Environmental and Health Impacts of Pesticides and Fertilizers and Ways of Minimizing Them

Envisioning A Chemical-Safe World

Chapter 6 of 12

Current pesticide risk reduction and risk management

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About

In December 2017, Resolution 4 of the 3rd Session of the United Nations Environment Assembly (UNEA 3) requested "the Executive Director to present a report on the environmental and health impacts of pesticides and fertilizers and ways of minimizing them, given the lack of data in that regard, in collaboration with the World Health Organization (WHO), the Food and Agriculture Organization of the United Nations (FAO) and other relevant organizations by the fifth session of the United Nations Environment Assembly". In response to this request, UNEP published a *Synthesis Report on the Environmental and Health Impacts of Pesticides and Fertilizers and Ways to Minimize Them*[1] in February 2022 (United Nations Environment Programme [UNEP] 2022).

The overall goal of the synthesis report is to provide the information base to enable other advocacy actions to be taken by stakeholders to minimize the adverse impacts of pesticides and fertilizers. Specific objectives of the synthesis report are to:

- Update understanding of current pesticide and fertilizer use practices;
- Present major environmental and health effects of pesticides and fertilizers, during their life cycle, and identify key knowledge gaps;
- Review current management practices, legislation and policies aimed at reducing risks in the context of the global chemicals, environmental and health agenda;
- Identify opportunities to minimize environmental and health impacts, including proven and innovative approaches.

This chapter on "Current pesticide risk reduction and risk management" is the 6th in a series of 12 chapters that make up a comprehensive compilation of scientific information. The chapters were developed to both inform and further elaborate on the information provided in the synthesis report. Please note that the disclaimers and copyright from the synthesis report apply

1 The Synthesis report is available at https://www.unep.org/resources/report/environmental-and-health-impacts-pesticides-and-fertilizers-and-ways-minimizing.

Current pesticide risk reduction and risk management

6.1 Managing and reducing the environmental and health risks of pesticides

The sound management of chemicals, including hazardous waste, aims to prevent and, where that is not feasible, reduce or minimize the potential for exposure of the environment and people to hazardous chemicals. Sound management includes the prevention, reduction, remediation, minimization and elimination of risks during the life cycle of chemicals (production, storage, transport, use and disposal) and of risks posed by the chemicals in products and articles (United Nations Environment Programme [UNEP] 2013; UNEP 2019).

In this chapter current measures to reduce pesticide risks are reviewed. The strengths and limitations of various types of measures are assessed, and key opportunities and constraints with regard to future effective implementation are identified. Much of the chapter is based on reviews and analyses in the previous chapters.

In Chapter 6.2 current risk reduction is described under regulatory measures; market-based measures; training and awareness building; and engineering controls and technology. Its effectiveness of current risk reduction is appraised in a summary format. It should be emphasized that this appraisal may diverge, in part depending on situations in regions, countries or locally. Moreover, although the appraisal is based on inputs by many experts and stakeholders, it remains open to differing views.

On the basis of this appraisal (together with inputs obtained through stakeholder consultations), various options to strengthen pesticide risk reduction are identified in Chapter 6.3. These options are intended to enhance existing risk reduction measures. They build on current experiences in different parts of the world and often do not require complex interventions. However, the ultimate impact that such measures have on the environmental and human health risks of pesticide use are likely to be limited.

More fundamental changes in the ways pests and pesticides are managed are proposed in Chapter 12. These transformative actions are also more comprehensive. They address broader linkages and root causes. To be successfully implemented, transformative actions will require more time and greater effort in all sectors. Nevertheless, the long-term impact of such actions on the adoption of sustainable pest management is likely to be greater.

6.2 Assessing current risk reduction

6.2.1 Regulatory measures

International conventions

Several international conventions address pesticides directly or indirectly. Their contributions to reducing the risks of pesticide use have been variable or not specifically assessed (Chapter 3.2.2). One of the main constraints of many conventions is that their success largely depends on national capacities to implement their provisions and on levels of commitment to do so. Another limitation is that relatively few current use pesticides are addressed under the conventions which directly pertain to pesticides.

On the other hand, these conventions are existing, operational international legal frameworks that address certain aspects of pesticide manufacturing, distribution and use. Most countries in the world are now a Party to them. Therefore, they present an opportunity to strengthen international and transboundary aspects of pesticide management.

Voluntary international instruments and mechanisms

Several voluntary international instruments and mechanisms specifically address pesticides. As in the case of legally binding conventions, their contributions to pesticide risk reduction have not been systematically evaluated (Chapter 3.2.3).

The advantage of voluntary instruments over conventions or treaties is that they tend to cover a broader range of standards and guidance relevant to the sound management of pesticides. Thus, they potentially have a more wide-ranging impact on national pesticide management. The disadvantage of voluntary instruments is that they lack compliance mechanisms, which can make their implementation less effective and more sensitive to national policy changes.

Voluntary instruments and mechanisms such as the Food and Agriculture Organization of the United Nations and World Health Organization (FAO/WHO) International Code of Conduct on

Table 6.2-1 Regulatory and policy measures used to reduce the environmental and health risks of pesticides: strengths, limitations, opportunities and challenges.

Measure	Strengths	Limitations	Opportunities	Challenges
International conventions Chapter 3.2	Address transboundary pesticide risks and set international standards Promote strengthening of national legislation Most countries are Parties to these conventions	The objectives and obligations of respective international conventions are by definition limited in scope Pesticide issues may exist that are outside the scope of current conventions	International frameworks are in place which can, in principle, be strengthened Global coordination, communication and information sharing are in place	Contribution to risk reduction largely depends on national priorities and capacity for implementation Addressing risk reduction measures outside the scope of respective conventions is limited and not obligatory
Regional instruments and mechanisms Chapter 3.3	Assembling countries that face similar situations facilitates mutual understanding and collaboration	Effectiveness of regional activities still highly dependent on national implementation	Regional collaboration mechanisms may be increasingly established	Mobilization of funding for regional structures and activities

