

Chapter 1

Questions Around the Persistence of the Pesticide Problem

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Introduction

Sustainable agriculture includes sustainable pest management. But how sustainable are current pest management practices that rely heavily on the use of pesticide products? This question has provoked considerable, often heated, debate. Positions in the debate have become entrenched, both on the side of those who believe that the (controlled) use of pesticide products can and does contribute to sustainable agriculture, and on the side of those who believe the opposite (Hamlin & Shepard 1993). The former point out that farmers who use pesticide products and other benefits of modern agricultural technology, such as fertilisers and seeds, are able to realise higher yields on their lands. Higher yields enable the feeding of a growing world population, and reserves land for uses such as recreation and nature conservation that otherwise would need to have been turned into productive agricultural land (Oerke *et al.* 1994). Their opponents argue that intensive agricultural use of land has led to serious environmental degradation while not providing a solution to hunger (e.g. Dingham 1993; Vorley & Keeney 1998). Moreover, they argue, by adopting intensive agricultural production systems, farmers lock themselves into a spiral of debts and further loans so as to invest in additional productivity growth. We do not wish to step into such a debate by choosing sides. It is our conviction that there is some truth on both sides. Much of the debate is unproductive black-and-white schematising. The greys have disappeared. Our ambition in this book is to bring the greys back into the debate. This volume aims to analyse the question of why the environmental impact of pesticide use continues to be of serious concern – the persistence of the pesticide problem – as well as to identify and critically assess various improvements and alternative strategies to circumvent the current problems of agricultural pesticide use.

This introductory chapter continues explaining the motives behind our questions and ambitions and developing a conceptual framework of three interrelated spheres – agricultural production, socio-economic institutions, and agricultural innovation – that has guided our selection and direction of the contributions in this volume. The chapters are introduced in the final section of this chapter.

Are environmental problems of pesticides still an issue?

While it is obvious that there are problems related to the past and current use of pesticide products, our question is: what is the origin and structure of the problem? One might expect that over time individual and institutional learning in three areas should have resulted in significant improvements: (1) policies regulating the use of pesticide products, (2) the operational use of pesticide products, and (3) science based innovation, including the development of new active substances, formulations, and application technologies, as well as alternatives to chemical crop protection. If, at least in the Western, industrialised world, pesticide products and their agricultural use have been regulated for at least half a century, if farmers have built up, individually and collectively, an accumulated experience with agricultural pesticide use over a period of anywhere between 50 and 150 years, depending on the geographical region, and if for over a century, industry has been trying to profit by marketing more effective, cost-efficient and safer pesticide products, why then are Western, industrialised societies still facing problems related to pesticide use?

Our approach is limited to pesticide use in Western, industrialised countries, which is not to downplay the adverse impacts of pesticide use in developing countries. On the contrary, we would agree with many observers that the pesticide problem is far worse in those countries, e.g. because of lower levels of education, illiteracy, lack of a functioning regulatory systems, lack of money for protective measures, and the availability of pesticide products forbidden in Western countries. However, our analysis of the pesticide problem in Western, industrialised countries is directed to a different end. We want to analyse the manner in which the differences in context of various elements of the pesticide problem structure the societal and individual learning of actors. Such learning experiences and the solution to partial problems of pesticide use have structured different but intertwined development paths.

Pesticide policies have always had a strong focus on regulating negative externalities. Early policies aimed at ensuring the efficacy of pesticides in killing or deterring undesired organisms. Pesticide producers were only allowed to sell products with proven efficacy. Early regulation was thus directed at ensuring effective transactions and avoidance of non-effective products. Later, additional policy objectives were introduced, including the protection of occupational health and safety (protection of farmers and husbandry) and food residues (protection of consumers). Since the early 1960s, when the negative environmental impacts of pesticide use became a topic of societal debate (Carson 1962; Briejèr 1967), an increasingly refined and detailed regime of measures was implemented in order to reduce environmental impacts of pesticide use. In this context, the implementation of EU Directive 91/414 and its annexes is to be considered a landmark. Pesticide policies, thus, focus on regulatory design to curb negative effects, notably by implementing maximum acceptable concentrations (norms) and threshold concentrations for individual compounds in specific environments (food, water, soil and air) and on pesticide application routines and techniques. Several positive changes have been achieved, including bans on various pesticides: outstanding are bans on DDT and the so-called 'drins', more recently on the 'dirty dozen' POPs, the persistent organic pollutants.

