit during the cropping season, as is the usual practice. The loans were repaid with the cash generated by the marketing of the lint. The gross margin was neutralised by the high cultivation input costs incurred and by the repayment of interest on their loans. IPM FFS farmers needed less credit as they had significantly reduced their pesticide purchases and had more net profit to invest in repaying debts and/or building physical capital. Where Non-IPM FFS respondents indicated an increase over time in their physical assets, they related this in contrast to other factors, such as land inheritance.

Human and Social Capitals

IPM FFS and Non-IPM FFS farmers perceived that their social and human capitals had increased, while control farmers perceived no change. The IPM FFS farmers attributed their personal growth to the knowledge and skills acquired through the field schools. The effect in this case was also extended to the Non-IPM FFS respondents. New farmer clubs had been formed after the completion of the IPM FFSs, whose agendas including on-site experimentation as well as social activities designed to help the poorest and most vulnerable (e.g., a mass marriage, a tractor race, small income generating activities such as neem seed collection by single women). As a result, the villagers enjoyed stronger social ties and collaboration among themselves. At the same time, in the control villages the respondents noted that various government development schemes had promoted and financially supported the formation of officially registered self-help groups. However, the lack of cohesion, common interest and shared strategies among the members was perceived as limiting the functionality and effectiveness of these groups.



a = significant ($P < 0.05$); b = non significant

Figure 1. Changes in capital stocks recorded between the baseline year (2002) and the impact year (2004) by three groups of farmers (IPM FFS, Non-IPM FFS and Control) in Warangal. N = natural capital, P = physical capital, H = human capital, S = social capital, F = financial capital.

Case 2: Dharwad District

The second case study was carried out at the end of a stressful season (Figure 2). Dharwad

District was subject to a severe drought in 2003-2004 and farmers experienced dramatic consequences ranging from negligible yields to complete crop failure.

Natural Capital

IPM FFS and Non IPM FFS farmers recorded no significant change in natural capital; control farmers perceived a significant decrease. The lack of rain was the major negative factor cited, which was linked by the respondents to the increasing deforestation over the last decade. IPM FFS farmers were affected by the drought but their perspective focussed on the long-term improvement in the management of their natural resource assets (e.g., soil fertility), which they perceived as an important step towards a more sustainable farm production system.

Financial and Physical Capitals

IPM FFS farmers perceived no change in their financial and physical capitals. The IPM FFS farmers explained that they had not incurred major financial losses, despite the drought and the poor harvest, thanks to decreased input purchases and reduced health expenditures. Non-IPM FFS respondents, in contrast, were caught in the usual debt trap because they had not changed their crop management, and they had had to run down their financial and physical assets. In the control villages, farmers reported a financial loss, but the drought had not affected their physical capital assets because of various development interventions in their villages.

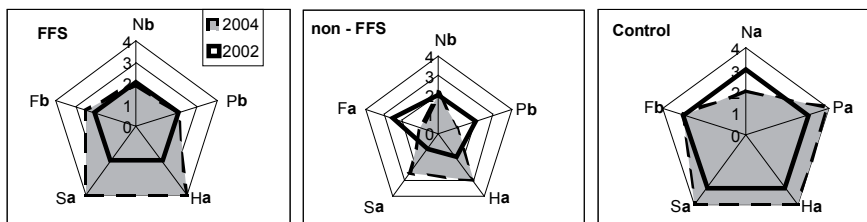


Figure 2. Changes in capital stocks recorded between the baseline year (2002) and the impact year (2004) by three groups of farmers (IPM FFS, Non-IPM FFS and Control) in Dharwad. N=natural capital, P=physical capital, H=human capital, S=social capital, F=financial capital.

Human and Social Capitals

All respondents perceived that their human and social capitals had increased remarkably. IPM FFS farmers claimed to have developed better decision skills that helped them to relate to the reality of the drought. The most significant improvement was perceived to be an increased ability and confidence in choosing their management practices on the basis of field observations, resulting in cash savings and higher yields. The visibility of these farmers in the district had increased, with the beginnings of collaboration between IPM Clubs, the department of agriculture, and local universities. The increase in their human capital was perceived in terms of new knowledge acquired and the establishment of new contacts – effects also reported by the Non-IPM FFS respondents. However, in the latter case, the perceived increase in human capital did not have positive spill over effects on their financial and physical capitals. This finding might support the respondents' comments that skills based on ecologically-informed understanding do not spontaneously diffuse as easily as information on simple practices.

Overall effects of the five capitals

Canonical discriminant analyses showed that the three groups overall were significantly different in respect of the changes perceived over the years 2002/2003 (significance level $P < 0.0001$ for the Warangal district, and $P = 0.01$ for the Dharwad district) (Figure 3). The control group was the most different from the other two groups in both cases. The factors distinguishing the control group from the other two were the changes perceived by IPM FFS and Non IPM FFS respondents in natural, physical and social capitals in Warangal district and in social capital in Dharwad district. The data for IPM FFS and Non-IPM FFS respondents were hardly different in the two cases ($P=0.08$ for Warangal and $P=0.75$ for Dharwad). This suggests again that there was a substantial impact of the IPM FFSs on non-participants in the same villages, especially in Dharwad, as already visualized in the spider diagrams. The discriminant analysis also showed that there were significant ($P < 0.0001$) correlations between financial and physical capitals (0.45 and 0.70 for Warangal and Dharwad, respectively), and between social and human capitals (0.44 and 0.51 for the Warangal and Dharwad districts, respectively). These correlations suggest that variations in the stock of one capital are tightly linked to change in other capital stocks – an effect claimed by IPM FFS respondents but never before substantiated.

Gender-segregated analysis

The scores from the IPM FFS participants and- Non-IPM FFS participants were pooled together to perform a gender disaggregated analysis (Figure 4). The analysis of the control data did not show any significant difference between men and women respondents and they are therefore not included in Figure 4.

The IPM FFS intervention appears to have generated gender distinctive outcomes. The baseline values for the social and human capitals were significantly lower for IPM FFS women when compared to non IPM FFS men and women. Yet IPM FFS female respondents attributed a high value particularly to gains in their human and social capitals. This might be explained by a selective mechanism in women's enrolment, but on the basis of the criteria adopted to establish IPM FFSs this explanation in this instance can be excluded. The results also could be explained by a retrospective underestimation of their initial capital stocks. The participation in the IPM FFS might have triggered in some women a process of self-realisation of the social boundaries that had restricted them. Women indeed reported that attending the schools was an opportunity to gain recognition of their personal skills and abilities. For instance, three of the women interviewed decided to become farmer trainers at the end of the IPM FFS and at the time of the interview were already conducting their farmer-to-farmer schools in the neighbouring villages. Their current sense of self-fulfilment perhaps exaggerated their recollection of their more subordinate and circumscribed position prior to attending an IPM FFS.

The gender analysis of the aggregated data also revealed a uniform increase in capital stocks to have been reported by the IPM FFSs male respondents, which could be caused by a biased over-reporting, typical of male respondents in response to development interventions (Annas, 2003). In order to check for this bias, each individual diagram was retrieved and

visualised. The results showed that the apparent uniformity was the result of a compensating effect among diagrams remarkably different from each other. Therefore, the reporting in this case can be considered reliable.

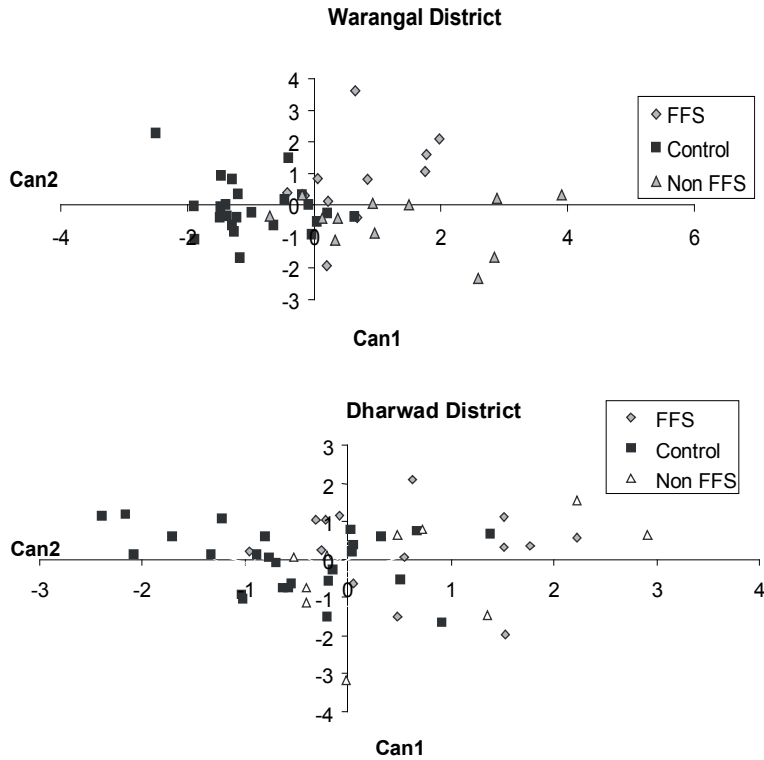


Figure 3. Plot of canonical discriminant variable 2 versus canonical discriminant variable 1 for the three cases (IPM FFS, Non-IPM FFS, and Control) in Warangal district and Dharwad District.

Discussion

The first contribution of this study is the establishment of the inner validity of the IPM FFSs intervention. We have shown that, from the IPM FFSs participants' own point of view, the IPM FFSs experience yielded significant gains beyond the reduction of pesticide application, such as improved managerial skills, better health, strengthened social ties and connections with institutions, higher self-confidence and social recognition. The analysis of the data carried out by the researchers further showed that these gains partially extended to non participants in IPM FFSs villages and not to control farmers in other villages, confirming the existence of a diffusion effect. However, exposed farmers reported that their confidence in implementing the new management practices was not strong enough to translate into a change in behaviour.

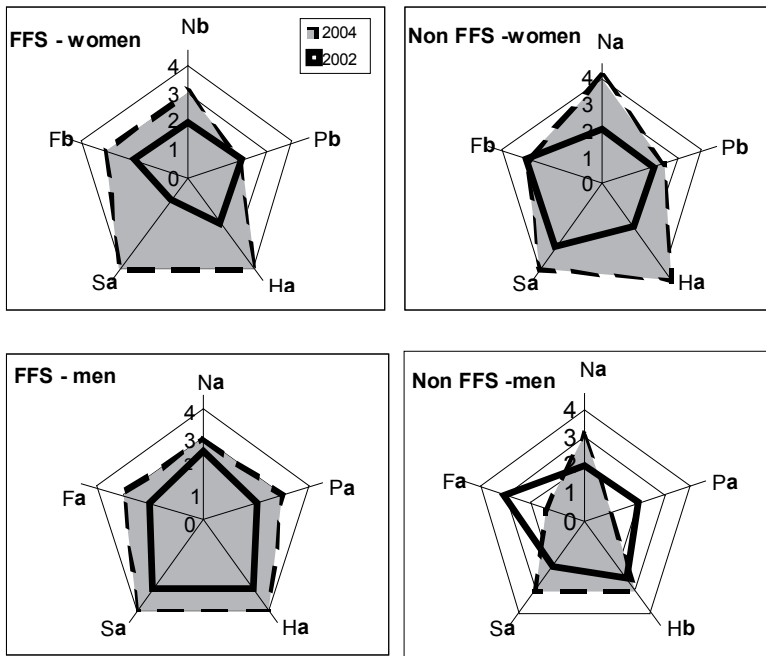
This supports the argument that an effective, empowering learning process is based on experience, rather than on simple information and technology transfer (Lightfoot et al., 2001).