Measure	Strengths	Limitations	Opportunities	Challenges
Highly Hazardous Pesticides (HHPs) risk reduction Chapter 3.2	Potentially high impact for limited investments	Addresses a limited number of pesticides; others may also pose high risks	Global Action Plan for HHPs risk reduction developed under the Strategic Approach to International Chemicals Management (SAICM)	Creating a sense of urgency on the part of policymakers Identifying cost-effective alternatives
National pesticide legislation Chapter 3.4	Provides a legal basis to implement sound pesticide management	Public health and other non-agricultural pesticides are often inadequately covered Implementation and enforcement weak in many countries	Most countries have some form of pesticide legislation in place Successes exist with national bans on HHPs for the purpose of suicide prevention	Effective implementation of legislation requires political awareness and support
Pest and pesticide management policy Chapter 3.4	Clarifies pest management and pesticide use goals and targets for all stakeholders	Very few countries have established dedicated, stand-alone national policies	Lessons can be learned from countries that have experience with such policies	Formulating policies that are applicable within broader national priorities and development plans Converting adopted policy into concrete actions
Control and enforcement Chapter 3.4	One of the main tools to ensure effectiveness of legislation	Even if legislation is in place, control and enforcement are often inadequate Coordination among responsible government entities is often inadequate	Lessons can be learned from countries with effective control and enforcement systems	Establishing or strengthening effective enforcement systems with only limited human and financial resources
Pesticide evaluation and registration Chapter 3.4	Ensures that pesticides authorized for use are effective and do not pose unacceptable risks, based on the available knowledge	Human and financial capacities for pesticide registration in low income countries are very limited Duplication of pesticide evaluations by different national regulatory authorities	Pesticide regulatory evaluations increasingly publicly available More regional collaboration for pesticide registration	Optimizing the use of limited resources to conduct efficacy and risk evaluations of pesticides, both nationally and internationally
Post-registration monitoring Chapter 4.3.7	Allows risk mitigation measures to be taken if adverse environmental, health, agronomic or economic effects are observed	Post-registration monitoring of pesticide use and impact is almost absent in low and middle income countries	Monitoring of pesticide sales or use is increasingly required Experiences exist with low-cost, community-driven monitoring	Integrating monitoring into the pesticide regulatory system Developing cost-effective monitoring systems, especially in low and middle income countries

Pesticide Management, the FAO/WHO Codex Alimentarius, the Globally Harmonized System of Classification and Labelling of Chemicals (GHS) of the United Nations, and WHO's pre-qualification scheme for vector control pesticides are broadly supported by governments and other stakeholders. Consequently, there are opportunities to strengthen their implementation further.

Regional instruments and mechanisms

Regional instruments and mechanisms can be an effective way to optimize limited national resources for pesticide regulation and management. Since countries in the same region tend to have similar issues that need to be tackled (as well as cultural, ecological and economic commonalities), mutual understanding and collaboration may be easier than in larger geographical country groupings.

Regional collaboration on pesticide registration is one way to optimize the use of limited resources. Such collaboration has been successfully implemented in West Africa and the European Union (EU). In other regions (e.g., East Africa, the Pacific, the Caribbean, the Andean region) countries collaborate on specific aspects of pesticide registration or have broader regional programmes. While fully regional pesticide registration systems exist only in West Africa and the EU, in most other parts of the world governments continue to prefer national evaluations and decision-making, thereby duplicating much work (Chapter 3.3).

It is not entirely clear what makes certain regional cooperation schemes very effective, while others have remained a good intention but with only limited results to be shown. However, it appears that initiatives which originated from the bottom up – that is, from countries themselves rather than top-down (e.g., from a regional economic organization) – have been most effective.

Various recent initiatives to strengthen or establish regional collaboration on pesticide management provide an opportunity to further develop this approach.

Highly Hazardous Pesticides initiatives

Initiatives to phase out or strictly regulate the use of Highly Hazardous Pesticides (HHPs) are potentially an effective way to reduce pesticide risks. They require relatively limited efforts which can have high returns. Considerable attention has been given during the last 15 years to reducing the risks posed by HHPs, but targeted activities by countries to identify these pesticides and mitigate their risks have so far been limited (Chapter 3.2.3).

A major obstacle to reducing the risks of HHPs appears to be lack of national capacity to identify cost-effective lower-risk alternatives. Moreover, for risk reduction measures to be effective they often need to be far-reaching (e.g., prohibition or severe restriction of the pesticide's use), which requires high-level national political support.

The Action Plan on HHPs, currently under discussion through the Strategic Approach to International Chemicals Management (SAICM), presents an important opportunity to create a sense of urgency and mobilize resources to reduce the risks posed by HHPs or regulate these chemicals much more strictly.

National legislation

Comprehensive pesticide legislation provides the legal basis for many risk reduction measures, in the case of both governments and the private sector. The fact that most countries have such legislation in place means the need to regulate pesticide distribution and use has been recognized. Therefore, a good opportunity exists to further strengthen pesticide legislation. While the number of countries with pesticide legislation has not increased much in the last decades, the quality and comprehensiveness of this legislation is generally considered to have improved. Gaps in legislation exist in many countries, however, related in particular to public health and other non-agricultural pesticides (Chapter 3.4.1).

Effective implementation of pesticide legislation faces a bottleneck in many countries, especially those with limited human and financial resources. This concerns not only establishing and

maintaining the infrastructure and instruments needed to implement legislation, but also ensuring enforcement. One of the main reasons for relative lack of implementation of legislation is that pesticide (or chemicals) management competes with many other important national priority issues, especially in low and middle income countries.

Pest and pesticide management policies

National pest and pesticide management policies set out the desired direction in which pest and pesticide management should develop in the future. They define clear goals and targets that will need to be achieved over a given period of time, including pesticide risk reduction. If broadly endorsed and supported, such policies are potentially useful tools to guide activities by all relevant stakeholders in the same direction and mobilize resources to do so.

So far, the adoption of stand-alone national pest and/or pesticide management policies has been rare and has been limited mainly to Europe and North America (Chapter 3.4.5). Given the limited experience with such policies, it is difficult to know whether they would effectively contribute to reducing the risks posed by pesticides in different economic and cultural situations.

Control and enforcement

Even if pesticide legislation is in place, effective control and enforcement are required to avoid legislation being merely a paper tiger. Inadequate enforcement is a problem in many countries, irrespective of their economic development, but this problem is especially critical in low and middle income countries (Chapter 3.4.3). Many stakeholders consider lack of effective control and enforcement to be one of the main impediments to sound pesticide management. For instance, trade in illegal, substandard or counterfeit pesticides is increasing in many countries.

Given that human and financial resources are deficient in many low and middle income countries, strengthening enforcement capacity is a major challenge. Due to government budget cuts and the decentralization of enforcement activities, pesticide inspection and control may actually have worsened rather than improved in recent years.

