6 Risk mitigation measures for the off-crop environment

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6.1 Introduction

Risk assessments often refer to the “off-field areas,” which may be defined as all the farmland areas that are not cultivated, as well as the areas that are not part of fields. It is not always clear how to define off-field areas compared with areas that are not cultivated or “off-crop,” and the boundary between “off-field” and “off-crop” areas has been explored in previous workshops (see for example Alix et al. 2011). For the benefit of a full understanding between risk managers and further harmonization, definitions were checked by participants and the outcome is proposed in this chapter.

More practically, off-field areas can be managed or unmanaged, non-sprayed, vegetated strips, wildlife corridors, habitat patches, conservation buffers, and greenways outside, but in a certain proximity (spatial relation) to the agricultural fields (Figure 6.1). As non-cultivated area, all of them implicitly represent a higher level of biodiversity than the crop area with regards to flora and fauna, although research to quantitatively appreciate these differences remains limited, as for example for non-target arthropods (de Lange et al. 2012). These areas are therefore thought to contribute to the environmental status of an agroecosystem in providing area for recovery of the agroecosystem wildlife, be a source of recolonization of the in-field areas, and contribute to ecologically stable agricultural landscapes. The latter is of special interest for agricultural production, as these landscapes provide additional functional services supporting integrated pest control. When implemented to reduce pesticide or fertilizer transfers from the cropped area (such as vegetated strips or wind breaks, for example), they also help reduce the exposure of off-field organisms. Together with other tools aimed at reducing transfers during application and adapted application strategies, these measures enter in the toolbox of risk mitigation measures that were identified during the workshop to mitigate risks to off-crop or off-field area and ecosystems. Their inherent benefit to the environmental status of agroecosystems is also reflected in the recommendations of the “Common Agricultural Policy” (CAP) and more particularly the listing of measures identified in the greening concept (EC 2013).

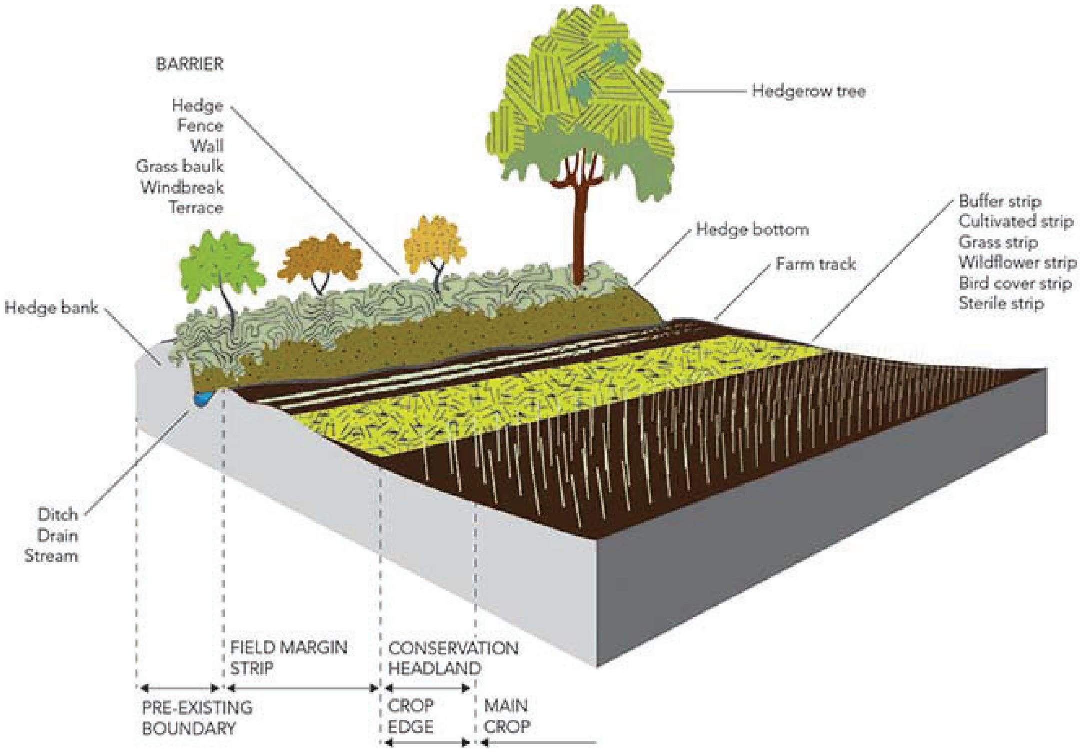


Figure 6.1: The main components of an arable field margin (after Hackett and Lawrence 2014).