FFS proponents argue that education based on experiential learning is a way to improve the ability of farmers to achieve self-determined objectives, and is a starting point for self-directed development of their own livelihoods (Gallagher, 2002). This study shows that, from the respondents' perspective, education was expected to play indeed a key role in raising their living conditions, by increasing the profitability of agriculture, preserving their own health, and conserving the environment. The cotton IPM FFSs addressed these areas directly by providing an opportunity to farmers to improve their farm management skills, reduce cultivation costs, limit pollution as well as occupational exposure to hazardous chemicals, and improve crop productivity. Some of these results have been established also by external evaluation conducted with sub-sets of the sample; for the environmental impact see Kooistra (2005) and for changes in practices Mancini (2005 in prep.). However, it is also clear from the discussions elicited by the spider diagramming in this study that the effectiveness of the IPM FFSs could have been enhanced by broadening the focus from a single crop to a broader systems approach, to address other matters, such as water management, crop rotation, crop diversification, and marketing.

The first case in Warangal District indicates that conventional cotton farming does not generate enough returns to uplift farmers' livelihoods even in favourable cropping conditions. Profits barely balance the cost of crop production and household expenditures. A necessary step to improving profitability is to cut the costs of production. According to the IPM FFS respondents the adoption of IPM had contributed to a certain extent to improving their financial assets. The second case in Dharwad District shows the vulnerability of farmers' livelihoods in the face of natural stresses. IPM FFS farmers felt that their production systems had become more resilient - they coped with the drought without having to run down their physical and financial assets thanks to the adoption of a lower-risk crop management strategy. However, some farmers also noted problems persisting with IPM, linked to the non-availability of IPM inputs in the market, especially insect traps and biological control agents.

The study also revealed that the process of personal growth stimulated by participation in IPM FFSs was particularly relevant to women and it confirms the importance of increasing women's access to educational programmes. But it also showed that the increased household cash flow – perceived by both men and women IPM FFSs participants – translated into the purchase of new physical assets mostly for men. This brings forward the question of who benefits from improved household cash flows and whether the curriculum was effective in ensuring fair benefits for both women and men.

DFID suggests empowerment can be understood in terms of individuals and groups securing greater influence over or satisfaction of one or more of the five capitals. This study has shown that IPM FFSs in this sense were an empowering experience for the participants. The longer term effects and impacts go beyond the scope of the present study; however, the question of where immediately empowering personal change leads in terms of enduring change in the circumstances of people's lives remains a legitimate enquiry.



a = significant ($P < 0.05$); b = non significant

Figure 4. Changes in capital stocks recorded between the baseline year (2002) and the impact year (2004) by three groups (IPM FFS, Non-IPM FFS and Control) of farmers separated into women and men. N=natural capital, P=physical capital, H=human capital, S=social capital, F=financial capital

Comments on the framework

The aim of the study was to test a framework to document the emic perception of change in people's livelihoods over time. The SL framework based on the five capitals proved to be valuable for this purpose. It offered conceptual clarity and research manageability in field conditions, was easily understood by farmers and allowed for an easy visualisation of correlated and inter-linked aspects, often difficult to establish in open or structured interviews. It supported a process of interactive reflection by making a visual record of the discussion available to the respondents. It had a number of otherwise hard to capture evaluative functions, such as analysis of interactions among capitals, based on the respondents' self-reporting. However, a number of limitations were also encountered: (1) the quantification of changes over time between groups is meaningful in the context of a comparative analysis only if the internal validity of shared conceptual meaning is established; (2) no objective measurements of the claims and perceptions are generated by this method; (3) on the analytical front, the consensus analysis does not have clear threshold values and the strength of consensus cannot be measured; (4) the baseline data were derived from recall information and therefore capture a retrospective

perception of the level of baseline capital stocks. However, this limitation extended to the control farmers as well (and since the aim of the study was to quantify the level of satisfaction of IPM FFS participants and not to measure the actual capital stocks, this is not a disabling limitation in this case); and (5) the authors relied on translated texts and this might have limited their appreciation of subtle differences among the respondents' reports. Limitations number (4) and (5) are not inherent in the method itself. The authors also have considered other possible sources of bias: the non-control villages' long association with the IPM FFSs and the programme's emphasis on farmers' empowerment that might have led to an over-reporting of the actual impact. In an attempt to check the validity of the respondents' reporting, all 95 individual spider-diagrams were compared to each other. The variation among the diagrams was high, but the risk of over-reporting cannot be entirely ruled out.

Conclusions

IPM FFSs in the two cases studied were found to have had broader effects than simply those relating to pest management. By use of a method that investigates these effects in terms of the components of sustainable livelihoods it has been shown that farmers do place values on these effects, and do perceive the inter-dependency of impacts in one domain and others. The results surfaced a number of surprises, such as perceived impacts on fodder quality and animal health that might result from reduced pesticide use, that merit further study. The method chosen also highlights the value of searching for innovative ways to capture and analyse impacts that can otherwise be dismissed or overlooked as merely accidental outcomes of investing in farmer education for self-development. IPM FFSs in the two cases studied were found to have had broader effects than simply those relating to pest management.

Acknowledgements

Particular recognition is owing to the Indian farmers who participated in the study. The authors are grateful to the EU-FAO IPM Programme for cotton in Asia for providing necessary financial help in carrying out this project. Special thanks go to P. Kenmore, P. Ooi, G. Walter-Echols, D. von Werner and P. Palanyswamy, who have been a continuous source of professional inspiration. The authors thankfully acknowledge the valuable contributions and comments of the following: Cathy Farnworth, Henk van den Berg, Jonathan Hellin, and the 'social learning group' at Wageningen University. Special thanks go to Aad Termorshuizen, Biological Farming Systems Group at Wageningen University for his careful revision and editing of the paper. Dagani Praveen and Anjum, IPM expert facilitators, were key persons in conducting the field study.

References

- Affi, A.A., Clark, V., 1984. *Computer-aided Multivariate Analysis*. Van Nostrand Reinhold, New York.
- Annas, J., 2003. Women and the quality of life: two norms or one? In: Nussbaum, M.C., Sen (Ed.). *The quality of life*. Oxford India Paperbacks. pp. 279-296.
- Bartlett, A., 2005. No more Adoption Rate! Impact Assessment Workshop, CIMMYT, El Batan, Mexico, October 19-21 2005.
- Bartlett, A., 2004. Entry points for empowerment. CARE, Bangladesh. Report.
- CAB (Cotton Advisory Board), 2005. Available at <http://cicr.in/dbcapp.html>
- Chambers, R., Conway, G., 1992. *Sustainable Rural Livelihoods. Concepts for the 21st Century*. IDS. Sussex.
- Dorward, A., Anderson, R.S., Clark, S., Keane B., Moguel, J., 2001. Asset functions and livelihood strategies: a framework for pro-poor analysis, policy and practice. *Proceedings 74th. EAAE Seminar: Livelihoods and Rural Poverty*. September 2001. Imperial College at Wye.
- Feder, G., Murgai, R. Quizon, J., 2004. Sending Farmers Back to School: The Impact of Farmer Field Schools in Indonesia. *Review of Agricultural Economics* (26) 1, 45-62.
- Gallagher, K., 2002. Common Questions, Answers and Suggestions on Farmer Field Schools. *International Learning Workshop on Farmer Field Schools (FFS): Emerging Issues and Challenges*, 21-25 October 2002, Yogyakarta, Indonesia.
- Haan de, A., Drinkwater M., Rakodi C., Westley K., 2002. Methods for understanding urban poverty and livelihoods. Available at http://www.livelihoods.org/info/docs/urb_pov2.pdf
- ICAC (International Cotton Advisory Committee), 2005. *Cotton Production Practices*. Technical Information Session. 64th Plenary Meeting, Liverpool, UK.
- Jiggins J. L. S., 2003. New approaches to evaluation. In *CIP-UPWARD. Farmer Field Schools: Emerging Issues and Challenges*. International Potato Center – Users' Perspectives with Agricultural Research and Development, Los Baños, Laguna, Philippines, pp. 49-68.
- Kenmore, P., 1996. Integrated Pest Management in Rice. In: Persley G. (Ed.) *Biotechnology and Integrated Pest Management*. CAB International, Wallingford, pp. 76-97
- Kooistra, K., Mancini F., Termoshuizen A. J., 2006. *Environmental Impact Assessment of cotton cultivation in Central India*. Submitted to *Agriculture, Ecosystems and Environment*.
- Lightfoot, C., R. Ramirez, A. Groot, R. Noble, C. Alders, F. Shao, D. Kisauzi, & Bekalo, I. 2001. *Learning Our Way Ahead: Navigating institutional change & agricultural decentralisation*. Gatekeeper Series no. 98. IIED. London.
- Mancini F., van Bruggen A.H.C., Jiggins L.S.J., Ambatipudi A., Murphy, H. (2005). Acute pesticide poisoning of cotton growers in Andhra Pradesh. *International Journal Occupational Environmental Health*; 11, 221-232.
- Mohr B. M. 1999. The Qualitative Method of Impact Analysis. *American Journal of Evaluation*. (20) 1, 69-84.
- PRDIS. 2003. *Impact Assessment of Cotton Integrated Pest Management Training Through Farmer Field School Approach*. FAO-EU IPM Programme for cotton in Asia Report. <http://www.cottonipmasia.org/> on June 2005.
- Reddy S.V. & Suryamani, 2004. Significant Gain Knowledge of Farmers on Cotton Pests and Production Management Practices through Farm Field Schools. *Regional Workshop on IPPM-IPM FFS Impact Analysis*, Bangkok, Thailand, June 2004.
- Rola, A., Jamias, S. & Quizon, J. 2002. Do Farmer Field School Graduates Retain and Share what they Learn? An Investigation in Iloilo, Philippines. *Journal of International Agricultural and Extension Education* (9) 1, 65-76.
- Rola, A.C., Pingali, P. L., 1993. *Pesticides, Rice Productivity and Farmers' Health: an economic assessment*. The International Rice Research Institute, Los Banos, Philippines and World Resources Institute, Washington, D.C.

