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Environmental Pest Management: The Need for Long-term Governmental Commitment

Moshe Coll and Eric Wajnberg

18.1 The Prevalence of a Pest-centric, Bottom-up Approach to Pest Control

For thousands of years, farmers have protected their crops by combating one pest at a time, using one control method (Lewis *et al.* 1997), with very little consideration of the surrounding environment. Over the years, new control methods, tactics and technologies have been adopted. These include employment of resistant crop genotypes; pest-retarding cultivation practices such as tillage, crop rotation, timing of planting and harvest and sanitation; chemical pesticides, including new chemistries, formulations and delivery tools; biological control agents; sterile insect techniques (SIT); transgenic crops; and now transgenic pests through gene-drive mechanisms. Such pest-centric approaches have remained the dominant dogma throughout the evolution of mainstream plant protection.

Some 55 years ago, a promising attempt was made to adopt a system-wide view of pest management. In its early form, Integrated Pest Management (IPM) was intended to provide a more holistic approach to pest management (van den Bosch and Stern 1962) than that offered by the supervised control commonplace at the time (Figure 18.1a). During the following decades, some pest management programmes were developed in the spirit of IPM. However, these also tended to target a specific pest or pest group in a particular crop. IPM thus remained focused on pest populations even when area-wide approaches were adopted. Interactions between pest control measures and human and ecological environments have not been incorporated in pest management programmes. Perhaps as a result, we have failed to reduce yield losses to pests and to produce more food in sustainable and environmentally compatible ways. It has been estimated that global crop losses to arthropods, diseases and weeds increased from 34.9% in 1965 (Cramer 1967) to 42.1% in 1988–1990 (Oerke *et al.* 1994) despite continuous intensification of pest control efforts.

In light of this, it is imperative that we renew our efforts to develop and implement pest management schemes that are effective, economically viable, sustainable and safe to humans and the environment. Towards this end, chapters in the present volume review the state of our understanding of pest population management and discuss

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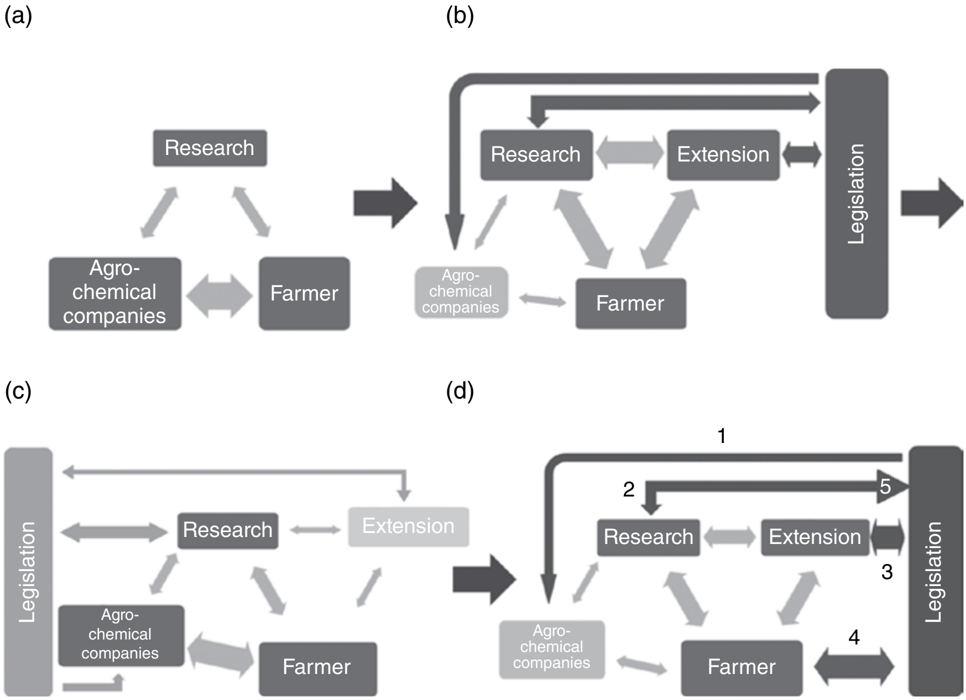

Figure 18.1 Primary players in pest control schemes over time. (a)1940s to early 1960s. (b) Mid-1960s to late 1980s. (c) Early 1990s to mid-2010s. (d) Proposed environmental pest management scheme: (1) pesticide regulation, (2) funding of invited research, (3) support for extension and farmers' participatory programmes, (4) policies to influence farmers' practices, (5) research outputs used to fine-tune governmental policies. Arrows indicate flow direction of inputs. Shade intensity of player's box and arrow width indicate relative importance of player's input.

current thinking and policy concerning the interactions among pest control actions, human health and the environment.