The development of a toolbox implies agreement or at least a common understanding of the terminology relating to non-target areas. A questionnaire was circulated to regulatory authorities, offering definitions for a range of terms referring to agriculture area and commonly used in the regulatory process. The feedback received is reproduced in Appendix 7. The series of definitions proposed in Table 6.1 result from this consultation and reflect the feedback of regulatory authorities. The compilation of the feedback received is proposed in Appendix 8.

Regulatory authorities agreed on a definition of the ”field“ that corresponds to the “crop.” Hedges and boundaries may be either managed or not, therefore their status may not be defined a priori. As a consequence in terms of protection of the off-field areas, a similar level of protection was considered for all off-crop areas as long as they do not belong to the farmer, since then their status is not known a priori.

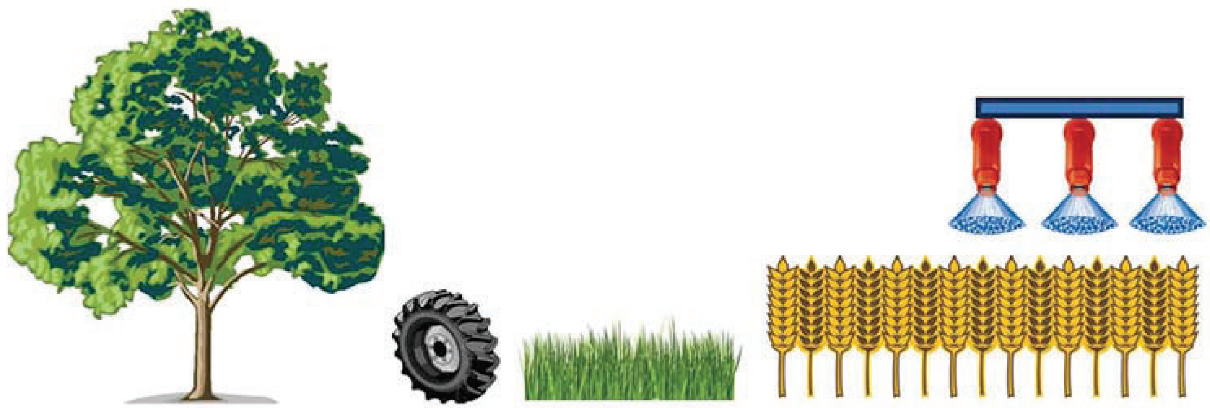
The definitions in Table 6.1 were approved with the recommendation that all areas of land not under the control of the farmer (i.e., not owned or rented land) should be considered as off-field area. Therefore in terms of risk management, off-crop and off-field areas may represent the same area when the off-crop area does not belong to the farmer.

Figure 6.2 provides an illustration of the set agriculture areas used in the regulatory process.

Table 6.1: Definitions of the agriculture area commonly used in the regulatory process, as agreed by workshop participants.

Term	**Definition**
In-crop area	Area sown with the crop plants, including the space between the crop rows
Sprayed crop area	Area of crop or soil sprayed with pesticides
Unsprayed crop	Area of crop plants left unsprayed with pesticides
Off-crop area	Area starting at the edge of the cropped area, which is not over sprayed with pesticides
Field margin (off-crop area)	Area in the field that is not planted with crop plants
Farm track	Area used for transport of farm machinery or vehicles

Field boundary	Trees, hedges, fences, walls, ditches (including planted wind breaks) at the border of the field area. This area is an off-crop area and may be in the field of the farmer but may also be off-field
Margin strip	Any area of bare soil or grass or wildflower area left untreated with pesticides
In-field area	Cropped area plus the field boundaries, any farm track, and any margin strip (planted or bare soil). For risk management purposes at the level of a farmland, the in-field area therefore corresponds to the farmland area, which is owned by the farmer
Off-field area	Area surrounding the in-field area, excluding neighboring in-field areas



Field boundary	Farm track	Margin strip	Unsprayed crop area	Sprayed crop area

Off-crop area	In-crop-area

Off-field area	In-field-area

Or, when the farmers own or manages the land off-crop:

Off-field area	In-field-area

In-field-area

Figure 6.2: Illustration of the agriculture areas used in the regulatory process.