- Ryan, G. W., J. M. Nolan, Yoder, P. S., 2000. Successive free listing: Using multiple free lists to generate explanatory models. *Field Methods* 12, 83–107.
- SAS Institute., 1994. *SAS/STAT User's Guide for Personal Computers*, Version 6 ed. SAS Institute, Inc. Cary, NC.
- van de Fliert, E., 1993. *Integrated Pest Management: Farmer Field Schools Generate Sustainable Practices: A Case Study in Central Java Evaluating IPM Training*. Wageningen University, The Netherlands.
- van der Waerden, B. L., 1969. *Mathematical Statistics*. New York: Springer-Verlag.
- Wu, S. Praneetvatakul, H. Waibel, Wang L., 2005. The Impact of FFS on Yield, Pesticide Cost and Gross Margin in Shandong Province, P.R. China: an Econometric Approach. In *The Impact of the FAO-EU IPM Programme for Cotton in Asia*. A Publication of the Pesticide Policy Project Hannover, July 2005. Special Issue Publication Series, No. 9, 103-108.

CHAPTER 7

General discussion

This chapter is partially extracted from the article “A methodological appraisal of an evaluation study of Integrated Pest Management Farmer Field Schools in Central India”, Mancini and Jiggins, 2006 pre-selected for publication in a special issue of the International Journal of Agriculture Sustainability.

Declining productivity and increasing production costs are affecting the economic sustainability of small-scale farming thereby compromising the only source of income for millions of people. This critical situation is particularly evident in the cotton farming sector because of the massive and ineffective use of pesticides (Shetty, 2003). In order to assist farmers in recovering farming profitability, the government of India has been supporting the re-adoption of more sustainable agricultural management through innovative extension systems (Rasheed Sulaiman, 2003). The Farmer Field School (FFS) model, a participatory approach to non-formal adult education, was introduced to train farmers in Integrated Pest Management (IPM) in the 1990s. FFSs are season-long discovery-based training conducted for farmers' groups or communities that are expected to generate outcomes in terms of economic, ecological and social benefits (Waibel et al., 1999). The question of their effectiveness has stimulated controversy (Feder et al., 2004) and there is therefore need for further evaluations to establish the contribution of FFSs to rural development. This thesis was conducted within the framework of the FAO-EU IPM Programme for cotton in Asia operative in India from 1999 to 2004. The Programme organised IPM FFSs in cotton IPM in the central and southern states of India with the aim of rehabilitating small-scale cotton farming.

Objectives and research design

The objective of this thesis was to evaluate the potential of the IPM FFSs conducted in India to increase the environmental, agronomic and social sustainability of cotton small-scale cultivation. The aspects of sustainability addressed by the research were: (i) the occupational health of male and female farm workers engaged in the handling and application of pesticides; (ii) the changes in agronomic farmer practices, particularly in input use, determined by the adoption of IPM management; (iii) the reallocation of labour associated with the introduction of IPM tasks and its gender implications (iv) the ecological impact of the emissions released in the environment by conventional, integrated and organic cotton cultivation and (v) the overall IPM FFS effects on livelihoods as perceived by participating farmers. A secondary aim of the research was to assess the role of the participatory approaches used in enhancing the relevance of the evaluation and to test innovative application of existing methods.

Data were collected between 2002 and 2004 from twenty villages in the cotton growing states of Andhra Pradesh, Maharashtra and Karnataka, to assess the short-term effects of IPM FFSs up to two years after the intervention. The overall design followed the Double Difference model (Feder et al., 2004) identifying FFS as the treatment variable and studying the pre- and post-situation for farmers who attended IPM FFSs and farmers who did not (control). The control farmers were those living in the IPM FFS villages or, in some cases, in villages where IPM FFSs had never been conducted. The matching criteria used to select control farmers were land-holding and cropping pattern. Baseline data sets (pre situation) were collected before the start of the FFS, whenever needed and possible.

Research methods

The research used the following range of methods:

1. A health self-monitoring tool (Murphy et al., 1999 and 2002) based on a list of 18 signs and symptoms of acute poisoning and details on the field operations. The monitoring was repeated pre and post IPM FFSs, but only the results of the pre monitoring are reported in this thesis. The control case was initially included in the study; however the response from the farmers not associated with IPM FFSs was poor and the data collection for the group was soon suspended.
2. Questionnaire-based farming system analysis, including labour use. The labour questionnaire was developed using the Socio Economic and Gender Analysis (SEAGA) tool (Wilde, 2001).
3. Life Cycle Analysis (LCA) (Guinee, 2002). This analysis was conducted in 15 conventional and 10 IPM cotton-growing farms. An additional 12 certified organic farms were included in the study to inform upcoming policy orientation towards organic farming. Data on input use at household level were retrieved from farm records and in interviews with farmers. This component included only post IPM FFS information.
4. Sustainable Livelihood Analysis (Chambers and Conway, 1992; Scoones, 1998; Ashley and Arney, 1999; DFID, 1999) using the five capitals concept: financial, human, social, natural and physical. This component included the FFS and control cases; pre information data were collected on a recall basis.
5. Photo-based self-reporting of participants' perceptions (known also as photo-visioning, see www.photovoice.com) of impact. This method enables people to record and reflect their livelihood issues by using cameras. The picturing technique is unstructured with no prior indication of 'impact domains' (Wang et al., 2004). It is not based on immediate farmers' responses and therefore allows time for reflection. The results of the photo visioning are not presented in this thesis, but its methodological contribution is discussed in this chapter.

Main findings

The evaluation generated findings on the outcomes (change in practices, labour allocation and yield) and impact (environmental pollution, human health, livelihoods) of cotton IPM FFSs.

The health self-monitoring study documented serious occupational illness experi-

enced by farmers exposed to pesticides and it revealed pesticide poisoning as another of the numerous dimensions of poverty (Chapter 2). A strikingly large majority (84%) of the monitored spray events led to mild to severe poisoning. Even though the mainstream literature focuses on people applying pesticides, the findings reported in this thesis show that handling pesticides to prepare chemical mixtures and refill tanks can be extremely risky. In the studied communities, as in general in the Indian villages, these operations were mainly performed by women, who experienced an extent of poisoning comparable to that of the men. Marginal farmers belonging to low-income classes proved to be 10-fold more subjected to poisoning than larger land owners, perhaps because of their grater malnutrition status and weakness due to other diseases.

The analysis of the agronomic practices in conventional and IPM-converted cotton systems showed that the current use of pesticides in cotton is largely superfluous; training in alternative plant protection measures (IPM FFSs) resulted in a drastic reduction in pesticide use (78%) without compromising crop yields (Chapter 3). This improvement was possible because farmers had learned the principles underpinning IPM through repeated field experience and had consequently changed their way of making decisions on pesticide applications. The FFSs failed to bring about improvements in other farming practices, e.g. soil fertility management, most likely because of the lower time provision made in the curriculum to deal with these topics, compared to insect ecology.

The adoption of IPM in the studied context had no consequences for the overall labour requirement of cotton cultivation, nor the total time spent on plant protection, but the type of tasks performed to control pest damage changed. A time shift from pesticide application to IPM tasks was reported, resulting in a higher contribution of female work to plant protection. It is important to realize that the introduction of new technology or management has social and gender implications that need to be taken into account in evaluation studies.

Cotton cultivation pollutes the environment causing loss of biodiversity, water contamination, global warming, acidification and eutrophication. The practices responsible for these adverse effects are the use of synthetic inputs and carbon-depleting operations such as the burning of organic matter in the field (this thesis). Organic management reduced these negative effects to negligible levels, while IPM reduced negative impacts associated with the use of pesticides, but not the global warming potential. The close-to-zero environmental impact of organic farms was reached at the cost of a substantially lower productivity (50% less than IPM, 20% than conventional cultivation). Organic farmers can bear such low productivity only when they receive premium prices for the organically grown products. IPM FFSs focused on farmers' profitability and occupational safety achieving yields comparable to or even higher than conventional farming (Chapter 3 and 5) with a minimum pesticide use. Thus, further field experimentation is needed to improve nutrient management and increase yields on organic farms, and to further reduce the environmental impact of IPM farms.

The gains reported above – better health and environment, reduced cost of cultivation and increased ecological knowledge - were also perceived by farmers as enhancing their livelihood (Chapter 6). However, in addition farmers expressed a clear appreciation of the increasing social capital associated with attending IPM FFSs, which were perceived as a re-

source to achieve better development and governance of their own destinies. Specifically, the social benefits were described in terms of higher collaboration between villagers and stronger connection with agricultural officers and village authorities. Collective action in the Indian rural society takes place typically in informal networks rather than in the official groups registered to receive the financial incentives given by the government. It has been shown that communities with higher collective action are more inclined to act for mutual benefits. Quantifying the manifestations of social capital poses an undeniable methodological challenge, but there are valuable examples in the literature that encourage further research on sustainable livelihoods in the context of IPM FFSs. For example, Krishna (2002) identified through years of participant observation that “dealing with crop disease individually or collectively” is a measure of social strength in north Indian villages.

Farmers in IPM villages who did not participate in IPM FFSs have been shown in this thesis to appreciate changes in relation to social capital and the environment, but not to report adopting new practices or change in their decision making process after exposure to the IPM FFS farmers. For such a transformational process to happen through diffusion processes might require more time (Rogers, 1995), however, no evidence was found that a process of strong diffusion had already started. This supports the argument that awareness and information may easily diffuse, but an effective, empowering learning process that translate into changed behaviour is based on first-hand experience. Finally, the SLA showed that FFS households and production systems had improved their resilience to natural shocks such as drought but also suggested that a broader systems approach, including water management, crop rotation and crop diversification, would have increased the IPM FFSs’ effectiveness according to the farmers’ own assessment.

In conclusion, this thesis suggests that the reduction in the use of toxic pesticides (Chapter 3) and the reduction in time spent on pesticide application (Chapter 4) brought about by attending IPM FFSs reduces the three factors determining pesticide poisoning: exposure time, pesticide rate and toxicity. The actual benefits to farmers’ health have been investigated in a second self-monitoring study, conducted by the same farmers the year after the FFSs reported here (Chapter 2) but the results were still being analysed at the time of submission of this thesis. If the results confirm the anticipated benefits, IPM FFSs can claim indisputably to be a viable solution to protect people’s health, particularly of vulnerable groups, e.g. women and poor people.

Methodological appraisal of the evaluation

The findings presented in this thesis prove the multidimensionality of FFSs outcomes, which defy conventional approaches to evaluation and demand new methodological and conceptual effort. Firstly, it has been shown that contributions from several disciplines are needed to address the overall values of such programmes. Secondly, the function and agency of evaluation have been highlighted. While some authors argue that external evaluation contradicts the FFSs’ core aim to transfer power to users (Bartlett, 2005), others have been more concerned with conventional methods’ inability to capture unpredictable, but relevant effects, thereby re-

ducing the relevance of the findings to improving programmes. Participatory methods, however, are regarded positively as remarkably flexible, i.e. able to evolve during their application to adapt to the specific context and to increase accountability to users (Goddard and Powell., 1994; Greene, 1994; Mohr, 1999; Murray, 2000). User participation in evaluation processes can have the functional role of increasing the efficiency of the programmes evaluated by providing useful feedback. In addition, user participation may be intended to empower users by prioritising the learning inherent to the evaluation process; this application has been defined as ‘empowering participation’ (Patton, 1997).