The rationale of regulating the negative externalities of pesticide use by authorising their use—or even the conditions of their use—is based on a strong belief in the possibility of prediction by various experimental methods and modelling the environmental fate of pesticide products. Today, for example, a pesticide company is permitted to market a pesticide product for a certain period of time, if it proves—with state-of-the-art science and technology—that the product is ‘safe’. In this context ‘safe’ means that, under the assumption of proper use by the farmer, the product is not expected to result in unacceptable environmental degradation. To this end, a set of criteria based on compound characteristics has been legally established including criteria on degradation, mobility and toxicity. Such an authorisation system implies the extensive generation and modelling of relevant data from laboratory and field tests under controlled conditions prior to submission of the authorisation request to the relevant authorities.

Farmers, too, have developed experience with pesticide products. Most farmers know about the hazardous nature of pesticide products and their handling, in some cases caused by unfortunate accidents, more often because they have read label instructions or listened to the advice of extension services or agrochemical sales advisors. Undoubtedly, neighbouring farmers and colleagues in farmers’ study groups will be very anxious to hear about experiences with newly introduced pesticide products, especially about the product’s efficacy in pest control, its cost and ease of handling. Learning and education with regard to use has been based on the experience as well as the marketing arguments of the agrochemical industry. Negative consequences have also been encountered from the interaction between methods and results. Thus widespread occurrence of resistance to chemicals on the one hand has certainly played a role in the growth of doubts within the farming community and a turn towards alternative methods. On the other hand it is one of the reasons why many farming organisations argue for a variety of chemicals and are disappointed at the slow introduction of new compounds.

Many new products have been introduced since the Bordeaux mixture was first applied about 150 years ago. Several substituted for older, less effective or more risky products. Modern pesticides show little resemblance to the by-products of the early chemical industry—pharmaceutical products, synthetic dyes, fibres and plastics—that were used as pesticide products. Today’s pesticide products are high-tech products: consider the systemic character of many fungicides, the low dose rates of several herbicides and the specificity of insecticides. They exhibit higher selectivity and reduced persistence by the introduction of new active ingredients and formulations. The agrochemical industry spends huge sums, not so much on the identification of new active ingredients, as on the testing for environmental, human and eco-toxicological characteristics of those compounds and on the quest for the most effective formulation. Additionally, many developments have taken place in application technology. Early application technologies were often based on the spraying of pesticide products from back-packed containers under air pressure. Mechanisation of spraying (larger containers, tractor or plane based), evolving spraying techniques (finer droplets, nozzle orientation), and improvements of formulation technology (seed coatings, water soluble granules, adhesives, flow compounds) are examples of further

developments that have taken place in the introduction of more effective application technologies. Containers have improved to make handling safer. In several countries, including The Netherlands, plane sprayings are restricted, and spray machinery has to be controlled annually in order to get the pesticide product where it should be, i.e. on the crop in the field, rather than drifting away into surrounding waterways, other fields, or non-agricultural areas.

Despite the evolution of the regulatory framework, the development of new agricultural production techniques and the refinement of the technical arsenal, in many industrialised countries there continues to be serious concern about the adverse impacts of agricultural pesticide use. Various problems related to pesticide use appear to be rather resistant. Fine tuning of the system has resolved some problem, but has also resulted in the emergence of new problems that may require a more fundamental reshaping of the system that has been build around the agricultural use of pesticide products. Simultaneously, incomplete knowledge of existing and potential effects may influence our perception of the dangers and benefits of pesticide use. Many examples to support our claims could be given; much has been published about the impacts, risks and dangers of pesticide use (e.g. Vorley & Keeney 1998; Dingham 1993; de Snoo & de Jong 1999; Hough 1998). Here is a selection of current issues.