Pesticide evaluation and registration

Pesticides are evaluated before they are authorized for use to determine whether they are effective, and whether they pose unacceptable risks under local conditions of use. Efficacy and risk assessments of pesticides are sophisticated when compared to assessments of many other chemicals on the market. Pesticide evaluations, which are becoming increasing data rich and complex, require considerable specialized technical capacity.

Pesticide registration authorities, especially in low and middle income countries, are often understaffed and have inadequate technical expertise (Chapter 3.4.2). Very few are currently in a position to conduct comprehensive, locally relevant and scientifically sound efficacy and risk evaluations of pesticides submitted for registration. However, high-quality evaluations of pesticides are being elaborated by regulators with greater resources (e.g., in the EU, the United States and Canada) and by international entities (e.g., the FAO/WHO Joint Meeting on Pesticide Residues, JMPR). Such evaluations are increasingly used by other regulators for local assessments of pesticides, thereby minimizing duplication of work.

Pesticide risk assessment methods have mainly been developed for temperate regions and for industrialized agriculture. Although some methods can be extrapolated to (sub-)tropical and hot, arid (agro-)ecosystems, clear gaps exist in the understanding of pesticide risks in these regions. Furthermore, certain pesticide risks are still insufficiently addressed, such as combination toxicity, endocrine disruption and ecosystem effects (Chapter 4).

Post-registration monitoring

Post-registration monitoring of pesticides in food, drinking water and the environment (as well as for environmental and human health effects) is an essential tool to identify unexpected direct and indirect effects of pesticides.

Monitoring of possible human health effects is mainly limited to pesticide residues in food, although a few (mainly high income) regions/countries have established regular surveillance programmes (Chapter 4.4.6). There are poison centres in less than half the world's countries. Pesticide poisoning cases are not monitored in most low and lower-middle income regions (Chapter 4.4.2).

In a few countries pesticide concentrations in the environment are monitored on a regular basis, particularly in surface water and groundwater (Chapter 4.3.2). Monitoring of pesticide effects on non-target organisms, on the other hand, is rare even in high income countries (Chapters 4.3.4 and 4.3.5).

Consequently, in most countries post-registration monitoring of environmental and human health effects is not an integral part of the pesticide registration process. Potential risks are generally assessed before a pesticide is authorized, but few data are gathered about a pesticide's fate and effects after it has been authorized for use. Information on the effects of pesticide use under real-life conditions is primarily compiled through ad hoc research projects. While this may seem the most-cost-effective approach to identify risks of pesticide use, unanticipated direct and indirect effects of pesticides on the environment and human health continue to become known.

To further strengthen post-registration monitoring of pesticide use and effects, it should be possible to take advantage of existing well-developed methodologies, especially for pesticide residues in the environment and food.

6.2.2 Market-based measures

Subsidies and taxes

Subsidies and taxes imposed on pesticides are potentially strong instruments to influence the type of pest management measures adopted by producers. Direct subsidies on conventional pesticides are currently not very common in countries, whatever their income level. Neither are subsidies that promote the use of low-risk pesticides (e.g., bioprotectants), although use of these pesticides appears to be growing (Chapter 2.7.11). Indirect subsidies, through exemptions from value added tax (VAT) or other general taxes, are still rather common, although they are increasingly being abandoned in high income countries. There is little quantitative information about the effects of providing subsidies, or abandoning them, on the types and quantities of pesticides used.

Taxes on pesticides, with the aim of discouraging pesticide use or moving towards low-risk products, have been implemented in only a few countries. For pesticide taxes to be effective, the tax rates should reflect damage/risks to the environment and human health (a "banded tax system"), as this not only encourages more conservative use of pesticides but also provides an incentive to use less harmful products (Chapter 2.7.11). However, experience so far shows that high rates of taxation are needed to reduce pesticide use. Furthermore, including a mechanism to redistribute tax revenues (as a form of compensation for farmers, or for earmarking further environmental uses and/or rebating it to the affected population and/or the sector) has been found to increase public acceptance.

The few low and middle income countries that have established pesticide taxes have done so at relatively low rates when compared to high income countries. It is unlikely that these taxes will affect pesticide use. However, redistributing revenues from relatively low taxes towards training, advisory services, and research and development (R&D) on low-risk alternatives may increase the effectiveness of such fiscal measures.

Private standards

Private standards, or voluntary sustainability standards, for agricultural commodities often include the application of integrated pest managment (IPM) and the prohibition of highly toxic pesticides among their requirements (Chapter 2.7.12). It can be expected that implementing private standards that include pest and pesticide management requirements will reduce the overall quantity of pesticides applied and/or their risks. However, no systematic

Table 6.2-2 Economic measures used to reduce the environmental and health risks of pesticides: strengths, limitations, opportunities and challenges.

Measure	Strengths	Limitations	Opportunities	Challenges
Pesticide subsidies (both direct and indirect)	Can promote the use of low-risk pesticides	Can result in excessive general pesticide use (including high-risk products)	Countries are increasingly abandoning general direct and indirect subsidies for pesticides Some countries have introduced targeted subsidies on low-risk or biological pesticides	Ensure that subsidies promote the use of low-risk pesticides
Pesticide taxes	Differentiated taxes can shift the behaviours of producers and consumers towards use of low-risk pesticides Even relatively low taxes can generate revenues for sound pest and pesticide management	Demand for pesticides is relatively inelastic, and high taxes tend to be needed in order to reduce pesticide use Taxes have been found ineffective if used in isolation from other policy measures	Lessons can be learned from countries which have applied different forms of pesticide taxes	Address concerns about producer competitiveness on the global market Ensure that tax revenues are used to support producers
Private standards	Standards that require organic production or IPM may reduce the environmental and human health effects of pest management A direct link is created between sound pest and pesticide management and the opportunity to sell produce	The number and strictness of private standards may disfavour small-scale farmers with limited technical support	Consumers and retailers, especially in middle and high income countries, are increasingly purchasing food produced with no or few pesticides	Certain (elements of) private standards may not be based on sound science Capacity needs to be built so that smallholder farmers can meet the standards Extra investments required to be made by producers should be covered through a bonus on the price paid for commodities produced according to the standard
Internalization of indirect health and environmental costs	Creates a level playing field for pesticides with different environmental and human health risks	Costs and benefits are not the only drivers of farmer behaviours regarding pesticide use	Lessons learned from targeted and differentiated pesticide subsidies and taxes, while still limited, might be applied elsewhere	Difficulty of calculating the value of externalities Existing estimates are outdated

assessments of the impact of such standards on pesticide use or risks have so far been conducted.