However, there are also authors that question the methods and practices of participatory evaluation for their generalised lack of rigour and objectivity. Others argue that the assumption that participation can lead to people’s empowerment is naive. Cooke (2002b), explains how the acts and processes of participation can reinforce injustice and existing unbalanced power relations, if the complex manifestation and dynamics of power are not understood. He claims that the currently available examples of applied participatory approaches can only reveal, but never challenge power inequalities, and that therefore a “misunderstanding of power underpins the participation discourse” (Cooke, 2002a).

The debate on how an evaluation should be assessed, what exactly should be assessed, and who should carry out the assessment is far from being solved, and probably there will always be divergent opinions, but it is clear that a broad array of evaluation approaches (Jiggins, 2003; Horton and Mackay, 2003; Johnson et al., 2003) and methodological innovation are required to follow the evolving concept of evaluating development.

Defining the degree of participation in the methods used

The extent to which each method used in this evaluation was participatory is defined here according to the four criteria described in Cousins and Whitmore (1998) and Lawrenz and Huffman (2003): (1) type of evaluation information collected, such as defining questions and instruments; (2) participation in the evaluation process; (3) decisions concerning the data to provide; and (4) use of evaluation information. ‘Outsider’ evaluators in each case reported in this thesis defined the study objectives and selected the research tools. Farmers’ involvement in the decision making pertaining to the four steps of the methodology is outlined in Table 1. The LCA and Farming System Analysis represent the non participative end of the spectrum, being based on questionnaires developed from the reference literature and leading to findings that were difficult to share directly with the local communities. The health-monitoring study had a primary research focus; however, it also had the additional educational value of being built into the FFS curriculum and therefore was coupled to access to a viable alternative to the use of pesticides. In the SLA, farmers decided on the type of information to be collected within the given framework. The closest to full participation, or empowerment evaluation, was the photo-visioning study which was entirely carried out by farmers. The information collected was processed during farmers’ workshops and translated into a collective commitment to move towards more sustainable farm management.

Table 1. Participation of farmers in decision making and programme evaluation

Method	Time of investigation in relation to FFSs	Decision on information to be collected	Farmers' participation in evaluation implementation	Format of data collection	Use of evaluation information*
1. Health monitoring	During and Post (1 year)	Outsiders	Required	Pre-developed visual format	Programme staff and donors, researchers, national policy makers, farming communities
2. Farming System Analysis	Pre and Post (1 year)	Outsiders Farmers (partial involvement)	Required in the planning phase	Questionnaire Focus Group Discussion	Researchers (Programme staff and donors, national policy makers)
3. Life Cycle Analysis	2 nd year after	Outsiders	Not required	Questionnaire	Researchers (Policy makers)
4. Sustainable Livelihood Analysis	1 st and 2 nd year after	Outsiders Farmers	Required	Open-question interviews	Farming communities (Programme staff and donors, researchers, national policy makers)
5. Photo-visioning	1 st year after	Farmers	Required	Photos	Farming communities (Programme staff and donors)

* In the column, the actual use made of the findings is indicated and in brackets the potential use is given.

Source: this thesis.

Strengths and limitations of the conventional methods used (LCA and Farming Systems Analysis)

The LCA generated comparable and repeatable results based on regional and global scale indicators. An objectivist approach was required in order to ensure an impartial evaluation and allow for generalisation (Feuer et al., 2002). It generated insights relevant at national level to policy advisers and cotton producers regarding strategic choices in minimising pollution. Scenario analyses are possible LCA applications in order to predict long-term trends and very often environmental policies have been shaped on the LCA's findings, but this application was not pursued further in this instance. However, modelling simplifies realities in theoretical systems that can be quite far from the real scenario and do not take into consideration the effects of local circumstances. Also, data collection can be rather difficult and expensive if extended to water quality.

The questionnaire used for the Farming System Analysis was developed in consultation with the farmers and therefore sufficiently comprehensive and representative of the specific agronomic context. The limitations experienced during the survey were in relation to recall memory and the degree to which respondents were willing to give accurate information (bias introduced by the respondents). In conventional methods, respondents rarely have a

direct stake in the results and this might ensure higher objectivity, but it can also result in lower motivation to provide accurate and precise information. For instance, in the context of agrarian subsidies and assistance, such as exist in Indian rural society, farmers might have reasons to over- or under-report information on yields, input use, or production costs. The risk of biases introduced by the respondents is thus shared by all methodologies that place people as the main informants, regardless of the degree of participation implemented.

Strength and limitations of participatory methods used (health-monitoring, SLA and photo-visioning)

Evaluation validity

Beneficiary Assessment (BA) - "an approach to information gathering which assesses the value of an activity as it is perceived by its principal users." (Salmen, 1995) – has become a widely recognised way to assess the validity of development interventions. The two example of BA reported in this study - the SLA and the photo-visioning methods - showed that health, environmental, production and social capital, were issues meaningful to the farmers, establishing the inner validity, but it also showed that the overall evaluation framework, developed externally, had overlooked other areas of impact relevant to farmers. It might be important to specify that these outsiders had an extended affiliation with FFS programmes and therefore were considered to be well informed about ongoing debates on FFS impact assessment. Development practitioners agree on the importance of understanding the complexity of people's livelihoods and the interlinkages that make impact in one area likely to be felt in others (Cleaver, 2002). SLA was instrumental in the analysis of these relational aspects and systemic interactions. For instance, the application to two different regions revealed that the implications of the knowledge acquired in the FFSs were determined by the farming context. Specifically, during a season favourable to cropping IPM FFS farmers achieved better yields, and in the circumstances of a drought were better able to minimise financial losses than the control farmers in the non IPM FFS villages. Given that drought in the study area is a rather regular calamity, an earlier application in the planning phase of the evaluation study would have supported the argument for a stronger focus on livelihood vulnerability and resilience.

However, the validating function of participatory evaluation also meets firm opponents. Mosse, (2002) asserts that in participatory approaches local knowledge is often manipulated and instrumentalized to legitimate project objectives and the decisions already made. He regards people's knowledge as a political artefact reflecting the expression of existing power relations among the participants, as well as participants' strategic adjustment of their needs to match project deliverables. Even though this seems to indicate areas for essential improvements, rather than invalidating the theory of participation, it was part of the evaluation experience reported in this thesis that dealing with existing unequal power relations to facilitate social inclusiveness and gender equity in IPM FFSs was a demanding task. In FFS weekly meetings, conflicts of interests among participants often surfaced and remained unaddressed. The participatory evaluation tools and processes used in this study were not able to investigate

problems arising from the representativeness of participation in IPM FFS implementation, nor in the evaluation process itself. This is a shortcoming that we acknowledge.

Evaluation accuracy

It has been observed that people who are motivated by feelings of ownership of the process provide more complete and accurate information (King, 1998). For instance, pesticide poisoning studies based on questionnaires have shown much higher figures than hospitals registries and directly observed poisoning rates have been recorded that are even higher than recalled information provided by farmers in questionnaires (Kishi, 2002). This suggests that measured health data through participant observation or participant farmers' monitoring, could increase data accuracy and contribute to reaching a better understanding of the issue.

In the case of this evaluation, farmers were inclined to disclose reliable information, assured by the trustful relationship that linked them to the facilitators. However, extensive and sympathetic interaction between project participants and evaluators can be seen as a source of possible bias (Scriven, 2005). In the health monitoring, for instance, the women were likely to be involuntarily biased towards reporting higher levels of poisoning. The authors of the health monitoring study estimated the level of over-reporting between 17% and 38% by introducing 3 dummy symptoms in the reporting format. In the SLA a generally positive attitude concerning change over time was recorded for the male respondents, who had been FFS participants and even though the variation existing among their reporting was high, the risk of bias due to their enthusiastic affiliation with the FFS programme remains a danger.

The language used to conduct participatory methodology is unmistakably the one spoken by the local communities. However, if the stakeholders involved speak different languages and/or the scope of the evaluation goes beyond evaluation at community level, some of the depth of the findings can be lost in the analysis. The authors of this study relied on translated texts, as the investigation was carried out in the local languages, and this might have limited the accuracy of the transcribed information.

Empowering evaluation?

The opportunities for empowerment provided by participatory evaluation are entailed in the process through which such evaluations proceeds – an experiential learning cycle. Starting from a concrete experience, participants conceptualize and apply new principles that can lead to a mental transformation (Percy, 2005). In this thesis the deeper understanding of the occupational hazard of handling pesticides induced a change in participants' attitude towards pesticides.

There are other features of participatory evaluation that can be seen as a means to increase the representation of people's will. For instance, one is the use of visual aids to assist the generation of knowledge through non-verbal representation and dialogue, uncommon in conventional methods. The photo-visioning in particular facilitated the expression of people less confident with verbal communication or with drawing techniques.

The health monitoring, however, provided an instance in which participatory principles were traded off against pragmatic aims. In the periodic meetings organised during the self-health assessment to review monitoring forms, a number of issues related to health were put forward, but not properly followed up because they went beyond the specific research outline. In a truly empowering participatory evaluation, local control and autonomy in the project would have overridden the need to comply with a set of fixed objectives. Asking the people to participate in the project's agency limited the empowering scope of the process.

Finally, participatory methodologies can be rather time-consuming (the health-monitoring). Their application at regional level can be difficult. Participatory techniques are usually applied with a small number of people to ensure wide interactions, and to study outcomes that are local-specific. However, participatory evaluation with a research purpose, while compromising on the empowering function of the process, can generate results through iteration of a rather standardised procedure, as was the case with the SLA study.

Participation and gender

Participatory techniques are not *per se* gender sensitive, but they can be if accompanied by an approach sensitive to ethnic, gender, age, class, religion and cultural diversity (Mertens, 2003). Particularly, the FFS model with its effort to establish a community consensus, might leave the priorities of weaker groups unexpressed or unaddressed (Guijt, 1998). The EU-FAO IPM Programme actively promoted the involvement of women in its activities with the result that, in 2004, 20% of the participants attending the FFSs funded by the programme were women. In order to generate gender sensitive findings, this study was conducted in selected villages where women's and men's participation were nearly equivalent. Prior to the evaluation, substantial time was dedicated to Focus Group Discussions and to the elicitation of labour calendars with both genders, and to period of participant observation. This work shaped the definition of data requirements and the data collection procedures. Data disaggregated by gender and social class were collected for every evaluation area, except that for the environmental assessment (LCA). The following study dimensions would have been missed without the participation of women in the overall evaluation.