- (1) Pesticides and their metabolites can be found everywhere: in fresh water, groundwater, soil, food, and even in faraway oceans. Some of the pesticides found have long been banned. In other instances, the residues found on food were of a pesticide not allowed for that particular application. Moreover, in many cases the concentration in which pesticides are found exceeds the established norms and threshold values, at times by factors of ten to a hundred (de Snoo & de Jong 1999). Some pesticides were found to have effects on the endocrine system and others proved to be carcinogenic. Several pesticide residues were found to accumulate in human and biological food chains. Although the days are past when birds fell dead from the sky, predator populations are still threatened by bio-accumulation of pesticide residues through food chains. Although in most OECD (Organization for Economic Cooperation and Development) countries there are effective food safety policies in place, this is generally not so in many developing countries.
- (2) The detection of persistent organochlorines in ecosystems far away from any industrial or agricultural source has raised concern about the possible ecological effects of these compounds in ecosystems of a pristine nature. Pesticides that are banned from most industrialised countries are still measured in remote regions. The question is whether present registration procedures are sufficiently conservative to avoid possible ecological effects of residues transported to remote areas. The reasons to be especially concerned about effects following long-range transport are: (a) once a pesticide becomes airborne, it is out of control, (b) pesticide residues are transported over large areas, (c) environmental conditions at remote ecosystems may promote long residence times, (d) organisms in remote ecosystems may be more vulnerable than agro-ecosystems (van Dijk *et al.* 1999)

- (3) Pesticides are commonly evaluated using a limited number of simple ecotoxicity tests as indicators for ecological effects. There is serious doubt whether such tests (usually short-term exposure to relatively high dose rates of a single species under artificial conditions) can be indicative of effects in natural systems in which trophic interactions, indirect effects and secondary poisoning may operate. Relatively little is known, too, about how ecosystems may recover from pesticide impacts and how the rate of recovery can be included in the risk assessment. Mesocosm studies show that the primary effects of pesticides can be well predicted from the laboratory experiments, provided that the exposure conditions in the mesocosm are measured. Secondary effects, however, are very difficult to predict, since these depend on the physical and ecological structure of the system, and many environmental parameters (Hill *et al.*, 1994; van Straalen & van Rijn 1998).
- (4) A rapidly increasing number of species have developed resistance to the action of individual as well as groups of chemically related active ingredients (Weber 1994). Due to the dynamic responses of local ecosystems to pesticide use (and other agricultural measures), such as the build-up of resistance and the occurrence of secondary plagues, attempts to control the side effects of pesticide use looks like hitting a moving target. In this respect, Zeneca scientists Clough and Godfrey observe that: 'As methods of crop production have become more intensive, the incidence and severity of fungal diseases have increased' (Clough & Godfrey 1995). The repeated use of the same pesticide over time leads to the evolutionary selection of those pest organisms that have developed resistance to a particular pesticide or family of pesticides. Accordingly, an increasing number of fungi, weeds and insects have become resistant to pesticide sprays. Indeed, some observers have noted a perverse effect of the general use of pesticides, namely that crop losses due to insect invasion have actually increased with increasing pesticide use (Dalzell 1994).

One cannot but conclude that if sustainable agricultural practice is considered the objective, current agricultural pesticide use and related policies fail in many respects. The question next to be addressed is: why is this the case?

A framework for analysis: Production, innovation, institutions

To understand why pesticide problems are so persistent, what the reasons are for 'regulatory failure', and how these problems might be solved or circumvented, is a complex and challenging endeavour. It is further complicated by the facts that the pesticide debate has become highly politicised and that the positions of several participants in the debate have become rather entrenched. It is simplistic to one-sidedly blame either the agrochemical industry or farmers for all the problems and uncertainties. Indeed, a large number of often inter-related factors have forced farmers increasingly to rely on pesticide products (Pretty *et al.* 1998). In our view, a workable starting point for this task is to take a broader view. In order to understand pesticide

use and the difficulty of controlling and regulating external effects of their use, one should consider a complex, dynamic and interactive system of agricultural production, agricultural innovation, and socio-economic institutions (Fig. 1.1). Broad lines of analysis should focus on these three subsystems or 'spheres', as well as their interaction. In the following we discuss the separate spheres as well as their interactions.

In the first sphere, agricultural production takes place—crop rotations are decided upon, investments made, and seed sown, in the prospect of making a profit. Under conditions of uncertainty, farmers make *ex ante* decisions that impact on the level of income they might gain and the level of risk they wish to run. Pesticide products have become an important variable in such decision making, and hence in agricultural production. To some extent, farmers' decisions on pesticide use are guided by the products and services of pesticide producers and extension services, as well as structural characteristics of their business environment: regulations, prices, and subsidies.

However, this sphere is not static; it has evolved over time. New technologies have become available for pest control. One particularly important setting is the chemical industry. In the public research laboratories, also, agronomic knowledge has provided new insights, partly in response to practical problems in agricultural production. Each of these innovative processes is denoted with the second sphere of agricultural innovation.