There was therefore an agreement that all the off-crop and off-field should a priori be protected similarly, with no distinction (e.g., between roads, farm tracks, and vegetated strips). Similarly, managed boundaries, or boundaries created for risk management purposes (i.e., wind break), would be a priori equivalent to non-managed natural boundaries. The reason for this is that if the purpose of these areas is not known by the farmer, in cases where he is not in charge of their management, he should avoid any spray drift onto them. Where these areas respond to specific functions and needs known by the farmers or under his responsibility then their protection will de facto be ensured for them to meet the expected needs.

The off-crop area also contains landscape features that need to be protected. These landscapes features provide habitat and food resource and the benefits to species and functions (such as pollination and biological pest control, for example) that we foresee in using them as risk mitigation. Landscape elements at distance of the field may get residues from airborne sprays or drift. Recent studies by FERA in the UK funded by the Department for the Environment, Food and Rural Affairs (DEFRA) have generated data for airborne drift up to a height of 2m at distances up to 20m from the sprayed crop area (DEFRA 2008, Glass et al. 2010). Therefore, a point is made in this chapter to appropriately protect non-target plants, i.e., the vegetation in the field margins or at the vicinity of the crops that is not targeted by treatments, but further consideration with regards to the extrapolation to landscape elements will be needed in future. It should also be noted, that farmers' motivation to voluntarily implement landscape structures such as vegetated buffer strips (e.g., under the CAP), or as risk mitigation measures, would be strongly impacted if additional requirements were imposed to protect these structures as pristine areas (e.g., in-field buffer zones to protect these in-field structures). This is partly solved when the ownership or land management is taken into account, as areas not directly owned or managed are to be protected as off-field areas, while the function of the off-crop land being owned or managed is well known and to be protected as such.

Section 2 of this chapter lists these measures and implementation recommendations. Section 3 discusses the aspects relative to the implementation of the measures proposed in the tool set as well as specific monitoring issues and related stewardship. Section 4 proposes recommendations for the development and implementation of this toolbox in future. The Risk Mitigation Measure Technical Sheets (RMMTS) that provide practical details, benefits, and possible constraints on the tools that may be implemented in European countries are reported in Appendix 1.

6.2 Risk mitigation measures to protect the off-crop area

Three questionnaires have been prepared in order to collect experience in European Member States with regards to risk mitigation options to protect off-field area. These questionnaires focused on:

- An inventory of the risk mitigation options already implemented or considered as promising in future as well as an inventory of the Safety Precaution phrases (Regulation (EU) No. 547/2011) implemented in European Member States (questionnaire #1)
- A consultation on experience with managed and natural recovery areas as off-field risk mitigation tools in farmlands (questionnaire #2)
- A consultation on the terminology used in the area of environmental risk mitigation (questionnaire #3)

The responses to questionnaire # 1 are reported in Appendix 7. The responses to questionnaires # 2 and # 3 are reported in Appendix 8.

The following table proposes a compilation of the risk mitigation tools identified through these questionnaires and additional information provided by the working group with regards to general aspects and the developments proposed for each of these tools in future. For each tool the group discussed the following criteria:

- Efficacy of the tool to appropriately mitigate risks

- Regulatory and legal aspects relative to the tool. For example, this criterion considers the legal status of the risk mitigation tool in the countries where it is implemented. This criterion also considers the possibility to take the risk mitigation measure into account in the risk assessment process
- Implementation aspects, and more particularly with regards to the acceptability of the tool to farmers

Each tool has then been ranked as explained in the introduction.

The risk mitigation tools identified as promising or well established are further detailed in dedicated Risk Mitigation Measure Technical Sheets (RMMTS). Where no specific recommendation from the group was considered necessary (risk mitigation measure already well established) the measure is simply described in this table and in the following notes.

Table 6.2: Overview of the risk mitigation measures (RMM) suitable to reduce environmental risks in the farmland. RMM are allocated into the following categories: Buffer Zones (BZ) aimed at reducing exposure of off-crop areas via spray drift; Field Margins (FM) and Compensation Area (CA) aimed at providing food sources and habitat to off-crop flora and fauna; Spray Drift Reduction Technologies (SDRT), which involve any technology associated to sprayers, nozzles, or spraying techniques that will reduce the drift; Dust Reduction Technologies (DRT), which involve any technology associated with seed coating, granule manufacture, or drillers to reduce the abrasion of seeds or granules at drilling or to reduce the spread of dust out of the cropped area; Good Agricultural Practices (GAP), which relate to product application (dose and application regime); Crop Management (CM), which relates to agricultural practice in the crop or the field margins aimed at reducing a source of exposure or transfer route; and Bee Management (BM), which relates specifically to measures applied to managed bees to keep them from exposure. The corresponding Risk Mitigation Measure Technical Sheets (RMMTS) are listed in the last column together with their location in the proceedings.