18.2 The Main Messages Presented in this Volume

Chapter 1: Environmental Pest Management: A Call to Shift from a Pest-Centric to System-Centric Approach

Pest control efforts have traditionally focused on specific pests in specific fields. This pest-centric approach was also commonly practised in Integrated Pest Management (IPM) programmes. We have largely failed to develop effective, safe and sustainable plant protection systems. To address this goal, a new pest management paradigm must be adopted: a system-centric approach should replace the historical bottom-up, pest-centric one. Furthermore, IPM programmes are likely to fail eventually because of the high variability and unpredictability of many interacting natural and anthropogenic factors. Therefore, goal-based environmental pest management schemes should be advanced.

Chapter 2: Approaches in Plant Protection: Science, Technology, Environment and Society

Since first proposed, the term IPM has been assigned highly diverse interpretations and meanings. Various interest groups have used the term to promote their own agendas to the point at which reduction in pesticide use and integration of multiple control tactics are no longer prioritized. The authors call for conceptual changes in IPM policy as part of a transformation of agricultural practice to systems that sustain the ecosystem services needed for viable and socially fair food production.

Chapter 3: The Economics of Alternative Pest Management Strategies: Basic Assessment

Pest control measures are prone to social conflicts since farmers act to maximize profit and are unlikely to consider the off-farm environmental consequences of their decisions. Yet many pest control practices affect neighbouring managed and unmanaged lands, and have an impact on the health of consumers and residents in nearby communities. Farmers may also fail to fully appreciate on-farm consequences of different pest control tactics.

Chapter 4: Effects of Chemical Control on the Environment

Pesticides affect the environment directly, through primary toxicity, indirectly through secondary poisoning, and in sublethal ways. In addition, constant use of pesticides leads to widespread resistance in populations of insects, weeds and micro-organisms. Resistance may be overcome by introducing new products to replace those that have become ineffective, but this solution is harmful to an environment that is already polluted with many types of toxic chemicals.

Chapter 5: Environmental Impacts of Arthropod Biological Control: An Ecological Perspective

Classic biological control has in the past been considered a safe and highly effective approach to pest management. However, in recent decades, there has been growing concern about the negative environmental impact of introduced organisms. In the release area, alien biological control agents may attack non-target organisms, thus jeopardizing biodiversity and altering the structure and function of native ecosystems. Therefore, the authors advocate that no introduction of foreign biological control agents be permitted without careful risk assessment weighing agricultural benefits and environmental risks of the proposed biological control programme and alternative pest control methods. The alternatives should also include a no-action option.

Chapter 6: Effects of Transgenic Crops on the Environment

Genetically modified crops may affect organisms in managed and natural ecosystems in a highly complex manner, both directly and indirectly. The authors of this chapter stress the need for prospective risk assessments, including quantitative uncertainty analyses.

As a whole, field impacts of genetically engineered crops on non-target organism and ecosystems have been rare. The longer temporal and larger spatial scales at which such effects may operate present further challenges for the development of comprehensive and reliable risk assessment tools.

Chapter 7: Ecosystem Services Provided by Unmanaged Habitats in Agricultural Landscapes

In many agro-ecosystems, the presence of natural and semi-natural vegetation has been shown to enhance the density and species diversity of predatory and parasitic arthropod communities. Despite this finding, most studies fall short of quantifying ecosystem services such as biological pest suppression and decrease in yield loss which are provided by native vegetation. Any suggestion concerning the manipulation of vegetation near crop fields should take into account the effects on non-target pest groups, natural enemies, pollinators, decomposers in the soil and other organisms. Unmanaged areas, for example, may serve as reservoirs for pesticide-susceptible pest populations that could then contribute to slowing the rate of resistance development.

Chapter 8: The Role of Ecosystem Disservices in Pest Management

Management of agro-ecosystems for sustainable pest management relies upon understanding the nature of interactions among multiple co-occurring ecosystem services, such as food production, biodiversity conservation, pest regulation and pollination. Each of such services has the potential for positive, negative or neutral effects on the others, but these interactions can be highly complex and their relative effects are thus difficult to quantify. This may explain the dearth of data in the literature on valuation of ecosystem disservices. In addition, patterns of ecosystem services and disservices vary greatly over local and regional scales within a landscape. This makes them even more difficult to evaluate.