In order to complete this picture we argue that many of the processes in agricultural production and innovation have a direct relation to political and economic processes that take place in a wider context of socio-economic institutions: our third sphere. Production and innovation is confined and restricted by socio-economic institutions, but simultaneously, the latter develop in response to internal and external problems of agricultural production and innovation. The eventual success of suggestions for improvements upon, and alternatives to, current pesticide use depends on how well they are received within the context of current socio-economic institutions, or to what extent the latter may be changed to increase the viability of promising improvements and alternatives.

In order to set the scene for the type of interactions between the three spheres we will discuss briefly the interaction between agricultural production and the socio-economic sphere. Over the past century, agricultural production has changed dramatically (den Hond *et al.* 1999). Before World War II agricultural production was

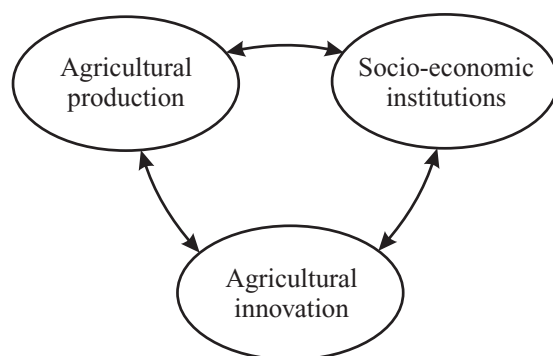


Fig. 1.1 A conceptual framework of three 'spheres'.

characterised by a relatively low input of capital, by high labour input, mixed farming, and relatively low yields. For most crops, yields were restricted by local climatic, geological (soil) and ecological conditions, although mineral fertilisers were known and applied already in the second half of the nineteenth century. In the period of reconstruction just after World War II, political and socio-economic pressure changed the nature of agricultural production. Food security at low prices for a growing population, self-sufficiency in agricultural production, and securing farmer income at acceptable levels became political priorities. These policy objectives translated into the maximisation of yields through the specialisation and rationalisation of agricultural production, by means of increasing scale, minimising labour input (e.g. through increased mechanisation), and maximising the efficiency of various inputs, such as improved cultivars, better timing of farming operations, and management of soil moisture. The large-scale and low-cost availability of inputs such as pesticides were instrumental in minimising labour input. In this way, the traditional limits on agriculture were eliminated. In Western Europe, EEC and EU agricultural policies have significantly enhanced this development, notably by ensuring minimum prices and subsidising exports to world markets.

In certain respects, this policy was highly successful. The shift to intensive farming systems in the aftermath of World War II has allowed a break from dependence on crop rotations and livestock. For instance, world-wide cereals production has increased more than 2.5-fold, a growth rate higher than that of population growth (Brown 1994). Similarly, Vos (1992) reports a more than doubling of tuber yields in potato production in The Netherlands since 1950. Countries that adopted agricultural policies to stimulate this shift obviously enhanced the competitiveness of their agricultural exports.

But undesired consequences must be pointed out as well, which relate to (1) pressure on farm profitability and (2) increased vulnerability of the farming system risk in terms of sustainability. The processes of specialisation, rationalisation and technological innovation have advanced to the extent that farm profitability has been adversely affected. By the late 1980s, political concern became widespread that self-sufficiency had turned into overproduction, incurring high social cost. Farmers' incomes were under pressure from low prices for most agricultural crops. According to many observers, because of increased specialisation the agricultural production system had become vulnerable to calamities, such as unexpected outbreaks of pests and diseases, extreme weather events, and the development of pest resistance. Pest resistance causes reduced marginal returns to pesticide and fertiliser input, increased costs to the farmer, and increased public concern about the preservation of landscape and the pollution of natural habitats. It is understood that such effects are a consequence of the intensive cultivation of a small variety of crops in large areas of monoculture.

Current agricultural policy—for example the new European common agricultural policy—is aimed at the reduction of overproduction, liberalisation of world trade, and the protection of landscape and natural habitats. Farmers have to increase the quality of their output in terms of product appearance, delivery and nutritional value, while reducing the environmental risk of the decisions they take regarding

crop management. Simultaneously, they have to control cost because of increased competition from the world market. This should be accomplished by, among other measures, a reduction of fertiliser and pesticide inputs and by the stimulation of more sustainable forms of agricultural production. Pesticides should be more effective at lower application doses, less toxic to non-target organisms, non-persistent, and not pose a threat to groundwater quality. Such demands pose a serious innovation challenge to the agrochemical industry, traditionally a major supplier and innovator of pest control technology. One could speculate about the industry's willingness and capability in redressing its innovative activity in addressing such changing market and social demands, as yet another causal factor for the persistence of the pesticides problem.