Risk Mitigation Measure	Category	Description	Status[1]	Countries Where Implemented #	Proposed New SPe Phrase in the Context of Regulation (EU) No. 547/2001 – see also Chapter 3	RMM Taken Into Account in the Risk Assessment	RMMTS
No spray buffer zone	BZ	See Chapter 4.3	4	All	**Adapted from current SPe3**	Yes	Not necessary - See Chapter 4.3
Wind direction – dependant no spray zone	BZ	See Chapter 4.3	3	SE	**Additional text to be associated to SPe3**	Yes - See chapter 4.2	Yes (RMMTS #1) – see Chapter 4.3 and Appendix 1
Buffer zone of bare soil	BZ	See Chapter 4.3	3	NL, UK	**See SPe 3**	Yes	Yes (RMMTS #2) – see Chapter 4.3 and Appendix 1
Vegetated buffer strip	FM	• Introduction of a managed orsemi-managed vegetated strip at the field margins to provide food source and habitat to a group of organisms, or to offer wind screen or runoff management • Generic or product-specific • Potentially from 5 to 50 m • Benefits on all off-field area and organisms through spray drift reduction • Additional benefits related to the purpose of the vegetated buffer strip (e.g., pollen and nectar seed mix, bird seed mix, runoff mitigation etc.)	3	BE, CH, DE, NL	**New SPe introducing vegetated strips to mitigate transfers via runoff (see Chapter 4.2)**	Yes for spray drift and runoff reduction. For beneficial effects on wildlife and biodiversity observed in monitoring studies, they do not yet translate into percentage risk reduction for a product	Yes (RMMTS # 3 to 9) in Appendix 1
Multifunctional field margins (e.g., as qualification of a vegetated buffer)	FM	• Introduction of a managed or semi-managed vegetated strip at the field margins to provide food source and habitat to one or several group(s) of organisms, or to offer wind screen or runoff management • Product specific or generic • Potentially from 5 to 50 m • See above: defined to present several of the benefits listed for vegetated buffer strips	3	-	**New SPe to introduce field margins to protect one or several groups of organisms and mitigate transfers via runoff (multi functional field margins):** To protect [birds / mammals / aquatic organisms / non-target arthropods / non-target plants] and limit risks related to situations of runoff, respect an unsprayed non-cropped vegetated buffer zone of (distance to be specified) to [the edge of the field / surface	Yes for spray drift and runoff reduction. For beneficial effects on wildlife and biodiversity observed in monitoring studies, they do not yet translate into percentage risk reduction for a product	Yes (RMMTS # 3 to 9) in Appendix 1

					water bodies] which should consist of [wild bird seed mix / wild flower mix / pollen and nectar mix/sown grass] in order to provide the requested benefits.		
Presence of recovery area in the farmland and Ecological focus areas	BZ/CA	• Introduction of recovery area in the farmland • Benefits on species in providing food source and habitat	3	DE, IE	n.a.	Beneficial effects on wildlife and biodiversity observed in monitoring studies, but do not yet translate into percentage risk reduction for a product	No, see note
Landscape-dependant buffer zones	BZ/CA	• No spray zone at the field border to avoid direct spray of off-field area, as a function of the presence of recovery area in the farmland, which indicate on the level of resilience of the farmland • Benefits on species in providing food source and habitat	3	DE	**Additional text to be added to a SPe aiming at introducing field margins to protect wildlife:** An implementation of this buffer zone for the purpose of wildlife protection may not be needed if recovery area such as semi-natural habitats are already present in the farmland	Yes for spray drift and runoff reduction. For beneficial effects on wildlife and biodiversity observed in monitoring studies, they do not yet translate into percentage risk reduction for a product	Yes (RMMTS #10) in Appendix 1