Chapter 9: Effect of Climate Change on Insect Pest Management

Global warming is expected to have implications for some aspects of almost every pest control measure, from pesticide residue and toxicity patterns, through the longevity of pheromone dispensers and pheromone plume patterns, to the activity of natural enemies and their ability to locate hosts. Climate change may also affect pest and enemy development, phenology (i.e. synchronization), behaviour, reproduction, survival, etc. In this respect, we would add that global warming may also influence pest–enemy interactions by altering their geographic distribution (Schuldiner-Harpaz and Coll 2013). Finally, other global climatic changes, such as elevated levels of atmospheric CO_2, greatly influence complex crop–pest–enemy interactions (Coll and Hughes 2008).

Chapter 10: Effects of Biological Invasions on Pest Management

The global impact of invasive species in ecosystems includes changes in the structure and function of pest and natural enemy populations in agro-ecosystems. Continuous monitoring, interception efforts and trade regulatory policies are needed to protect crop plants from pests that may be transported through commodity trading and become established in non-endemic areas. These efforts require global policies and international co-operation that promote greater biosecurity in trade and travel. Similarly, multidisciplinary collaboration among researchers would help to more effectively integrate and transfer information pertinent to invasive species.

Chapter 11: Pesticides and Human Health

Pesticides undergo rigorous premarket toxicity testing with regard to carcinogenicity and other health hazards. However, these tests do not capture the full range of chronic diseases and many of the methodologies used have serious shortcomings. In addition, and because premarket testing is relatively limited in its scope, results are often obsolete by the time additional trials are conducted; many of the compounds have been taken off the shelf by then, because of declining efficacy due to resistance development, development of cheaper compounds, and other reasons. Thus, no comprehensive data are available for most widely used pesticides. The authors call for standardization of pesticide safety testing.

Chapter 12: Human Health Concerns Related to the Consumption of Foods from Genetically Modified Crops

The assessment of the health risk associated with GM foods has technical limitations that make it difficult to demonstrate that they are safe for consumption. These technical limitations can be addressed by a wide range of testing protocols which must be standardized in order to combine global efforts to ensure a safe food supply.

Chapter 13: Effectiveness of Pesticide Policies: Experiences from Danish Pesticide Regulation 1986–2015

The authors state that the sparsity of relevant comparative data on pesticide consumption across nations constitutes a critical limitation for the development of effective global pesticide policy. They call for legislators to solicit this type of data collection.

Chapter 14: Impacts of Exotic Biological Control Agents on Non-target Species and Biodiversity: Evidence, Policy and Implications

This chapter discusses major issues such as the administrative constraints on funding or on simply requiring the applicant for a natural enemy release permit to perform a postrelease validation and report the findings. The sole objective for regulators entrusted with granting release permits is to reduce risk. Postrelease monitoring of new biological control agents does not serve to mitigate risk. As a result, postrelease assessments are rare, and predictions made at the permit-granting stage remain untested. This greatly limits our ability both to assess risk and to support an effective decision-making process in the future.

Another shortcoming of most procedures for granting release permits is their focus on potential risk assessment while neither taking into account expected benefits nor weighing up the risks and benefits posed by alternative measures, including a 'do-nothing' approach. As a result, potential risks involved in the release of a biological control agent are not considered against all potential benefits or risks involved in the employment of alternative pest control measures, such as pesticide application.

Chapter 15: Pesticides in Food Safety versus Food Security

The need to provide the growing human population with sufficient, safe food of adequate nutritional quality may result in a trade-off between food safety and food security. Pesticides may help to increase food production while at the same time jeopardizing human health. The nature of such trade-offs varies among regions. Tolerance of the risk of chronic pesticide effects, for example, may be higher in regions characterized by high levels of food insecurity and/or shorter life expectancy. Therefore, the trade-off between food safety and food security can be managed only at governmental levels, where data about expected demographic changes, future food production and imports may enable the construction of models to assess the risks associated with pest control.

Chapter 16: External Costs of Food Production: Environmental and Human Health Costs of Pest Management

In many cases, some of the costs involved in implementing pest control measures are covered by neither the farmer nor by the producer of the products used. For example, the negative effects of pesticide use on human health and the environment are a burden to society, but entail no cost to pesticide users, vendors or manufacturers, all of whom benefit from the use of chemicals. The net societal good could be enhanced by governmental regulations aimed at increasing the benefits of pesticide use together with reducing their overall burden to society.