Overall coverage of voluntary sustainability standards is still limited (about 1 per cent of global cropland). However, in the case of certain crops (e.g., cocoa, coffee, tea, bananas) they are applied on 10-30 per cent of total acreage. For some of these crops these standards can achieve considerable reductions of pesticide risks. In most low and middle income countries private standards are used mainly for export crops, and much less for production destined to be sold at local markets.

It will be challenging to expand the amount of cropland under voluntary standards while at the same time building capacity for smallholder farmers, making it possible for them to meet requirements and not be left out of export and local markets.

Internalization of externalities

The use of pesticides may cause many externalities, that is, indirect effects whose costs are not borne by the pesticide user but by society as a whole (Chapter 5.2). Even conservative estimates of such externalities amount to billions of dollars globally. Externalities also lead to an uneven playing field for pest management practices with different degrees of environmental and human health effects (e.g., those of high-risk conventional pesticides versus low-risk biopesticides) since indirect environmental and human health costs are passed on to society.

Governments typically correct for this type of market failure by imposing taxes, providing subsidies or strengthening regulations. However, as discussed above, neither subsidies on low-risk pest management options nor taxes on high-risk pesticides are much used globally. Externalities therefore continue to be passed on to society as a whole. Stricter regulations on pesticides are increasingly being imposed, but so far mainly in high and middle income economies.

Overall, economic measures are potentially powerful instruments to influence pesticide use and direct behaviours towards lower risk pest management approaches. However, the use of economic instruments for this purpose has been limited up to now.

6.2.3 Training and awareness building

Awareness about the risks of pesticides to the environment and human health, as well as ways such risks can be minimized, is a prerequisite (although it is not in itself sufficient) for changing policy and behaviours towards more sustainable pest and pesticide management. Awareness of and concerns about such risks appear to have increased considerably on the part of the public, pesticide users and policymakers in the last 10 to 15 years (Chapters 2.7.14 and 2.7.18). At the same time, such awareness has not led to fundamental changes in the quantities of pesticides used and the ways they are used. A challenge in the near future will be to ensure that awareness building effectively translates into changing national policies, as well as the behaviours of pesticide users and consumers.

There is currently more information available on sound pest and pesticide management than ever before, for example through the internet and smartphone apps. However, it has also become increasingly difficult for farmers, spray applicators, other pesticide users, input dealers and extension staff to identify relevant and reliable information among the large volume of data available. Moreover, independent public extension and advisory services have seen their budgets and staff cut. Thus pesticide users have fewer options for obtaining independent information, especially in low income countries where they often do not have the means to turn to private advisory services.

Training on good pesticide application practices has been shown to increase the knowledge and awareness of farmers and other pesticide users about the risks posed by pesticides. However, in many cases better knowledge and awareness has not led to long-term changes in behaviours which could reduce pesticide risks (Chapter 2.7.20). Training and awareness building, when carried out in isolation, is unlikely to be sufficiently effective in reducing these risks (Chapter 2.7.21).

Table 6.2-3 Training and awareness building used to reduce the environmental and health risks of pesticides: strengths, limitations, opportunities and challenges.

Measure	Strengths	Limitations	Opportunities	Challenges
Awareness building about pesticide risks for policymakers, pesticide users and the public	Prerequisite for changing policy and behaviours Awareness has increased in the last 15 years	Greater awareness has not (yet) led to fundamental changes in pest and pesticide management	Social media allow better targeting of information	Ensure that awareness effectively translates into changes in policy and behaviours
Training on judicious pesticide use	Increases knowledge and awareness about good practices and risks	Often does not improve the behaviours of pesticide users	Integration into broader policy measures to reduce risks posed by pesticides	Avoid judicious pesticide training being provided in isolation from that in IPM
Training in biointensive IPM	Leads to changes in farmers' behaviours which reduce risks of and reliance on pesticides	Relatively expensive, so that upscaling has been constrained	Integration into broader policy measures to reduce risks posed by pesticides Combine with modern technologies to provide information and maintain contact	Mobilize long-term funding Long-term political commitment

More intensive and participatory capacity building approaches, such as farmer field schools, have been shown to be effective in achieving long-lasting changes in behaviours and a transformation towards biointensive integrated pest management (Chapter 2.7.5). However, due to the relatively high cost and a lack of national commitment, mainstreaming this type of capacity building into extension and advisory services, and upscaling it to reach more farmers/pesticide users, has been slow and is subject to considerable constraints. This may contribute to unwarranted impacts including on the environment, MRLs and trade etc.

Training and awareness building are important elements of a strategy aimed at reducing reliance on pesticides and minimizing their environmental and human health risks. However, they need to be combined with other policy measures to be successful in the long run.

Given the gender differences in health risks posed by pesticides, but also in the different roles that men and women may have in agricultural production and pesticide use, care should be taken that information dissemination, training and awareness building are gender responsive. This to ensure that appropriate crop protection technologies and practices are adopted, farmers' exposure to pesticides is reduced, and environmental quality is improved.

6.2.4 Engineering controls and technology

Engineering controls

Engineering controls, such as closed and ventilated tractor cabins, closed circuit tank filling and rinsing systems, and drift-reducing nozzles are being used to reduce the environmental and human health risks posed by pesticides (Chapter 2.6).

Many of these technologies have been developed for tractor mounted or pulled spray equipment and have become mandatory in certain high income countries. However, most pesticide application in low and lower-middle income countries is carried out using manual or motorized backpack sprayers, for which such technologies are less or are not applicable. Advanced sprayer technology that reduces environmental and occupational exposure therefore has only limited relevance currently in low and lower-middle income countries.

Precision agriculture

A variety of technologies are being used for precision spraying, i.e., varying the amount of pesticide applied in a field according to the site-specific characteristics of the crop. These technologies used include variable rate application and intermittent (spot) spraying, linked to (remote) sensors that identify canopy density or other characteristics such as the presence of crop diseases (Chapter 2.6). The objective is to apply pesticides only where they are needed and in the right amount.

Other techniques for precision spraying include robotic spray platforms and drones, which generally reduce occupational exposure and may limit the quantity of pesticide applied. However, using drones may increase pesticide drift.

Currently, precision spraying technologies require considerable investments and are primarily used in the case of high-value specialty crops. As these technologies are being used increasingly, however, they may become more affordable, including in low and middle income countries, especially if actively promoted through economic incentives.