Countries which are now trying to restructure their agriculture along ecological lines, with incentives for reduced dependence on chemical inputs, are facing the prospect of World Trade Organisation (WTO) action against trade barriers. For example, European Commission rulings against national bans on the imports and sales of Bt corn in Austria, Italy and Luxembourg may be partially understood from the fear of violating WTO/GATT free trade rules. And even today the shift to intensification continues as horticultural production is moving to where labour costs and climate allow lowest cost production and year-round availability on supermarket shelves. This has consequences for pesticide use, worker protection, externalities of long-distance transport, and suppression of local (seasonal) production. Thus, one may argue, the scope for pro-active pesticide policies is limited. Authorities are trapped in a set of administrative procedures which were designed in an earlier period, and which are limited in their concerns as exemplified by current registration procedures.

In our discussion, 'socio-economic institutions' thus comprise, but are not restricted to, the regulatory system around the introduction and application of pesticide products. The regulatory subsystem has also evolved enormously over time. On the one hand, evolution in the regulatory system can be seen as a reflection of societal concern over external effects of pesticide use (Howard 1940; Carson 1962), which depend on the products themselves and how they are being used in practice. Apparently, acceptance of external effects has steadily decreased over time, forcing the regulatory system to lower risk levels. On the other hand, science, notably analytical chemistry and systems ecology, has achieved considerable progress, allowing for earlier detection of increasingly more subtle external effects. Relative inertia in the agricultural production system may be caused by its slow response to regulation, or by the relative dynamics of the regulatory system imposing shifting objectives onto the agricultural system.

Further limitations to regulatory control of the environmental impacts and other externalities of agricultural pesticide use are likely to include their incompleteness and the constant need of renewal and revision, if only because potential externalities of new active ingredients and new formulations cannot be fully known beforehand. Additionally, pesticide authorisation and regulatory control is likely to be restricted as far as it has traditionally considered farmer behaviour as a constant factor, rather than as a variable; there are indications that farmers may apply pesticides in ways that differ significantly from label instructions, not to mention illegal use. Moreover,

it is likely that the societal definition of what are undesirable externalities will continue to evolve, partly in relation to the further development of ever-refined analytical techniques to detect residues.

This conceptual framework of three spheres allowed us to raise broad questions about potential causes of the persistence of the pesticide problem. Why are pesticide products applied in agricultural production in the first place, and how serious is the pesticide problem? How responsive is agricultural production to regulations attempting to reduce external effects? To what extent are socio-economic institutions, among which the pesticide authorisation system is eminent, setting the proper conditions for desired farmer behaviour, and more sustainable agricultural production? How effectively do innovations develop and diffuse into actual agricultural production activities? How tailored is agricultural innovation to solving internal and external problems in agricultural production, such as external effects of pesticide use? What are the more likely directions of innovation under the conditions set by prevailing socio-economic institutions? The brief sketch provided here has been used as a guiding tool for the invited contributions in this book. We have asked the authors to submit a first paper that was discussed in a workshop held in June 2000 in Egmond aan Zee, The Netherlands. We used the workshop to strengthen the contributions, establish links between chapters and identify what approaches we needed to establish a more complete discussion. Subsequent rewriting and a round of comments by reviewers has resulted in the present volume. Not all of these questions will be covered by the chapters in this book, and we will return to the insights that can be generated by combining different expert views at the end of this volume in the concluding chapter.

Summary of chapter coverage

This volume is an attempt to bring together, confront and eventually integrate the insights of experts from various backgrounds including law, agronomics, agricultural economics, environmental sciences, ecological sciences, chemistry, and social sciences; many of the chapters themselves have already an interdisciplinary character.

Struik & Kropff (Chapter 2) present their broad vision regarding the agricultural use of pesticides. Over the past century, an encompassing technology package has developed, aimed at the modernisation and rationalisation of agricultural production, which includes chemical fertilisers, hybrid seeds, sophisticated knowledge, and the replacement of labour with machines. During this time, the use of pesticides in agricultural production has, on the other hand, significantly contributed to increases in productivity by suppressing predator species that feed on crops (parasites, diseases, herbivores) and species that compete with crops for light, nutrients and water (weeds). On the other hand, external effects (environmental pollution, impacts on non-target organisms) and second-order effects (resistance) of pesticide use have developed to such an extent that the alleged agro-economic benefits can be seriously questioned and environmental and social sustainability is threatened. What is needed, according to Struik & Kropff, is a drastic reduction of the dependence of chemical inputs, and the amount of chemical inputs used in modern agriculture. This translates into a

systems approach to agricultural production, in which pests, weeds, diseases and so on are controlled, suppressed, or prevented by making use of ecological principles. Pest control decision making should consider strategic aspects, such as implications for the entire cropping system. The authors are optimistic about the steps already taken in improving relevant ecological and agronomic knowledge and the promises of further developments in this respect.