Chapter 17: The Role of Pest Management in Driving Agri-environment Schemes in Switzerland

In Switzerland, the role of pest management in agro-environmental schemes is limited to the reduction in pesticide use and in other agricultural inputs. Thus far, these schemes have failed to promote additional environmentally desirable pest control measures such as enhancement of biological control services through flower stripping, cover cropping or cultural practices. Systems currently in use also fail to externalize health and environmental costs of pesticide use.

18.3 The Role of Governments in Pest Management

The role of governmental legislation and regulatory agencies is in evidence in most of the topics reviewed in this volume, and greater involvement is often called for. This is particularly important for:

- co-ordinating health and environmental safety testing for pesticides and GM foods
- standardizing and possibly legislating a definition of IPM
- regulating postrelease assessment of biological control agents
- externalizing pesticide costs

- incorporating ecosystem services and disservices in pest management systems
- mitigating adverse effects of climate change and biological invasions
- regulating pesticide registration
- weighing food safety *versus* food security concerns
- incorporating all of these issues into agro-environmental schemes that direct more attention towards pest management concerns.

We argue that governmental commitment is critical for the sustainable employment of environmental pest management. In its early days, the IPM approach acted to displace pesticide use with other, safer pest control measures (Figure 18.1b). This was implemented through intensive public support of research, extension and participatory action research (PAR, also known as farmer participatory research, FPR) (Matteson 2000). In time, public support declined. In the USA, public funding for extension grew at the rate of 6.7% annually during the years 1915–1949, and then at 2.39% per year from 1950 to 1980 (Pardey *et al.* 2013). Public funding for extension then declined by 0.25% annually between 1980 and 2006 (Pardey *et al.* 2013). As a result, the US federal government provided 62% of the funds supporting extension in 1919, but only 21% of this funding in 2006 (Pardey *et al.* 2013). Similar trends were seen in other countries, such as the UK and New Zealand, where extension services and research were privatized and funding for farmer training was discontinued. Likewise, the most important obstacles listed by pest control practitioners and farmers to the adoption of IPM in developing countries involve lack of supportive governmental policies and farmer training (Parsa *et al.* 2014).

The vacuum created by falling public support was soon filled by the agro-chemical companies, promoting their new pest control compounds (Figure 18.1c). This is evident in a recent survey which indicates that 81% of responding extension officers in the USA are in a partnership with industry (Krell *et al.* 2016). Moreover, a significant amount of extension research is now funded by the private sector, with more than 14% of the officers acknowledging the potential risk for conflict of interest (Krell *et al.* 2016). The actual number is probably much higher.

As multinational agro-industrial conglomerates began to dominate the market, producing conventional and transgenic, herbicide-tolerant seeds, and manufacturing compatible herbicides and other pesticides, the private sector once again became a major and sometimes the sole force in pest management practice. These companies promote sales by advocating their own brand of 'IPM' ('the other IPM' *sensu* Ehler 2006), an approach that encourages the use of 'soft' pesticides as the main and often only means of pest control. Such 'soft' materials require low delivery doses of active ingredients, and have a short half-life and thus low residual effects. While the latter traits are highly desirable, the current approach is far from an integrative, sustainable and environmentally compatible strategy for pest management.

The dominance of the private sector in current pest control thought and practice is clearly evident in Krell *et al.* (2016), in which Dow AgroSciences affiliates propose that the public extension service create a partnership with the private sector to provide information to farmers (Krell *et al.* 2016). This preposterous proposal echoes the weakening of the extension service: in a 1994–1995 US Department of Agriculture survey, 69% of responding farmers reported that they obtained information from agricultural retailers and private scouting services, and only 15% from other sources, such as extension officers (Padgitt *et al.* 2000). The situation has not improved since then: 69% and

58% of Iowa farmers rely on agricultural chemical dealers for information on insect and weed management, respectively (Arbuckle *et al.* 2012).

The major reversal of the pest control approach from the original scheme of IPM back to calendar spraying is well documented, for example in the rice crop in South-East Asia (Bottrell and Schoenly 2012; Heong and Hardy 2009). While a few, mostly 'supervised control' IPM programmes are still implemented, many others have been discontinued. In California, USA, for example, almond growers have actually ceased monitoring their orchards for pests and simply spray routinely with inexpensive pesticides. Only a very few 'true IPM' programmes are now employed globally, mostly in organic farming systems, which occupy an extremely small proportion of the total arable land in the world. Therefore, in the vast majority of cropland around the world, pests are currently controlled chemically with little consideration for human and environmental health. The pest control industry once again dominates farmers' decisions by offering them new and temporarily highly effective pest control methods as they become available. These include (1) the employment of pest sex pheromones for monitoring, mass trapping and mating disruption, (2) the development of highly potent and inexpensive pesticides, and (3) the introduction of insect-resistant and herbicide-tolerant transgenic crops. In contrast, a recent study shows that IPM programmes in Asia and Africa have brought about a 30.7% reduction in pesticide use while increasing yields by 40.9% across 85 projects in 24 countries. In 30% of the cases, IPM eliminated pesticide use entirely (Pretty and Bharucha 2015). Moreover, and against the claims of the agro-chemical industry, the authors found that at least 50% of pesticide use was unnecessary.