The list of operations surveyed by the labour allocation analysis included a number of secondary operations performed by women that are frequently overlooked. Their inclusion allowed for a more accurate estimation of the labour requirement in cotton farming. In turn, the study showed that female labour availability is a factor influencing the rate of IPM adoption, invalidating the misconception that plant protection measures are entirely a male domain. The gender labour analysis, paired with participant observations, also laid the fundamentals for the health monitoring by revealing the separation of roles in pesticide application. The SLA revealed that building human capital was particularly relevant for women, who developed through the IPM FFSs the confidence to speak out for their needs and opinions.

The evaluation did not analyse the social class, religion or any other cultural variables of the women attending IPM FFSs in relation to the total village population and it cannot therefore offer conclusions on the issue of social inclusiveness in the IPM FFSs. Capturing these

aspects was beyond the initial scope of the evaluation and not in reach of the methods used. However, the study has provided evidence that IPM FFSs are relevant to women and poor farmers and that targeting strategies, including facilitators' training on problem solving skills and gender-sensitive approaches, are needed to overcome barriers to their participation.

The study also did not attempt to assess longer term outcomes and impacts. A complementary investigation of the cost-effective approach to the assessment of the chronic health effects of pesticide use is underway in India and Pakistan (van Bruggen, 2004) in order to contribute to the continuing development of understanding of the long term costs to society.

Implication for programme and policy development

FFS programme implications

The focus of the cotton IPM FFSs in India was on the whole production cycle, rather than on plant protection measures alone. Nevertheless, facilitators' competence and time allocation in the training were skewed towards insect ecology and bio-control principles; not surprisingly, the higher gains were yielded in these areas. The outputs of FFSs are highly curriculum- and facilitator-dependent (Röling and Jiggins, pers. com). Commitment to the cause of people's development, excellent communication and technical skills, non-judgemental attitude, and an ability to interact sympathetically with different people, are just some of the qualities required to be an effective facilitator. The lesson we can learn from this thesis is that investment in the quality of the training is required to bring about tangible changes. A spontaneous farmer-to-farmer diffusion process is unlikely to spread the full spectrum of the benefits generated by IPM FFSs to non-participants. The evidence is that there is no diffusion effect (Feder et al, 2004), or that if there is what actually diffuses are specific techniques or technologies or awareness and indirect benefits e.g. environmental reduced pollution and increased social capital (this thesis). This thesis thus supports the suggestion that IPM FFSs should be combined with other strategies to increase the access to locally-relevant quality education to all farmers (van Mele, 2005). Other countries have already experimented with self-financed FFSs (Gallagher, 2004). In the case of India, farmers were trained to become facilitators and conduct FFS in the neighbouring villages. Evaluating the outcomes of these and others approaches is of primary importance.

Finally, conducting meaningful evaluation is necessary but also time and resource consuming; adequate budgetary arrangements need to be made in programme design for this task.

Pesticide Policy implications

The evidence on the environmental and social costs of the pesticide use presented in this thesis confirms the urgent need for policy interventions that ban the use of hazardous pesticides, viz. products belonging to WHO toxicity class I and II. In the industrialized countries of the European Union and USA the use of many products has been banned, restricted or is under re-evaluation on the basis of their effects on people's health and the environment (van der Wulp et al., 2005). In developing countries systems for the legislation of pesticides are in

place but not yet effectively enforced. A number of policy instruments are available to assist the governments of developing countries to rationalize the use of synthetic pesticides and reduce the risks associated with their use. The Code of Conduct on the Distribution and Use of Pesticides released by the FAO in 1985 (FAO, 2002) is an important foundational instrument. Two conventions followed the Code, on Prior Informed Consent (PIC) (FAO, 1990) to limit export of toxic pesticides, and on Persistent Organic Pollutants (POPs) (UNEP, 2001) to phase out production and use of twelve organic pollutants. Policy advisory documents with similar orientations have been also formulated by scientists, for instance the Minimum Pesticide List (MPL, Eddleston et al., 2002). The MPL consists of a short list of pesticides selected for their efficacy, safety and cost in order to keep the number of pesticides registered at the minimum level required. The effectiveness of restricting policies in limiting the deaths from poisoning has been proved in several cases reviewed by Konradsen et al. (2003). Contrarily, most of the industrial 'Safe Use' campaigns have failed to achieve tangible results (Atkin, 2002; Dinham, 2005; Sherwood et al., 2005), because no safe use is possible in the agro-climatic conditions of tropical countries. Developing countries have made some progress, but further policy support is needed to reduce the millions of poisoning cases occurring yearly worldwide. Civil society organizations are playing a key role in catalyzing this change by calling for higher responsibility and accountability from the industry and by monitoring policy change and implementation. Raising consumers' awareness of the food safety issues involved is another possible way to encourage further regulation of pesticide use.

Agriculture policy implications

The evidence for IPM efficiency confirms that the current use of pesticides in cotton is unnecessary and determined by issues other than sustaining production. Policies to promote the use of environmental control methods, already in place in many countries, continue to be a pertinent way to minimize the risks associated with pesticide use. The shortcomings of the extension effort dedicated to supporting the large-scale adoption of these methods in terms of meeting the Millennium Development Goals has been well established in the research literature. The evidence provided in this thesis indicates that farmer-centred educational approaches are a far more effective strategy to support sustainable development, without sacrificing yield.

The FFSs model has been institutionalized by the state Department of Agriculture of Andhra Pradesh, Karnataka, Maharashtra and Tamil Nadu and existing budgets for IPM training have been reallocated to support the spread of IPM FFSs. However, if the users' feedback documented in this thesis could be built into extension policy and programme development in these states the outcomes could be enhanced considerably. A cross-departmental strategy, to include child and women welfare, livestock production and health, watershed management, on the basis of the evidence provided by this study, would seem warranted.

Research policy implications

The informal networks existing among development officers, academics from various universi-

ties and international consultants with expertise ranging from human health to insect ecology made the realization of this evaluation possible. Those who participated were willing to learn and work also in disciplines other than their own field of expertise to create inter-disciplinary areas of investigation. Organising more interdisciplinary courses and financing cross-departmental research programmes in universities would provide the necessary technical means to bring this kind of research orientation closer to the needs of sustainable development. The study demonstrated that the measure of outcomes and impacts that have been used to guide FFS and extension programme investments in the past, such as yield, pesticide use, and fiscal sustainability, are insufficient to inform policy decisions, or as the sole basis of policy research. Further development to generate the necessary data is warranted, especially in the areas of gender disaggregated outcomes and impacts, environmental effects, and on livelihoods.

Conclusions

The evaluation study applied two methodological approaches - conventional and participatory – which made different, but equally rigorous, claims to knowledge. The former provided an objective measurement of selected environmental and social impacts generated by different cotton production systems. The findings generated are particularly relevant to refine the technical content of the IPM FFS curriculum as well as national plant production and protection policies to minimise pollution and sustain farmers' returns. The latter described farmers' appreciation of the same changes introduced in the systems by the IPM FFS project. It revealed that the same training had different impacts on the livelihoods of women and men, of wealthy and poor farmers, by giving them the opportunity to express their opinion. It was not possible to feed the information directly back into the EU-FAO IPM Programme for cotton in Asia programme implementation, since it ended in October 2004, but the findings can be relevant in the development of future FFS programmes strategies.

References

- Ashley, C., Arney, D., 1999. *Sustainable Livelihoods: Lessons from early experiences*. ODI, London.
- Atkin, J., 2002. *Safe and Effective Use of Crop Protection Products in Developing Countries*. CABI Publishing, Wallingford, UK.
- Bartlett, A., 2005. No more Adoption Rate!. Paper presented at the Impact Assessment Workshop. CIMMYT, El Batan, Mexico.
- Chambers, R., Conway, G., 1992. *Sustainable Rural Livelihoods. Concepts for the 21st Century*. IDS, Sussex.
- Cleaver, F., 2002. *Institutions, Agency and the Limitations of Participatory Approaches to Development*. In: Cooke, B., Kothari, U. (Eds.), *Participation: the New Tyranny?* Zed Books, London, New York, pp. 36-45.
- Cooke, B., 2002a. *The Social Psychological Limits of Participation?* In: Cooke, B., Kothari, U. (Eds.), *Participation: the New Tyranny?* Zed Books, London, New York, pp. 56-71.
- Cooke, B., 2002b. *The Case for Participation as Tyranny*. In: Cooke, B., Kothari, U. (Eds.), *Participation: the New Tyranny?* Zed Books, London, New York, pp. 1-15.
- Cousins, J., Whitmore, E., 1998. *Framing participatory evaluation*. In: Whitmore, E. (Ed.), *Understanding and practicing participatory evaluation* Jossey-Bass. *New Directions for Evaluation*, San Francisco,

- CA, pp. 5-24.
- DFID, 1999. Sustainable livelihoods guidance sheets. London.
- Dinham, B., 2005. Corporations and Pesticides. In: Pretty, J. (Ed.), *The Pesticide Detox. Towards a More Sustainable Agriculture*. Earthscan, London, Sterling VA, pp. 55-69.
- Eddleston, M., Karalliedde, L., Buckley, N., Fernando, R., Hutchinson, G., Isbister, G., Konradsen, F., Murray, D., Piola, J.C., Senanyake, N., Sheriff, R., Singh, S., Siwach, S.B., Smit, L., 2002. Pesticide poisoning in the developing world - a minimum pesticides list. *Lancet* 360, 1163-1167.
- FAO, 1990. International Code of Conduct on the Distribution and Use of Pesticides (Amended to Include Prior Informed Consent in Article 9 as adopted by the 25th Session of the FAO Conference in November 1989). Rome.
- FAO, 2002. International Code of Conduct on the Distribution and Use of Pesticides. Rome.
- Feder, G., Murgai, R., Quizon, J.B., 2004. Sending farmers back to school: The impact of farmer field schools in Indonesia. (vol 26, pg 45, 2004). *Review Of Agricultural Economics* 26, 314-314.
- Feuer, M., J., T., L., Shavelson, R.J., 2002. Scientific culture and educational research. *Educational Researcher* 31, 4-14.
- Gallagher, K., 2003. Common Questions, Answers and Suggestions on Farmer Field Schools. International Learning Workshop on Farmer Filed Schools (FFS): Emerging Issues and Challanges. Yogyakarta, Indonesia.
- Goddard, A., Powell, J., 1994. Using naturalistic and economic evaluation to assist service planning. *Evaluation Review* 18, 472-492.
- Greene, J.C., 1994. Qualitative Programme Evaluation: Practice and promise. In: Denzin, N.K., Lincoln, Y.S. (Eds.), *Handbook of Qualitative Research*. Thousand Oaks, CA: Sage, pp. 530-544.
- Guijt, I., Kaul Shah, M., 1998. The Myth of Community. *Gender Issues in Participatory Development*. Intermediate Technology Publications in Paticipation. UK, pp. 320.
- Guinee, J.B., 2002. Life Cycle Assessment: An operational guide to the ISO standards. Ministry of Housing, Spatial planning and Environment (VROM) and the Centre of environmental Science, Leiden University (CML), The Netherlands.
- Horton, D., Mackay, R., 2003. Using evaluation to enhance institutional learning and change: recent experiences with agricultural research and development. *Agricultural Systems* 78, 127-142.
- Jiggins, J., 2003. New Approaches to Evaluation. International Learning Workshop on Farmer Filed Schools (FFS): Emerging Issues and Challanges. Yogyakarta, Indonesia.
- Johnson, N.L., Lilja, N., Ashby, J.A., 2003. Measuring the impact of user participation in agricultural and natural resource management research. *Agricultural Systems* 78, 287-306.
- King, J., 1998. Making sense of participatory evaluation practice. In: Whitmore, E. (Ed.), *Understanding and practicing participatory evaluation* Jossey-Bass. New Directions for Evaluation, 80, an Francisco, CA, pp. 57-68.
- Kishi, M., 2002. Farmers' perceptions of pesticides, and resultant health problems from exposures. *International Journal Of Occupational And Environmental Health* 8, 175-181.
- Konradsen, F., van der Hoek, W., Cole, D.C., Hutchinson, G., Daisley, H., Singh, S., Eddleston, M., 2003. Reducing acute poisoning in developing countries - options for restricting the availability of pesticides. *Toxicology* 192, 249-261.
- Krishna, A., 2002. Enhancing political participation in democracies - What is the role of social capital? *Comparative Political Studies* 35, 437-460.
- Lawrenz, F., Huffman, D., 2003. How can multi-site evaluations be participatory? *American Journal of Evaluation* 24, 471-482.
- Mertens, D.L., 2003. The inclusive view of evaluation: Visions for the new Millenium. In: Donaldson, S.I., Scriven, M. (Ed.), *Evaluating social programs and problems: vision for the new millennium* Lawrence Erlbaum, Mahawah, NJ, pp. 91-108.
- Mohr, L.B., 1999. The qualitative method of impact analysis. *American Journal of Evaluation* 20, 69-84.
- Mosse, D., 2002. "People's Knowledge", Participation and Patronage: Operations and Rrepresentations of