The Struik & Kropff chapter is well placed at the beginning of this volume, since other chapters specify and refine their analysis and make suggestions for the opportunities and conditions under which the identified improvements and alternatives might be realised. Chapters 3 to 7 primarily focus on the persistence of the pesticide problem; Chapters 8 to 13 primarily focus on improvements and alternatives.

Vogelezang-Stoute (Chapter 3) discusses the working of the admission and regulation system around pesticides from the perspective of juridical practices and procedures. Pesticides have to be authorised or registered before they can be sold on the market. Originally, authorisation was granted if the product was proven effective. Later on, additional criteria were added to the authorisation process, such as matters concerning occupational health, protection of consumers, protection of husbandry, protection of non-target organisms, and protection of groundwater reserves and the environment at large. This development can be seen as the administration's responses to increasing public and scientific concerns over a widening range of topics related to the external effects of continuing agricultural pesticide use. Vogelezang-Stoute considers the authorisation process from the point of view that current procedures may not be able to prevent the occurrence of adverse effects of pesticides on the environment. The harmonisation of pesticide regulations under the European Commission's Directive 91/414 is advancing improvements in national regulation and implementation. However, there remain bottlenecks, which relate to the need for updating of earlier decisions on the authorisation of pesticides under consideration of more recent standards; the speed of development of new scientific insights, and their subsequent inclusion in authorisation standards, on the cumulative and aggregate exposure to pesticides; and on the lack of an operational elaboration of the so-called 'substitution principle' according to which the necessity of pesticide authorisation is considered against the availability of less risky chemical or even non-chemical alternatives. While her analysis is based on Dutch legal practice and its adaptation to Directive 91/414, the effects of harmonisation and the introduction of non-health considerations have a wider importance and clearly show the important role of design of regulation.

Den Hond (Chapter 4) addresses the role of innovation in the agrochemical industry. The agrochemical industry has been hampered by increasingly high costs of research and development (R&D) efforts regarding the introduction of new chemicals. As R&D costs are such a dominant factor, competition appears to be more focused on the introduction of new agrochemicals in the light of strategic positioning *vis-à-vis* competitors, rather than on product development in relation to societal needs. This argument is developed starting from a detailed analysis of the development of strobilurin fungicides, the elaboration of what appears to be the industry's technological paradigm, and a discussion of the drivers and radicality of

agrochemical innovation. The relevance of the latter is not so much ‘radicality’ *per se*, but in what respect the innovations are radical. If, as Struik & Kropff suggest in their chapter, a radically new approach to crop protection is to be developed, one that is based on a systems approach in which the use of pesticides is one of a considerably expanded set of means for crop protection, to what extent is the agrochemical industry responsive to such demands? It would appear, then, that the industry has serious difficulty in moving in this direction.

Irwin & Rothstein (Chapter 5) provide an ‘institutional’ analysis on the role of science in establishing standards for environmental and health protection, e.g. at what concentration level should a certain compound in some environmental compartment be considered as undesired pollution, and in the compliance testing of new active ingredients and pesticide products, e.g. how to prove that under specified use conditions a pesticide product will not build up to such concentrations in some environmental compartment that standards for environmental protection are exceeded. Such regulatory systems are dependent on the input of science and scientists, but the functioning of such systems does not and cannot be solely ‘scientific’, given factors such as the important commercial consequences of the outcomes, prevailing scientific uncertainties regarding ‘accuracy’ and ‘pedigree’ of the outcomes (Funtowicz & Ravetz 1990), externally-set deadlines for decision making, and highly politicised decision environments. To suggest that scientists are captured in such systems to the extent that their results cannot be trusted in other ways than as the products of loyal servants to their paymasters, is as misplaced as to consider standard setting and compliance testing as mere technical issues that do not deserve further interest. While agrochemical companies increasingly have integrated anticipatory tests and analyses within their R&D activities, it is argued that active involvement of these companies in the EU regulatory system is also based on their ability to provide essential information to regulators. In such a situation, it is hardly surprising, that Irwin & Rothstein observe a striking consensus among the parties involved that problems in the regulatory system do not lie in the safety reviews, but in processes of implementation and enforcement: e.g. in relation to illegal use and misuse of (banned) pesticide products. Another consequence of this closely-knit community of experts is that it is hard for external parties to obtain access, which might be considered an impediment to the development of more broadly-shared and transparent risk management strategies.