While a 20-year-old call by Lewis *et al.* (1997) for a shift from a therapeutic to a total system approach in pest management is a step in the right direction, we argue that such a shift would be possible only through strong and permanent commitment by governments and their regulatory agencies (Figure 18.1d). At the United Nations Sustainable Development Summit in 2015, leaders of 193 countries adopted the 2030 Agenda for Sustainable Development. It includes a set of 17 Sustainable Development Goals (SDGs) to end poverty, fight inequality and injustice, and tackle climate change by 2030. Of these 17 identified goals, goal #2, 'End hunger, achieve food security and improved nutrition and promote sustainable agriculture' is directly relevant to the way in which we practise pest control. Two other goals are also pertinent to pest control: goal #12, 'Ensure sustainable consumption and production patterns' and goal #15, 'Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss'. This goal-setting initiative was preceded by a National Research Council report (NRC 1996) that called for 'a paradigm shift in pest-management theory […] that examines processes, flows, and relationships among organisms' and others that emphasized that, in its present form, crop protection treats only the symptoms of pest outbreaks instead of their causes (Zorner 2000).

18.4 Characteristics of Top-down, Environmental Pest Management

To date, some countries have adopted regulatory tools in order to achieve various agricultural and environmental goals, but these goals and approaches vary greatly among countries. Some schemes, for example, promote biodiversity conservation while others focus on agricultural productivity (see discussions in Rey Benayas and Bullock 2012, Straub *et al.* 2008, Tschumi *et al.* 2015 and Whittingham 2011). Nevertheless, pest management plays only a negligible role, if any, in these overall schemes. In Europe, for instance, conservation biological control is promoted implicitly with the objective of enhancing species diversity.

Yet synergistic promotion of ecosystem services, effective and sustainable agricultural productivity and biodiversity conservation can advance safe and environmentally compatible pest management practices. For example, increased environmental and health risk awareness in recent decades has led to a parallel increase in regulation of pesticide use and employment of genetically modified crops. Governmental involvement would also facilitate co-ordination and communication between landowners within a landscape and a thorough understanding of local and regional patterns of multi-scale ecosystem services and disservices, the provision of which is likely to be a key factor for effective and sustainable agricultural management (Bommarco *et al.* 2013; Mitchell *et al.* 2014).

However, this legislation is often handled and enforced by different governmental agencies, typically with little co-ordination among them. Intergovernmental and international co-operation is also needed in light of demographic, technological, trade, marketing and climatic considerations. This co-operation would replace the current situation in which growers, extension personnel and crop protection researchers are responsive mainly to changes in pesticide availability, due to regulatory banning and availability of new chemistries, and to the development of new technologies. Governmental involvement would also lend itself to the solicitation of invited research to fill gaps in our understanding. These new data could then be incorporated into policy decisions.

As outlined in Chapter 1, grassroots research, extension and farmer training efforts must be backed by legislative, regulatory and enforcement actions taken by governments. Governmental inputs acting to promote sustainable agricultural practices and nature conservation should have four main objectives that are currently missing in most legislation:

- the establishment of goal-based agro-environmental schemes
- externalizing the true costs of pesticide use
- strengthening of the public extension service
- soliciting goal-specific research.

Properties and methods used for the implementation of these objectives would certainly vary greatly among countries. Governmental and social structures, economic forces, traditions and other factors will shape needs, impose constraints and determine feasibility of means, and thus influence goals and approaches. In some cases, the required infrastructure already exists and needs only to be adjusted to the new objectives. The State of California, for example, charges a 'Mill Assessment' fee on pesticide sales (California Environmental Protection Agency 2016). This mechanism could be adopted to discourage pesticide use and cover health and environmental costs related to pesticide application.

For practical, marketing or ideological reasons, growers should be allowed to meet regulatory requirements in different ways: through organic farming, permaculture, IPM or by adopting just a few practices which promote desirable outcomes. Finally, centralized schemes and policies could be amended and fine-tuned as more information becomes available and with changes in agricultural production and market conditions.

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