- in Rural Development. In: Cooke, B., Kothari, U. (Eds.), *Participation: the New Tyranny?* Zed Books, London, New York, pp. 16-34.
- Murphy, H., Sanusi, A., Dilts, R., Djajadisastra, M., Hirschhorn, N., Yuliantiningsih, S., 1999. Health effects of pesticide use among women Indonesian farmers: Part I: Exposure and acute effects. *Journal of Agromedicine* 6, 61-85.
- Murphy, H.H., Hoan, N.P., Matteson, P., Abubakar, A., 2002. Farmers' self-surveillance of pesticide poisoning: A 12-month pilot in Northern Vietnam. *International Journal Of Occupational And Environmental Health* 8, 201-211.
- Murray, P., 2000. Evaluating participatory extension programs: challenges and problems. *Australian Journal of Experimental Agriculture*, 519-526.
- Patton, M.Q., 1997. Empowerment evaluation: Knowledge and tools for self-assessment & accountability - Fetterman, DM, Kaftarian, SJ, Wandersman, A. *Evaluation Practice* 18, 147-163.
- Percy, R., 2005. The contribution of transformative learning theory to the practice of participatory research and extension: Theoretical reflections. *Agriculture and Human Values* 22, 127-136.
- Rasheed Sulaiman, V., 2003. Innovation in agricultural extension in India. Sustainable Development Department (SD), FAO, Rome.
- Rogers, E.M., 1995. *Diffusion of Innovations*, 5th Ed. The Free Press, New York. pp. 518.
- Salmen, L.F., 1995. *Beneficiary Assessment: An Approach Described*. Social Assessment Series No. 23. World Bank Environmental Department Paper, Washington, DC, USA.
- Scoones, I., 1998. *Sustainable Rural Livelihoods: A Framework for Analysis*. IDS, Brighton.
- Scriven, M., 2005. Review of the "Empowerment Evaluation Principles in Practice. D. Fetterman and A. Wandersman (Eds.). New York: Guilford, 2005. *American Journal of Evaluation* 26, 415-417.
- Sherwood, S., Cole, D.C., Crissman, C., Paredes, M., 2005. From Pesticides to People: Improving Ecosystem Health in the Northern Andes. In: Pretty, J. (Ed.), *The Pesticide Detox. Towards a More Sustainable Agriculture*. Earthscan, London, Sterling VA, pp. 55-69.
- Shetty, P.K., 2003. Ecological implications of pesticide use in agro-ecosystems in India. In: Environmental Studies Unit, National Institute of Advanced Studies. Indian Institute of Science Campus, Bangalore, India.
- van der Wulp, H., Pretty, J., 2005. Policies and Trend. In: Pretty, J. (Ed.), *The Pesticide Detox. Towards a More Sustainable Agriculture*. Earthscan, London, Sterling VA, pp. 55-69.
- van Bruggen A. H. C., 2004. IPM Europe Domain Task Forces 2004/5 on: Chronic health effects caused by pesticide exposure. A comparison between high intensity pesticide crop management and alternative farming systems - IPM and organic. GTZ, Germany
- van Mele, P., Slahuddin, A. Magor, N.P., 2005. *Innovation in Rural Extension. Case studies from Bangladesh*. CABI Publishing Wallingford, Oxford, UK. pp. 307.
- Waibel, H., Fleischer, G., Kenmore, P.E., 1999. Evaluation of IPM programs: concepts and methodologies: papers presented at the first workshop on evaluation of IPM programs, Hannover, March 16-18, 1998. A Publication of the Pesticide Policy Project. Publication Series No. 8, Hannover University.
- Wang, C.C., Anderson, R.M., Stern, D.T., 2004. Using Photovoice To Explore Professional Values, Social Responsibility, and Health Policy Issues. *Medical Education* 38, 1190-1191.
- Wilde, V., 2001. *Socio-economic and Gender Analysis Programme*. Field Handbook. FAO, Rome.

Summary

The intensification of agriculture catalyzed by the diffusion of high yielding modern varieties from the late 1950s onwards has undoubtedly and significantly increased crop productivity worldwide. Genetically improved crops perform optimally where there is high investments in synthetic inputs, irrigation and good soil fertility and they have mainly benefited farmers with access to adequate natural and economic resources. On the contrary, farmers living in disadvantaged agroecological zones have experienced real economic losses. These negative consequences of the green revolution are particularly dramatic in the sector of small-scale cotton farming in India. The country has the largest area under cotton cultivation in the world (around 9 million hectares). The cotton commodity chain generates employment for 60 million people; the export volume is equivalent to 30% of the domestic product. Yet, a significant number of suicides, a few hundreds in Andhra Pradesh alone, are recorded yearly in cotton farming communities due to financial crises. The use of pesticides in cotton cultivation has increased strongly and it has lost its efficiency to control pest damage in many areas due to development of resistance. Consequently, the cost of cultivation has risen and cotton growers are often burdened with debts that they are unable to repay. Occupational pesticide poisoning is frequent because the products used are highly toxic and the use of protective gear is impossible in the climatic conditions of the region. The Government of India is supporting the re-adoption of a more sustainable agricultural management to reverse these negative trends. Integrated Pest Management is one of the viable solutions promoted to reduce the use of pesticides. The Farmer Field Schools (FFS) model, a participatory approach to farmer education that assists farmers in experimenting with new practices directly in their own fields, was introduced in the 1990s to train farmers in IPM. FFSs offer a season-long curriculum based on farmers' discovery learning and group or community action and it is expected to strengthen farmers' capacities to build their own development. Even though the importance of promoting farmers' empowerment for a sustainable development currently meet with large support, the effectiveness of the FFS approach in achieving substantial gains has been questioned. The objective of this thesis was to assess the changes introduced by Integrated Pest Management FFSs in cotton farming systems in terms of: (i) farmers' occupational health and exposure to pesticides; (ii) agronomic practices in cotton cultivation and farmers' ecological knowledge; (iii) labour allocation and its gender implications; (iv) polluting emissions released in the environment and (v) overall livelihood changes as perceived by farmers.

The research was carried out between 2002 and 2004 in three states of India, namely Andhra Pradesh, Karnataka and Tamil Nadu. The studied villages (10 IPM FFS villages and 10 control villages) were selected in districts where the EU-FAO IPM Programme for Cotton in Asia (1999-2004) was operative. Overall, the research design followed the so-called Double Difference model, including the four cases: pre-IPM FFSs, pre-control, post-IPM FFSs and post-control. Data were collected by means of conventional methods, e.g. questionnaires and participatory exercises, which included self-monitoring and photo-reporting.

In order to establish the rate of acute pesticide poisoning occurring among cotton

growers, fifty female farmers monitored their health and those of their male relatives for one spraying season (Chapter 2). A startling high proportion of the exposure events (84%) were revealed to be associated with mild to severe poisoning. Not only the men who applied pesticides, but also the women working in the sprayed fields were severely affected. Pesticide poisoning was also another of the many dimensions of poverty, as low-income farmers were shown to be 10-fold more prone to illness than the wealthier farmers. During the entire monitoring period farmers never sought medical care, indicating that official hospital records are a serious underestimate of the actual extent of pesticide poisoning.

The diffusion of IPM to minimize pesticide exposure has been slow under the technology-driven and expert-led extension system in place during the 1980s. This has been partially explained by the complexity of the method, that depends on farmers' ecological knowledge. IPM FFSs are considered the appropriate approach to build farmers' confidence in IPM for their participatory nature. To verify this hypothesis, the agronomic practices of 73 farmers trained in IPM FFSs and 64 control farmers were compared before and after the IPM FFSs had been conducted (Chapter 3). The pesticide use in IPM FFS cotton farms was substantially reduced (by 78%) and low comparatively to conventional farms (one sixth). Those farmers who had learned more about pest and predator ecology attained the highest reductions. Crop productivity was not affected, suggesting that a large part of the current use of pesticides in cotton cultivation is unnecessary. However, no improvements in the other practices, e.g. nutrient management, were achieved, perhaps because insufficient emphasis was placed on these topics in the training curriculum.

Another factor that has been reported to limit the adoption of IPM is labour organization. Data on labour use were gathered from 42 IPM FFSs farms and 52 conventional farms again before and after the IPM FFSs had been conducted to investigate the changes in labour pattern and their gender implications (Chapter 4). Cotton cultivation was shown to be a labour-intensive activity, requiring 287 days/ha. In the small-scale farms analysed, women provided 74% of the whole requirement. The time spent in plant protection measures was around 3-5% of the total. The adoption of IPM was not associated with an increase in the total labour demand, however, the tasks performed in plant protection were different and required a higher family female work share. The female to total ratio of the time spent in plant protection from 0.31-0.33 to 0.49. The availability and opportunity costs of women workers might therefore influence the rate of IPM adoption. The reduction in time spent in applying pesticides is expected to generate beneficial effects on the health of the farmers; however the consequences on the farm-household welfare of an increased women's workload would need to be explored.