Both Wossink & de Koeijer (Chapter 6) and de Snoo (Chapter 7) discuss inefficiencies in agricultural production at the level of the individual farmer and the difficulties that exist in overcoming them. They argue that farmers must make *ex ante* decisions regarding pest control in conditions of uncertainty, e.g. regarding weather and other factors that influence pest, disease and weed incidence and gravity of infestation. Because of greater pest mobility, risk averse behaviour, such as preventative spraying, is more likely to occur against insects and diseases than against weeds. Since, moreover, overuse of herbicides is more likely to affect the crop yield and quality than overuse of fungicides and insecticides, the stage is set for farmers to make non-optimal pest control decisions.

Wossink & de Koeijer argue theoretically, and show empirically for the case of nitrogen and herbicide input in a sample of sugar beet producing farmers in

Flevoland, The Netherlands, that these farmers are more likely to be economically efficient than environmentally efficient, that improving technical efficiency is key in improving economic and environmental efficiency, and, moreover, that over the years inefficiencies tend to be located with the same subset of farmers. However, telling these farmers how inefficient they are and what they could do about it is not necessarily going to improve this situation, because the rational response of a farmer to increased insight into best practices—the production possibility frontier (PPF)—depends on various factors, including in what respect the farmer is inefficient, the form of the PPF, and the desired level of environmental quality. Their result poses a considerable challenge to designing policies that aim at both increasing or at least maintaining farm profits and increasing environmental quality.

De Snoo specifies the significance of variations from average and maximum recommended dose rates in a number of agricultural and horticultural crops: the per hectare cost of pest control might be a good predictor of pesticide overuse. Similarly, there is significant variation in the environmental impact of pesticide use among farmers who grow the same crop in the same area. However, since there is no direct relationship between a pesticide's potency (as indicated by the recommended dose rate) and the environmental impact of its use (depending amongst others on compound characteristics but also on factors such as mode and condition of application), policy instruments such as levies and taxes on pesticide products should be designed skilfully in order to reduce environmental impact of pesticide use. Such considerations provide convincing arguments for de Snoo to advocate pesticide reduction policies at the level of individual farms that impact upon operational decision making around crop protection.

Parris & Yokoi (Chapter 8) review three main types of agri-environmental indicators that are being developed in OECD countries in the context of pesticide policies: pesticide use, risks of pesticide use and pest management. While there is a clear need for such indicators from a policy perspective, it is less clear what they should look like in order to be effective. Various conflicting demands have to be brought together, such as scientific accuracy *versus* simplicity in order to enhance comprehensibility to policymakers and other stakeholders, and relevance *versus* data availability. The latter, data availability, is a major problem for indicator development since in several OECD countries the only data available—if at all—are data of pesticide sales rather use. The implication of this disenchanting argument is that in such countries one can only speculate about the impact of pesticide policies.

Govers and his co-authors (Chapter 9) start by arguing that current registration policies are flawed in several important respects, e.g. that the required tests focus on active ingredients without consideration of potential impurities or metabolites. Moreover, the monitoring of active ingredients and their metabolites in biotic and a-biotic systems is not organised in such a way as to enable feedback into re-authorisation decision making. The integration of tests and testing information along such lines would increase the chance of proper safety testing and procedures. The uncertainty surrounding the complete picture of effects of pesticides requires a more flexible approach to the application of scientific insights. To this end, a 'safety net' approach is sketched that covers all life cycle stage of pesticides. The safety net is built around

chemical reactivity, because this is a key property with respect to the prediction and detection of potential impacts of new active ingredients. The authors review the availability of methods enabling the prediction and detection of environmental occurrence and effects of pesticides, their impurities and metabolites. Two examples are given and analysed. The case of MCPA emphasises the importance of early prediction of the formation of unwanted side products (impurities) during production. The second case of monoterpenoids—potential substitutes for current pesticides—treats the prediction of biodegradation.