Personal protective equipment

The purpose of using personal protective equipment (PPE) is to reduce occupational exposure to pesticides. Since even good quality PPE does not provide complete protection against

Table 6.2-4 Engineering controls and technologies that can be used to reduce the environmental and health risks of pesticides: strengths, limitations, opportunities and challenges.

Measure	Strengths	Limitations	Opportunities	Challenges
Engineering control	Risk reduction is integrated into the application equipment Direct reduction of environmental and human exposure	Increases costs of equipment	Greater use of these technologies may reduce costs and increase availability	Develop and market effective engineering controls appropriate for application methods used in low and middle income countries
Precision spraying	Optimizes use of pesticides May directly reduce environmental and human exposure	Significantly increases costs of equipment and application May be dependent on external technical inputs (e.g. remote sensing data)	Greater use of these technologies may reduce costs and increase availability	Provide affordable access to these technologies by smallholder farmers
Personal protective equipment (PPE)	Direct reduction of environmental and human exposure Relatively cheap and easy to use	Not worn because uncomfortable, expensive, unavailable May lead to unsafe practices if seen as offering complete protection	Voluntary standards and certification systems require use of appropriate PPE	Creating a culture in which PPE use is standard Developing affordable, effective and comfortable PPE, particularly for use in low and middle income countries

pesticide exposure, it is generally considered a last line of defence after other risk reduction measures have been applied. Furthermore, the effectiveness of PPE under actual working conditions may be overestimated (Chapter 4.4.5).

In many parts of the world farmers and farm workers do not have access to appropriate PPE, either because it is not available on the local market or because it is too expensive. Even if PPE is available, working conditions (e.g., high temperature and humidity) may be such that pesticide users will not use certain items because they are uncomfortable or even dangerous (e.g., they may cause heat stress).

Relying on the use of PPE as the single or main way to reduce occupational risks, especially those of more hazardous pesticides, is therefore a questionable approach. Regulatory decisions to authorize a pesticide under the assumption (or even if there is a requirement) that PPE will be worn may be severely flawed, especially in the case of subsistence farmers in hot climatic conditions.

However, appropriate PPE will likely contribute to reducing pesticide exposure (if used as a last line of defence) in combination with other risk reduction measures. This is especially true in situations where a culture of voluntary PPE use already exists, where compliance can be ensured, and where pesticide users obtain clear (economic) benefits from using PPE (e.g., on farms producing under voluntary sustainability standards, or where PPE use is directly linked to professional certification of the farmer or pesticide applicator).

6.2.5 The effectiveness of current risk reduction

One way to look at the effectiveness of pesticide risk reduction measures is through the hierarchy of controls. This is a generic, but well-established method of ranking risk reduction measures according to their reliability and efficacy. The principles embodied in the hierarchy of controls (Figure 6.2-1) date back to the 1940s and have been applied since that time as a standard for risk reduction in occupational health and safety, for example in the United States (Office of Technology and Assessment 1985; National Institute for Occupational Safety and Health 2015) and the EU (European Agency for Safety and Health at Work 2021) as well as by the International Labour Organization (ILO) (Alli 2008). The risk reduction methods at the top of the triangle are potentially more effective and protective than those at the bottom.

Figure 6.2-1 The hierarchy of controls as applied for occupational risks by the United States National Institute for Occupational Safety and Health (NIOSH). NIOSH (2015).

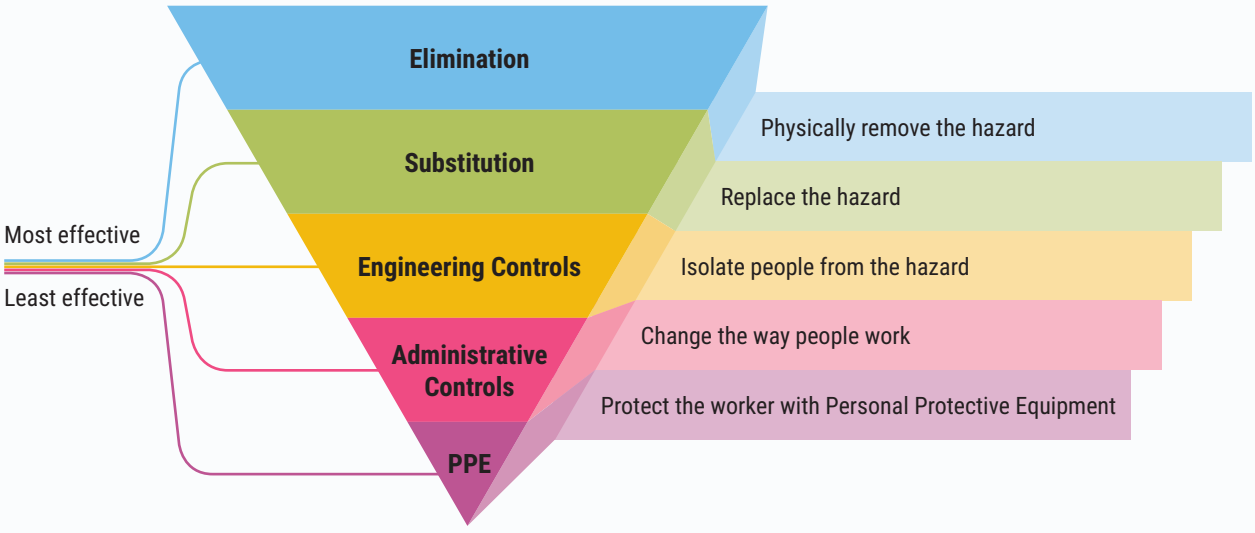

Table 6.2-5 Examples of pesticide risk mitigation measures for environmental and human health risks at different levels in the hierarchy of controls.