Agricultural intensification in India has caused degradation of soil fertility, water depletion and contamination by nitrate, phosphate and pesticide residues, and loss in biodiversity. To assess the contribution of cotton cultivation to this environmental damage, a Life Cycle Analysis of conventional, integrated and organic farms was carried out (Chapter 5). The ecological assessment focused on a selected number of environmental indicators namely Environmental Index Quotient (accounting for pesticide impact), global warming, acidification, eutrophication, and soil erosion. The use of pesticides and fertilizers and the practice of burning

crop residues in the field were mostly responsible for the pollution caused by cotton cultivation. Organic farms had a negligible overall impact, but fairly low productivity. In the IPM farms, the impact caused by the pesticide use was about 75% lower and the contribution to acidification and eutrophication were respectively around 33% and 50% lower than in conventional farms, while the yields were nearly 50% higher (1093 kg ha⁻¹). In term of contribution to global warming, the IPM farms were more polluting than the conventional farms (nearly 25%).

Finally, to establish the inner validity of the evaluation, a participatory assessment of the overall effects of IPM FFSs on farmers' livelihood was carried out using the Sustainable Livelihood Analysis (Chapter 6). Farmers reported that they had experienced significant empowerment gains in terms of their natural, human, physical and financial assets. In addition, they highly appreciated the increase in social capital due to improved collaboration and connection with outsiders as a means to achieve better village development and governance. Farmers living in the same villages where IPM FFSs were conducted, but not participating in the training enjoyed a number of the environmental, social and human outcomes with women participants in particular reporting personal and social gains; however no clear changes in farming practices resulting in financial improvements were reported.

The findings generated by this thesis showed that development strategies based on education can achieve tangible livelihood improvements, provided that farmers have access to quality training. The composition of the FFS curriculum plays a key role in ensuring this quality. In the studied context, future FFS programmes could increase their effectiveness by embracing a wider system approach than a target crop.

This evaluation was carried out at house-hold level and proved the potential of the FFS model in strengthening farmers' livelihood. Spill-over effects from participants to neighbour farmers were reported mainly in terms of indirect social and environmental benefits and not in terms of new management and decision making skills. Thus, further studies on a regional scale are needed to support the development of FFS scaling-up strategies which must be economic and effective.

In conclusion, the current massive use of pesticides in cotton cultivation was shown to be both unnecessary and harmful to human health and the environment. The study did not address a number of consequences determined by the use of pesticides, such as the chronic effects on human health and animal welfare, or the contamination of water and food, that deserve further investigation. Nonetheless, the evidence of this study is that restrictive policies to phase out the most dangerous products (WHO toxicity class I and II) and limit the use of the others, are urgently needed to contain the many cases of pesticide poisoning occurring yearly in the world. It is important that the governments continue to support the spread of ecological approaches to farming and that research agendas focus on improving the profitability of these approaches for farmers. Collaboration between farmers, researchers and policy makers is essential to achieve these goals.

Samenvatting

De intensivering van de landbouw door middel van o.a. moderne cultivars heeft sinds halverwege de vorige eeuw bijgedragen aan de sterke toename van de wereldwijde landbouwproductie. Moderne cultivars functioneren in het algemeen optimaal bij een hoog niveau aan investeringen in synthetische inputs, irrigatie en kunstmest, waardoor de voordelen van deze cultivars vooral ten goede gekomen zijn aan die landbouwers die zich deze investeringen kunnen getroosten. Daartegenover staat dat de landbouwers uit voor landbouw minder geschikte regio's economisch forse verliezen hebben geleden. De gevolgen van de groene revolutie zijn dan ook met name dramatisch voor de kleine telers zoals die van katoen in India. Dit land is met 9 miljoen hectare de grootste katoenproducent ter wereld. De katoenteelt en -verwerking levert arbeid voor 60 miljoen mensen en de export van katoen bedraagt 30% van het nationaal product. Toch is de katoenproductie in India in een financiële crisis, die alleen al in Andhra Pradesh enkele honderden zelfmoorden per jaar tot gevolg heeft. Tegen plaaginsecten worden in toenemende mate bestrijdingsmiddelen ingezet, maar hun effectiviteit neemt af doordat plaaginsecten steeds resistenter worden tegen deze bestrijdingsmiddelen. Hierdoor nemen de kosten van katoentelers toe en uiteindelijk leidt dit tot leningen die niet meer terugbetaald kunnen worden. Vergiftiging door het gebruik van bestrijdingsmiddelen komt onder telers algemeen voor door de hoge toxiciteit van de gebruikte middelen die daar gebruikt worden en doordat ze niet op de juiste wijze gebruikt worden, vooral doordat er geen beschermende kleding en maskers gebruikt worden.

Om deze negatieve ontwikkelingen een halt toe te roepen stimuleert de regering van India duurzame ontwikkelingen in de landbouw. Geïntegreerde landbouw (Integrated Pest Management, IPM) is een van de oplossingsrichtingen voor minimaal en verstandig gebruik van bestrijdingsmiddelen. Om telers te trainen in IPM zijn in de 1990'er jaren de Farmers Field Schools (FFS) ontworpen, een voorlichtingsbenadering waarin telers zelf kunnen experimenteren met nieuwe teeltmethoden op hun eigen land. In FFS ontwerpen telers oplossingen voor hun eigen problemen. Ondanks de huidige populariteit van FFS is de effectiviteit hiervan niet duidelijk. Daarom was het doel van dit promotie-onderzoek om de veranderingen die teweeggebracht zijn door FFS bij katoentelers in te schatten met betrekking tot (i) de gezondheid van de telers en de blootstelling van telers aan bestrijdingsmiddelen; (ii) teeltkundige praktijken in de katoenteelt en de ecologische kennis van telers; (iii) verdeling van werk binnen families; (iv) invloed op het milieu; en (v) verandering in leefomstandigheden zoals ervaren door de telers.

Het onderzoek werd uitgevoerd tussen 2002 en 2004 in drie provincies van India, namelijk Andhra Pradesh, Karnataka en Tamil Nadu. Hierin werden in totaal tien dorpen onderzocht waarin FFS hadden plaatsgevonden in het kader van het IPM-programma 'katoen in Azië' van de EU en FAO (1994-2004) (IPM FFS) en, ter vergelijking, tien dorpen waarin deze niet hadden plaatsgevonden (controle). Gewerkt werd volgens het zgn. Double Difference Model, waarbij zowel alle dorpen met IPM FFS als die van de controle, vóór en na het tijdstip dat de IPM FFS had plaatsgevonden, werden onderzocht. Gegevens werden verzameld

door middel van interviews en oefeningen zoals zelfwaarnemingen en fotorapportages.

Acute gevallen van vergiftiging door bestrijdingsmiddelen werd gekwantificeerd door de gezondheid van 50 katoentelende echtparen vast te stellen gedurende een teeltseizoen (Hfst. 2). Een opmerkelijk hoog percentage van 84% had enige tot zware vergiftigingsverschijnselen. Niet alleen mannen die de bestrijdingsmiddelen toepassen, maar ook de vrouwen die in met bestrijdingsmiddelen bespoten velden werkten bleken zeer frequent vergiftigingsverschijnselen te vertonen. Vergiftigingsverschijnselen door bestrijdingsmiddelen bleken tien maal frequenter voor te komen onder relatief arme telers. Telers bleken nooit medische hulp in te roepen, waardoor ziekenhuisstatistieken over vergiftiging door bestrijdingsmiddelen de werkelijke situatie waarschijnlijk fors onderschatten.

Sinds de introductie van het IPM-concept is de verspreiding van de kennis hierover op het platteland traag geweest. De oorzaak hiervan is wel gezocht in de complexiteit van de methode, die mede afhangt van de ecologische kennis van de teler. FFS is een concept dat aan deze problemen tegemoet komt door proefondervindelijke ervaringen op eigen velden te stimuleren waardoor het vertrouwen van telers in IPM toeneemt. Om deze veronderstelde effectiviteit van IPM FFS te verifiëren werd de teeltpraktijk van 73 IPM FFS-telers en 64 controle-telers (niet-IPM FFS) vergeleken vóór en na uitvoering van de IPM FFS (Hfst. 3). Het bestrijdingsmiddelengebruik door de IPM FFS-telers was gereduceerd met 78%, waarmee het gebruik slechts 16% was van dat door gangbare, niet-IPM-telers. Telers met de grootste ecologische kennis gebruikten de geringste hoeveelheid bestrijdingsmiddelen. Ondanks het geringere gebruik van bestrijdingsmiddelen was de gewasopbrengst van IPM FFS-telers gelijkaan die van de controle-telers, wat aangeeft dat veel van het bestrijdingsmiddelengebruik overbodig is. Het nutriëntengebruik door IPM FFS-telers was echter niet anders vergeleken met dat van de controle-telers, wellicht doordat tijdens de FFS hieraan relatief weinig aandacht is besteed.

Een andere factor die wellicht de trage verspreiding van IPM verklaart is de organisatie van het werk. Gegevens hierover werden verzameld op 42 IPM FFS- en 52 controle-boerderijen, vóór en na introductie van IPM FFS (Hfst. 4). Katoenteelt blijkt arbeidsintensief te zijn, met 287 dagen arbeid nodig voor de teelt van één hectare. Bij de kleine katoentelers, waarop het onderzoek gericht was, deden vrouwen gemiddeld 74% van het werk. Aan gewasbescherming (toepassing van bestrijdingsmiddelen) werd 3-4% van de tijd besteed. IPM FFS-telers bleken niet meer tijd nodig te hebben voor de katoenteelt, maar wel werkten vrouwen relatief meer dan mannen, in vergelijking met controle-telers. Het succes van IPM FFS kan wellicht ten dele voorspeld worden door de beschikbaarheid van vrouwelijke werkrachten. De geringere tijd die door IPM FFS-telers besteed wordt aan de toepassing van bestrijdingsmiddelen heeft hoogstwaarschijnlijk een gunstig effect op hun gezondheid.

Intensieve landbouw in India heeft geleid tot verlaagde bodemvruchtbaarheid, uitputting van waterbronnen en eutrofiëring door nitraat, fosfaat en residuen van bestrijdingsmiddelen, en vermindering in biodiversiteit. Om de gevolgen van katoenteelt op het milieu te kwantificeren werd een Levenscyclusanalyse (Life Cycle Analysis, LCA) uitgevoerd met betrekking tot gangbare, geïntegreerde (IPM) en biologische katoentelers (Hfst. 5). Hiertoe werd een schatting gemaakt van de Environmental Index Quotient (gevolgen van gebruik van

bestrijdingsmiddelen), klimaatverwarming, verzuring, eutrofiëring en bodemerosie van de teelt van katoen. De toxiciteit van de hoeveelheid en soort van bestrijdingsmiddelen die door IPM-telers werd toegepast was 75% minder dan die door gangbare telers. Voor verzuring en eutrofiëring was dit een reductie van respectievelijk 33 en 50%. De opbrengsten waren bij de IPM-telers gemiddeld bijna 50% hoger (1093 kg ha⁻¹). Alleen wat betreft klimaatverwarming scoorden IPM-telers gemiddeld slechter dan de niet-IPM-telers: zo'n 25% hoger.