Swinton (Chapter 10) discusses the opportunity that exists to reduce the environmental impacts of agricultural pesticide use through the emerging agricultural practice of site-specific pest management (SSPM). Within fields, pest incidence may vary considerably, implying that not everywhere in the field equal doses of pesticides need to be sprayed. SSPM aims at accomplishing precisely this task; spraying only where spraying is needed. The earlier mechanisation of agricultural production resulted in uniform treatment of entire fields, because it would be too costly, or very impractical indeed, to use the machinery (planes) on, for example, only a section of the field. The combination of recent developments in a number of technologies, including those of geographic information and positioning, as well as those of pesticide application and automated sensing, promises cost reductions and environmental benefits in applying pesticide products only where needed. However, SSPM technologies do not provide equal opportunities for each type of pest to be managed. Important gains can be made in the management of weeds and perhaps nematodes, but due to their mobility, insect pests and diseases are more difficult to manage in this manner. Another potential limitation in the deployment of such technologies may be the amount of initial investment which might be difficult for individual farmers to bear.

Carr (Chapter 11) analyses the claims and counter claims regarding the application of biotechnology in pesticide reduction strategies. Arguments in the discussion include economic benefits in terms of increased yields, reduced pesticide applications and increased farmer income *versus* assessment of environmental and health risks in terms of resistance development, transfer of genes to other, related species and exposure to unexpected toxins and allergens. Today, practical experience with genetically modified (GM) crops has been limited to a few crops (mainly herbicide-tolerant corn, soybean and cotton, and Bt corn and cotton), a handful of cropping seasons, in restricted geographical areas in the United States. This limited availability of practical experience is a serious obstacle to a rigorous assessment of the robustness of the various claims on benefits and risks. The evidence so far would suggest that GM crops might be a tool in what Carr calls the ‘environmental management’ form of sustainable agriculture, that is, a form of agriculture as an integrated system in which management skills are used to minimise the impact of agricultural production on the environment. However, this requires many institutional provisos relating to the control of this technology. How these are to be fulfilled remains a topic for further debate.

Carr’s approach to the biotechnology debate, in particular the potential risks and benefits, is very productive because of the scrutiny by which she analyses claims

and counter claims. As van Dommelen (1999) has suggested, this allows for unfounded claims to be refuted, or refined in such a way that proponents and adversaries may develop a common understanding of which issues and questions are crucial for decision making about biotechnology.

Van der Grijp (Chapter 12) signals that currently a number of constituencies, outside of the traditional range of government authorities concerned with agricultural production, food safety and environmental quality, have organised themselves so as to influence pesticide use in agricultural production. Notably supermarkets and food processing companies feel a strategic need better to control the conditions of agricultural production. Consumers have become more critical of food safety issues, particularly in the aftermath of the European BSE scare and other outbreaks of diseases in livestock, but the issues also include concerns over consumer health and safety of GM food and pesticide residues. Supermarkets and food processors have responded to these issues by implementing policies that are aimed at invoking consumer trust in their brands, rather than in the food production system at large, as has been the objective of food authorities in various countries. The policies imply increased control over the precise conditions of, and operational decision making in, agricultural production. They have done so successfully, it would appear, since the spectacular growth of sales of organic products started when supermarkets created space on their shelves for such products.

Barling (Chapter 13) addresses the question of how international agricultural policies, such as the Common Agricultural Policy (CAP) and its recent reforms in the European Union, and international trade agreements, such as developed within the context of the WTO, may impact on the development of and prospects for organic farming as one example of an agricultural production system that provides a clear alternative to the heavy use of pesticide products in conventional agriculture. Organic farming, but also other labels used for alternatives in agricultural practice, need to be assessed as a reaction to various aspects of current farming that forced farmers to change both their methods and scale of operation. Organic farmers have benefited from state support, but the consequential growth of their movement has had the effect of institutionalising organic production practices. In this respect has organic farming, as a producer of social goods—such as biodiversity, the sustaining of natural habitats, landscapes, and local communities—lost out to organic farming as a productionist, yet intensified (because pesticide-free) alternative to conventional agricultural production systems? Paradoxically, the future for organic farming depends not only on the movement's own appraisal of this shift in orientation, but also on the question of whether necessary state support for organic farming is considered as contributing to the production of social goods (which is expected to be allowed) or to direct or indirect farmer income or production subsidies in the productionist mode, which is expected to be increasingly difficult under international regulations.

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