Stage in the hierarchy of controls	Human health risks			Environmental risks
	Occupational	Resident/ bystander	Dietary	
Elimination	Do not use pesticides (e.g. use resistant crop varieties, grow a healthy crop, conduct mechanic weed control, promote natural biological control) or Do not register the use of a high-risk pesticide (for a specific use) (e.g. ban, non-approval, cancellation, non-renewal)			
Substitution	Replace pesticide with high human health risk with a lower risk one			Replace pesticide with high environmental risk with a lower risk one
Engineering controls	Drift reducing nozzles, equipment calibration, deflectors		Equipment calibration	Drift reducing nozzles, equipment calibration, container rinse system, precision spray technology
	Closed tractor cabin, closed pesticide transfer system, container rinse system, hand wash water supply			
Administrative controls	Training, certification, best practices, application rate and frequency			
	Worker rotation, re-entry intervals	Notification of neighbouring properties	Pre-harvest intervals	Unsprayed buffers, vegetated filter strips, timing of applications during the day or season, notification of beekeepers
Personal protective equipment (PPE)	Require or recommend PPE as part of registration (e.g. on the label)	n.a.	n.a.	n.a.
Rehabilitation	n.a.	n.a.	n.a.	Multifunctional field margins, ecological recovery areas

Based on Coffman *et al*. (2009); Weinberg, Bunin and Das (2009); NIOSH (2015); Alix *et al*. (2017); Lukey and Paras (2017)
n.a. = not applicable

Similar hierarchies of controls are used to determine waste management options according to what is best for the environment (the "waste hierarchy") (e.g., Department for Environment, Food and Rural Affairs 2011) or to identify best practices to reduce environmental impacts (the "mitigation hierarchy") (Lukey and Paras 2017). The hierarchy of controls is further developed for the environmental and human health effects of pesticides in Table 6.2-5. A distinction is made between occupational, resident/bystander, dietary and environmental risks. While the general principles of the hierarchy of controls apply in the case of all of these risks, the risk reduction measures taken may differ.

Based on the assessments in other parts of this report, the effectiveness of various pesticide risk reduction measures is summarized in Table 6.2-6,. The table focuses on the use of these measures in low and lower-middle income countries. Country income has served as a proxy for available human and financial resources. For each measure listed in the table, an appraisal was carried out of whether it had become more or less effective in reducing the environmental and human health risks of pesticide use during the last two decades. Evaluations of effectiveness and trends over time are necessarily approximate, as they are highly dependent on the situation in individual countries.

Table 6.2-6 Effectiveness of pesticide risk reduction measures during the last two decades and overall trend, with a focus on low and lower-middle income countries.

Measure	Effectiveness in reducing environmental and human health and risks			Overall trend
	High	Moderate	Limited	
Regulatory measures				
National pesticide legislation	H	M, L		↑
Pest and pesticide management policy		H	M, L	↑
Control and enforcement		H	M, L	↓
International conventions		M, L	H	↔
Voluntary international instruments		M, L	H	↔
Regional instruments and mechanisms		H, M, L		↑
HHP risk reduction		H, M, L		↔
Pesticide registration	H	M, L		↑
Post-registration monitoring		H	M, L	↔
Economic measures				
Pesticide subsidies		Not evaluated		
Pesticide taxes		H	M, L	↑
Private standards		Not evaluated		
Training and awareness building				
Awareness about pesticide risks		H, M	L	↔
Training and extension		H	M, L	↓
Engineering controls				
Spray technology		H, M	L	↑
PPE		H	M, L	↔

Trend: ↑ = improved; ↓ = declined; ↔ = unchanged
H= high income countries, M= middle income countries, L= low income countries

Many current pesticide risk reduction approaches and measures have had only limited effectiveness, particularly in low and lower-middle income countries. The most successful ones mainly been successful in high income and, to a lesser extent, middle income countries.

The availability of resources (financial, technical, human, information) is a critical variable determining the success of specific risk reduction options. Risk reduction measures that have been effective in middle or high income countries will not necessarily be effective in countries, situations or communities where resources are inadequate.

When comparing the effectiveness of current pesticide risk reduction measures in Table 6.2-5 with those shown in the hierarchy of controls in Table 6.2-5, some commonalities and clear divergences can be distinguished.

Training, awareness building and use of PPE are relatively low in the hierarchy of controls. They have not been found to be very effective in current pesticide risk reduction, particularly in lower income countries. Some regulatory measures which are high in the hierarchy of controls have been found to be moderately or highly effective in pesticide risk reduction, but this has often been limited to higher income countries. The effectiveness of regulatory measures has had mixed outcomes, with many being only moderately effective. Engineering controls, again only moderately effective in the hierarchy of controls, were considered effective in reducing pesticide

risks, but primarily in high income countries where such controls are available and cost-effective.

Clearly no silver bullet exists that will reduce pesticide risks in all circumstances: one size does not fit all.

6.3 Strengthening pesticide management: options for actions

In this section actions are proposed that could strengthen existing pesticide risk reduction and risk management measures.

As described above (and in more detail in Chapters 2, 3, 4 and 5), numerous measures are being taken in countries to promote the sound management of pesticides and reduce their risks to the environment and human health. Nevertheless, the degree to which such measures have been implemented or are successful varies greatly among countries and regions. This diversity of choices and levels of progress creates opportunities to draw lessons from countries that have implemented measures with more or less success.

In the following chapter options are proposed to further progressively strengthen measures which, based on the assessments in this report, appear likely to contribute effectively to pesticide risk reduction. Depending on the degree of current implementation, and local regulatory, economic and cultural situations, countries may choose to develop and adopt specific measures. However, experience has shown that it is essential to develop a coherent and comprehensive set of measures based on a concrete policy vision if these measures are to be effective.

Single and/or fragmented measures are rarely adequate and may even be contradictory if implemented by different government or private entities. The elaboration or updating of a comprehensive national pest or pesticide management policy may be a good starting point for setting risk reduction goals and developing roadmaps or action plans leading to them.

It is recognized that the various options introduced will be more or less applicable to a specific situation prevailing in a given country or region.

6.3.1 Strengthening governance of the production, trade and use of pesticides

Elaborate and implement national sustainable pest and pesticide management policies

By adopting a national pest and pesticide management policy, sound management of pesticides can be placed and/or maintained on the national government's policy agenda. Such a policy should define clear objectives and targets for pest and pesticide management within a foreseeable time period, and be aimed at promoting sustainable pest management and reducing pesticide risks. This can be achieved through a stand-alone pesticide management policy which includes pesticides, but also by using other approaches to pest management or by incorporating elements of such policies in national legislation, regulations or policies on related topics (see Chapter 3.4.5). All stakeholders need to be involved in elaborating, implementing and monitoring this policy in order to secure wide support for its objectives and measures. Such a policy needs to be put into practice through effective legislation and their enforcement.

Develop and update national pesticide legislation to include all elements of the pesticide life cycle

Most countries have adopted dedicated pesticide legislation. In principle, this legislation should

cover all types of pesticides and all aspects of the pesticide life cycle in order to further strengthen the legal basis for sound pesticide management. This could involve ensuring the inclusion of essential elements such as administration, registration, import and export, licensing, packaging and labelling use, advertising, storage, transport and disposal, information collection, monitoring and incident reporting, inspection offences and penalties.