Tot slot werd met een Sustainable Livelihood Analysis het effect van IPM FFS op de levensomstandigheden van de telers uitgevoerd (Hfst. 6). Telers ondervonden van IPM FFS duidelijke verbeteringen met betrekking tot hun gezondheid en inkomsten alsmede met betrekking tot effecten op het milieu. Verder waren ze van mening dat IPM FFS hen ook sociale voordelen bood door verbeterde onderlinge samenwerking. Telers die in de dorpen wonen waar wel IPM FFS werd uitgevoerd maar die daar zelf niet aan deelnamen ondervonden wel positieve effecten met betrekking tot milieu en sociale factoren, maar geen financiële voordelen.

De resultaten van dit onderzoek laten zien dat ontwikkelingswerk dat gebaseerd is op onderwijs tot aanmerkelijke verbeteringen kan leiden in de levensomstandigheden, op voorwaarde dat boeren toegang hebben tot hoogwaardige training. De samenstelling van het FFS curriculum speelt een sleutelrol tot het succes ervan. In het studiegebied zou de effectiviteit van toekomstige FFS programma's nog verbeterd kunnen worden door een bredere systeemgerichte aanpak in plaats van specifieke aandacht voor één bepaald gewas als katoen.

De algemene conclusie uit deze studie is dat Farmer Field Schools het welzijn van boeren kunnen versterken. Effecten van deelnemers aan FFS op naburige telers werden ook waargenomen. Deze hadden wel positieve gevolgen wat betreft sociale en milieu-aspecten, maar verbeteringen in de capaciteit om weloverwogen beslissingen te nemen en het beheer aan te passen werden niet waargenomen. Daarom is verder onderzoek op regionaal niveau nodig dat FFS kan opschalen.

Deze studie laat zien dat in de katoenteelt in India het hoge gebruik aan bestrijdingsmiddelen zowel overbodig als schadelijk is voor mens en milieu. De langetermijneffecten van bestrijdingsmiddelen (op mens, landbouwhuisdieren en milieu) zijn niet in dit onderzoek betrokken. Desondanks is het evident dat een verbod op de meest schadelijke bestrijdingsmiddelen (toxiciteitsklassen I en II van de Wereldgezondheidsorganisatie) en inperking in het gebruik van andere middelen een hoge prioriteit dienen te hebben om het aantal vergiftigingen wereldwijd te beperken. Om een alternatief te kunnen bieden voor deze bestrijdingsmiddelen dienen regeringen ecologische benaderingen verder te stimuleren, mede door onderzoek aan de economische rentabiliteit van deze benaderingen. Samenwerking tussen boeren, onderzoekers en beleidsmakers is essentieel om dit doel te bereiken.

Curriculum Vitae

Francesca Mancini was born on October 31st, 1970 in Genoa, Italy. In 1995, she graduated in Tropical and Subtropical Agricultural Science at the University of Florence. In the following years she worked as a plant pathologist on cotton diseases for a number of European research projects in Italy and Greece. She also co-ordinated research activities on natural forest regeneration as well as staff exchange and training between the University of Florence and research institutes in West African countries. She organised international training and workshops, and lectured in the University. In 1999 and 2000, she acted as the National Focus Point of Italy for the European Tropical Forest Research Net (ETFRN). During 2001- 2004, she was employed by the Food and Agriculture Organisation (FAO) of the United Nations to collaborate on the implementation and impact assessment of the Integrated Pest Management (IPM) Programme for cotton in India. Her main task was organising educational activities, e.g. Farmer Field Schools and Training of Facilitators on cotton IPM using gender sensitive approaches. In the same years, she worked with the National IPM Programme of Pakistan as a resource person under the FAO project on pesticide risk reduction for women and communities. In 2004-2005 she was the Scientific Coordinator's assistant of the Interdisciplinary Research and Education Fund (INREF) Project 'Strengthening science-based policy-making in pest management' in Wageningen. She is currently the scientific supervisor of the IPM Europe Domain Task Force on Chronic health effects caused by pesticide exposure operative in India and Pakistan. Her main expertise and interest is facilitating the building of institutional and human capacity to promote the spread of socially and ecologically acceptable agricultural practices.

List of Publications

- Mancini F., Jiggins, J. L. S., 2006. Participatory and conventional approaches to programme evaluation: a case study on evaluating Integrated Pest Management Farmer Field School in India. Preselected for publication of a special issue in International Journal of Agriculture Sustainability.
- Mancini F., Termorshuizen A. J., van Bruggen A. H. C., 2006. Impact of Integrated Pest Management Farmer Field Schools on pesticide use and farmers' ecological knowledge on cotton farming in India. Plant Protection Science. Submitted.
- Mancini F., Wesseler J., Jiggins, J. L. S., 2006. The effects of Integrated Pest Management on labour organization and gender roles in small cotton farms in India. Agricultural Systems. Submitted.
- Mancini F., van Bruggen A. H. C., Jiggins, J. L. S., 2006. Evaluating Farmer Field School Outcomes using the Sustainable Livelihood Approach, Experimental Agriculture. Submitted.
- Karst K. J., Termorshuizen A. J., F. Mancini, 2006. Environmental Impact Assessment of cotton cultivation in Central India, Agriculture, Ecosystem and Environment. Submitted.
- Mancini F., van Bruggen A. H. C., Jiggins J. L. S., Ambatipudi A., Murphy, H., 2005. Acute pesticide poisoning among female and male cotton growers in India. International Journal of Occupational and Environmental health 11(3):221-32.
- Mancini F., van Bruggen A. H. C., Jiggins J. H. L., Ambatipudi A., Murphy, H., 2005. Incidence of Acute Pesticide Poisoning among Male and Female Cotton Growers. In: The Impact of the FAO-EU IPM Programme. Eds. P.A.C.Ooi, S. Praneetvatakul, H. Waibel, G. Walter-Echols. Pesticide Policy Project. University of Hannover. Publication Series Special Issue No. 9., Hannover University, Germany.
- Ooi, P.A.C., G. Walter-Echols, D. Weidong, A. L. Morales-Abubakar, L. Guan Soon, P. Pachagounder, M. H. Soomro, C. Galvan, F. Mancini, R. Petersen, K. Kamp. (eds). 2004. Environmental Education for Poor Farmers.FAO Regional Office for Asia and the Pacific.
- Ragazzi A., Moricca S., Capretti P., Dellavalle I., Mancini F., Turco E., 2001. Endophytic fungi in *Quercus cerris*: isolation frequency in relation to phenological phase, tree health and the organ affected. Phytopathol. Mediterr., 40, 165-171.
- Apetorgbor M., Mancini F., Turco E., Cobbinah J.R., Ragazzi A., 2001. The involvement of fungal pathogens in dieback-decline of *Milicia excelsa* saplings in plantations. Journal of Plant Diseases and Protection, 108, 568-577.
- Mancini F., Apetorgbor M., Cobbinah J.R., Ragazzi A., 2001. Potential of fungal pathogens on seeds and seedlings of *Milicia excelsa* in three ecological zones of Ghana. Journal of Plant Diseases and Protection, 108, 31-38.
- Ragazzi A., Moricca S., Dellavalle I., Mancini F., 1995. Infection of Cotton by *Fusarium oxysporum* f. sp. *vasinfectum* as affected by water stress. Phytoparasitica, 23, 315-321.
- Ragazzi A., Vecchio V., Dellavalle I., Cucchi A., Mancini F., 1994. Variations in the pathogenicity of *Fusarium oxysporum* f. sp. *vasinfectum* in relation to the nutrient medium. Z. PflKrankh. PflSchutz, 101, 263-266.

Ragazzi A., Dellavalle I., Mancini F., 1994. New findings on the behaviour of *Fusarium oxysporum* f.sp. *vasinfectum* from a saline-enriched medium. Proceedings of the Third Israeli-Italian Phytopathological Symposium, Kfar Ha'Maccabiya, Israel, June 14-17, 1994. *Phytoparasitica*, 22, 177.

Ragazzi A., Giomi P., Mancini F., Turco E., 1994. Microrganismi associati ad alcune colture negli Stati del Ceará e del Pará (Brasile). *Rivista di Agricoltura Subtropicale e Tropicale*, 88, 277-296.

PE&RC PhD Education Statement Form

With the educational activities listed below the PhD candidate has complied with the educational requirements set by the C.T. de Wit Graduate School for Production Ecology and Resources Conservation (PE&RC) which comprises of a minimum total of 32 ECTS (=22 weeks of activities)

Review of literature (ECTS 4)

Socio-economic and gender analysis of cotton cultivation in four villages in Karnataka, South India

Writing of Project proposal (ECTS 4)

Impact of Integrated Pest Management on the environment, health and livelihoods of female and male cotton growers in South India

Post-Graduate Courses (ECTS 7)

- Seventh International training programme on Establishing Certified Organic Management Systems for Production, Processing and Marketing, ENCON, India, (2004)
- Science of Organic Production: from Ecology to Socio-Economics, Wageninigen, (2005)
- Socio-cultural Fields Research Methods, Wageninigen, (2005)
- Advanced Statistics, Wageninigen, (2005)
- Professional Communication Strategies, Wageninigen, (2005)

Deficiency, Refresh, Brush-up and General courses (ECTS 0,5)

- Working with EndNote8 (2005)
- Guide to Digital art work (2005)

PE&RC PhD discussion groups (ECTS 5)

- Agricultural production systems in temperate systems, (2004/2005)
- Social Learning Group (interdisciplinary University Group), (2004-2005)
- Biological Farming Systems meetings, (2004-2005)

PE&RC annual meetings, seminars and Introduction days (ECTS 0,5)

- Introduction weekend, (2005)

International symposia, workshops and conferences (ECTS 5)

- Planning and evaluation meeting of the IPM Programme for Cotton in Asia, Ho Chi Minh City, Vietnam, FAO, (2001)
- Status of Bt cotton studies in China Review Workshop, Bangkok, Thailand, FAO, (2001)
- Conference on an Alternative for Cleaner Production and Pest Management by 2015, Bangkok, - Thailand, FAO, (2001)
- Conference on "Health Effects of pesticides" Malaysia, PAN, (2002)
- International Plant Pathology Conference in the Tropics, IPPCT, Malaysia, (2003)
- Regional Workshop on IPM-FFS Impact Assessment, Thailand, FAO, (2004)
- Impact Assessment Methodologies workshop, Hannover University, Germany, (2004)
- Impact Assessment Workshop, CIMMYT, El Batan, Mexico, (2005)

Laboratory training and working visits (ECTS 3)

- Field training Assessing pesticide acute poisoning by Dr. H. Murphy

Pictures





Cover design by Achille Mancini, Carl Looijen
Photos by Francesca Mancini
Printed by Ponsen & Looijen BV, Wageningen, the Netherlands