It is crucial that pesticide legislation be harmonized with national environmental, agricultural, health and economic regulations and policies aimed at pest and chemicals management, and that policy incoherence is avoided. To accomplish this, a national regulatory framework for control of pesticides may encompass a much broader set of legislation (e.g., legislation on environmental protection, public and occupational health, food safety, water, wildlife, plant protection and general chemicals management) than that which only directly addresses pesticides (see Chapter 3.4.1).

Enhance enforcement capacity to bolster effective implementation of national legislation

In many countries there is an urgent need to increase the effectiveness of the inspection and control of pesticide-related activities during manufacturing, importation, distribution, sales, disposal, and use. Ways to increase effectiveness include strengthening inspection services, tightening collaboration with other law enforcement entities, and establishing laboratory capacity for pesticide quality control. In addition, a culture of compliance by all stakeholders should be cultivated, for example through information exchange, compliance incentives, and appropriate forms of self-certification. Increased effectiveness of inspections and enforcement can be achieved by developing guidance and knowledge products with respect to what is required for compliance and increasing awareness in the regulated community. There is also a need to increase government capacity and enable regulatory entities to effectively carry out inspections, and to prosecute and adjudicate violations of pesticide legislation (see Chapter 3.4.5).

Establish or strengthen regional collaboration in pesticide management and, where relevant, harmonize pesticide legislation regionally

Regional collaboration can be an effective way to address transboundary or regional issues related to pesticides, such as cross-border trade in both legal and illegal pesticides, efficacy and residue testing of pesticides, pesticide residues in regionally traded commodities, pesticide pollution of transboundary watersheds, and information sharing on the observed efficacy and effects of pesticides and alternative pest management options. The regionalization of activities may include collaboration on the evaluation, authorization, inspection and control of pesticides and may occur through simple information exchange mechanisms or through more complex common decision-making. Regional collaboration can enhance the possibilities to control cross-border (illegal) trade in pesticides.

Regional harmonization of pesticide legislation goes a step further than collaboration. While more complex to establish and implement, regional harmonization can be beneficial for governments as well as the private sector, particularly in areas such as pesticide registration, pesticide quality standards, maximum residue levels (MRLs), and the control of illegal trade in pesticides. Regions may choose, for example, to harmonize their pesticide testing protocols, set up regional pesticide management action plans or introduce regional pesticide registration. (see Chapter 3.3).

6.3.2 Strengthening monitoring of pesticide use and effects

Collect statistics on the manufacturing, importation and sales of pesticides

Monitoring pesticides' use and effects is critical to inform decision-making and policy development. Countries should consider establishing or strengthening, as a minimum, the collection of national statistics on manufacturing, importation and sales of pesticides. One key area to achieve this would be to include information collection in pesticide legislation. Specifically designating powers and responsibilities, including the ability to impose reporting requirements on manufacturers,

importers, distributors and sellers of pesticide (see Chapter 3.4.1). Where possible, data on the use and disposal of pesticides should be compiled. After a pesticide is marketed, data collection and assessment may take place through regular monitoring, specific scientific studies, or feedback about incidents (see Chapter 4.2).

Establish pesticide residue monitoring systems and poison centres

Countries may consider establishing, where they do not exist, national pesticide residue monitoring programmes for food, feed and drinking water. Although more complex, countries should also consider establishing post-registration monitoring of pesticides and their transformation products in the environment, especially in areas where there is high use intensity. In addition, national or regional poison centres that operate effectively are essential to better understand the health effects of pesticide use (see Chapter 4.4.2).

Ensure feedback into policy- and decision-making

An analysis and reporting system needs to be put into place to ensure that the results obtained by monitoring and surveillance will inform policy- and decision-making on the authorization and use of pesticides. For example, post-registration monitoring and studies that complement prospective risk assessments are therefore important tools, especially given that data on environmental settings and human populations can only become available after the market authorization of a compound. Pesticide registrations should be subject to a periodic review process for re-authorization if consecutive evaluations show that use of a pesticide under local conditions results in unacceptable risks based on the outcomes of post-registration monitoring and studies (see Chapter 4.2).

6.3.3 Strengthening pesticide evaluation

Develop more integrated approaches to pesticide evaluation

Pesticides are currently evaluated on their individual merits and risks. If a pesticide is found to be effective and does not pose unacceptable risks, it will generally be authorized for use. However, its risks and benefits compared to those of other pesticides or pest management approaches are not assessed, nor is its contribution to the long-term sustainability of pest or vector management.

This approach to pesticide registration can be transformed to promote broader sustainable pest management solutions. Alternative pest management options should be evaluated as part of the decision-making process, along with their environmental and economic impacts. Evidence-based and interdisciplinary decision-making should drive pest management choices, while explicitly taking into account uncertainties and knowledge gaps in a precautionary manner (see Chapter 4.4).

Establish robust pesticide risk assessment methods for low and middle income countries

Since the human and financial resources available for pesticide evaluation are limited in many low- and middle-income countries, the extensive pesticide risk assessment approaches developed by some high-income countries generally cannot be applied there. There is an urgent need to develop robust and pragmatic environmental and human health risk assessment methods applicable to conditions of use in major world regions, with a focus on tropical, sub-tropical and semi-arid regions. This need may be addressed by extrapolating existing methods for use in neglected ecosystems and regions (see Chapter 4.4). Particular attention should be given to vulnerable groups and specific risks related to gender.

Optimize resources for pesticide evaluation

To optimize the use of limited resources for pesticide evaluation and minimize duplication of work, further internationalization of efficacy and risk assessments is needed: evaluate hazards globally – assess efficacy and risks regionally – authorize pesticides nationally/regionally.

Pesticide hazards are typically independent of use conditions. They can therefore be evaluated globally. Pesticide efficacy and risks are influenced

by conditions of use, as well as by environmental and agronomic circumstances, but they can be evaluated on a regional or (agro-)ecosystem basis rather than repeatedly at the national level. Registration decisions will also be influenced by the economic and social circumstances in which a pesticide is being used. Although based on international or regional efficacy, hazard and risk assessments, these decisions are therefore best taken at the national or regional levels (see Chapter 4).

Fill gaps for pesticide risk assessment

Environmental and human health risk assessment has greatly improved in the past decades. Nevertheless, evaluating certain pesticide risks requires further scientific inputs, including the environmental and human health risks of pesticide mixtures and of endocrine disruptors, pesticides' health effects during child development, and their environmental risks in (sub-)tropical and (semi-)arid regions. Other principal directions for improving pesticide environmental and human health risk assessments are proposed in Chapter 4.3.7 and 4.4.8.

Increase transparency in decision-making

In a number of recent cases, confusion has occurred as a result of apparent inconsistencies in evaluations conducted by different regulatory and scientific bodies. This has partly been due to use of different data sets and lack of access by non-regulators to data considered confidential.

To maintain public trust in the independence and comprehensiveness of regulatory risk assessments, there is a need to redefine the mechanisms that ensure the confidentiality of business information, but also to ensure public access to and third-party verification of environmental and human health information. These may be embedded in the legislation through, for example, registration and Information collection, monitoring and incident reporting, (see Chapter 3.4.1)

6.3.4 Innovate pest management through targeted research and development (R&D)

Promote multi-stakeholder innovation

Through the identification, development and implementation of innovative, context-appropriate and cost-effective technologies for pest and vector management requires collaboration between farmers or other pesticide users, public research bodies and the private sector. Such collaboration should not be limited to new pest control products. It can be broadened to innovative pest management approaches, including associated new skills that need to be adopted by farmers and other pesticide users. This can lead to more successful reductions in environmental and human health risks as a result of reduced application of pesticides, expanded use of reduced risk products, improved pesticide application practices, or better use of precautionary measures.

Develop low-risk pest control technologies

Public and private sector actors should prioritize and facilitate the development of low-risk pesticides and bioprotectants. This could include fast-track regulatory procedures, but also the establishment of local production facilities for beneficial macroorganisms and biopesticides, as well as services for the placement and monitoring of non-chemical pest control systems (e.g., traps, robotics, predator release) (see Chapter 2.7).

Innovative pest management technologies, such as RNAi for gene silencing in pests or CRISPR for breeding disease and pest resistant crops, may yield promising pest management approaches. They should be evaluated for efficacy and safety, as well as for access by smallholder farmers. More efficient pesticide application technologies, which reduce pesticide use and risks, also require further investment in R&D.

Assess costs and benefits

There is an urgent need to conduct comprehensive assessments of all economics variables associated with the use of pesticides, including direct and indirect costs and benefits, with the aim

of designing pest management strategies that are cost-effective at both the private and societal levels. Studies should also take into account other pest management options or the costs of externalities. For example, assessments may be made on the economic benefits of pesticide use at either individual pesticide level or a larger geographical scale as well as more comparisons between the overall costs of pesticide use with their estimated benefits (see Chapters 5.3.1 and 5.3.2).

Regularly review existing knowledge

To make better use of the large body of research that continues to be generated on the efficacy and risks of pesticides, there is a need for regular systematic reviews of new knowledge and insights. Sound scientific approaches should be applied in order to conduct such reviews, ensure the quality of the data involved, and ensure the inclusion of these reviews in the regulatory (re-)evaluations of pesticides. For example, more systematic reviews on pesticide risks and their mitigation options can be carried out (see Chapter 4.3.7 and 4.4.8).

6.3.5 Inform and educate for change

Ensure independent information provision to farmers and other pesticide users

To allow farmers and other pesticide users to make informed and objective decisions about pest management options, public agricultural extension systems and other independent advisory services need to be strengthened further. Integrated pest management (IPM) and integrated vector management (IVM) should be promoted through the training of agronomists, extension agents, input distributors and farmers.

Participatory and experience-based learning has been shown to be effective in ensuring the long-term adoption of sustainable behaviours and technologies, with specific attention given to building the capacities of youth and women. Better use can also be made of digital technology and social media to provide information and complement education and training, while ensuring the inclusion of marginalized groups.

Include sustainable pest management in educational curricula

Sustainable agriculture, agroecology, integrated pest management (IPM) and integrated vector management (IVM) could be included in the curricula and courses of agricultural schools, universities and other relevant training providers to a much greater extent. A highly participatory model which has been applied to build capacity in IPM management is farmer field schools (see Chapter 2.7.21).

Training in IPM, IVM and biocontrol should be considered a fundamental requirement for licensing of pest control operators.

Train health care and environmental professionals about pesticide risks

Health care professionals need to be prepared to diagnose and treat cases of pesticide poisoning, particularly in areas where there is high pesticide use. Furthermore, environmental professionals (e.g., those engaged in carrying out environmental inspection and monitoring, or staff at watershed authorities) should be trained on the identification and remediation of pesticides' environmental effects (see Chapters 4.3 and 4.4).

All environmental and human health incidents documented by professionals should be reported, so that they feed back into the pesticide decision-making process.

6.3.6 The need for policy coherence

Many strategies, programmes and projects have been developed and implemented during the last few decades to strengthen pest and pesticide management in all regions of the world. However, they have often addressed only a specific aspect of pest or pesticide management such as updating pesticide legislation, promoting integrated pest management (IPM) or biocontrol, strengthening pesticide registration, upgrading pesticide residue laboratories, disposing of obsolete pesticide stocks, training farmers in good agricultural practices, or transforming pesticide taxes or subsidies.

While such activities individually may have been quite successful in most parts of the world, they have not fundamentally changed how pests are managed or reduced the risks posed by pesticides. For example, pesticide use intensity is increasing, pesticide residues are ubiquitous in the environment, pesticide resistance continues to increase, occupational pesticide poisoning still occurs, surface water and groundwater are polluted by pesticides, and unanticipated environmental and health effects of pesticides are observed after the pesticides are authorized for use.

There is a need for integrated national and regional policies which address all aspects of pest management and aim to make it sustainable in the long term. Such policies, which have been rare so far (Chapter 3.4.5), need to combine regulatory and economic measures, ensure engagement to provide independent and relevant information, find effective ways to reach and train farmers and extension staff, develop innovative technologies accessible to stakeholders, and level the economic playing field for low-risk pesticides and pest management approaches. By their nature, these policies must be interdisciplinary, inter-ministerial and multi-stakeholder.

As shown by Lee, den Uyl and Runhaar (2019) (Chapter 3.4.5), pesticide risk reduction policies require an intelligent combination of measures which should be implemented in parallel or consecutively to achieve the goals that have been established. Integrated, more holistic approaches which reduce reliance on pesticide use are needed, including measures and incentives from the local farm level to the national (and even international) levels. Such approaches should set clear goals and targets, identify measures that contribute to achieving these targets, and include an assessment of measures that may be counterproductive.

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