					represents (percentage to be specified) of the farmland surface.		
Drift reducing nozzles (incl. adjusted spray pressure, etc.)	SDRT	See chapter on spray drift	3	AT, BG, CH, CZ, DE, ES, FR, HU, IT, NL, BE, PL, SE, UK	**Additional text to be added to a SPe3**	Yes	Yes (RMMTS #11) - see Chapter 4.3 and Appendix 1
Special equipment or machinery (Wings-/Tunnel-/Band sprayer etc.)	SDRT	See chapter on spray drift	4	DE, NL	**Additional text to be added to a SPe3**	Yes in these countries, therefore there is a possibility to harmonize	Yes (RMMTS #12) - see Chapter 4.3 and Appendix 1
Directed spraying techniques (one-sided spraying, forward-speed, reflection shield, boom-height adjustment, etc.)	SDRT	See chapter on spray drift	4	CH, DE, IT, SE, NL	**Additional text to be added to a SPe3**	Yes in some of these countries, therefore there is a possibility to harmonize	Yes (RMMTS #12) - see Chapter 4.3 and Appendix 1
Precision treatment (as sprayers' equipment)	SDRT	See chapter on spray drift	1	-	n.a.	n.a.	Yes (RMMTS #13) - see Chapter 4.3 and Appendix 1
Dose of product (reduction or limit)	GAP	• Label language limiting the application rate to a maximum • Derived from the risk assessment • Benefits related to the group of organisms having	4	BE, DE, ES, FR, NO, SE, UK	**New SPe proposing adapted Good Agricultural Practices (GAP) to reduce exposure of wildlife and/or transfers via**	Yes	Not necessary The risk assessment already takes into account

		driven the risk assessment			**runoff:** To protect [birds / mammals / aquatic organisms / pollinators / non-target arthropods / non-target plants/limit risks related to situations of runoff] respect an application rate of maximum (application rate to be specified) /do not apply this product more than (time period or frequency to be specified)/ do not apply during the bird breeding period / restrict applications to (dates or growth stages to be specified).		modified application regimes where necessary
Application frequency (reduction), interval between applications	GAP	• Label language defining application regime • Derived from the risk assessment • Benefits related to the group of organisms having driven the risk assessment	4	BE, DE, ES, FR, NO, UK	As for reduced application rate	Yes	Not necessary The risk assessment already takes into account modified application regimes where necessary
Timing of applications (e.g., overnight; before or after flowering)	GAP	• Label language defining application regime with regards to crop growth stages • Derived from the risk assessment • Benefits related to the group of organisms having driven the risk assessment	4	BE, CH, DE, ES, FR, EL, HU, NO, NL[2], UK	As for reduced application rate	n.a.	Not necessary The risk assessment already takes into account modified application regimes where necessary
Excluding types of application techniques (e.g., canon application)	GAP	• Label language excluding some application techniques to be used for a specific product • Derived from the risk assessment • Benefits related to the group of organisms having driven the risk assessment	3	-	n.a.	Yes	Not necessary The risk assessment already takes into account modified application regimes where necessary
Treated seeds - low wind speed	DRT	• Restriction of the drilling period to favourable wind conditions • Generic • Benefits on all off-field	3	DE, FR	In the scope of SANCO 10553/2014	n.a.	In the scope of SANCO 10553/2014

		area and organisms through dust reduction					
Treated seeds - high quality of treatment and drillers	DRT	• Implementation of high quality criteria to drillers and seed coating quality in order to reduce abrasion of seeds and granules to a minimum during drilling and during all the steps of seeds and granule handling • Generic • Benefits on all off-field area and organisms through dust reduction	4	DE, FR	In the scope of SANCO 10553/2014	In the scope of SANCO 10553/2014	In the scope of SANCO 10553/2014
Forest aerial application - max. 50% area treated, no spray on the forest edges, standard buffer zones Aerial applications	BZ	See chapter on spray drift	3	DE, FR	n.a.	n.a.	Not necessary (see note) Product and use specific and to be managed at the country level based on policy relative to aerial applications
Remove or cover bee hive, close bee hive 1 day before spraying	BM	• Physical protection of the hives during spraying activities • Implies an information of the beekeeper prior to applications	3	UK	**Adapted from current SPe 8:** Dangerous to bees./To protect bees and other pollinating insects do not apply to crop plants when in flower./Do not use where bees are actively foraging./Remove or cover beehives during application and for (state time) after treatment./ Do not apply when flowering weeds are present./ Do not apply before (state time)./ Respect a flowering strip of [width to be specified] at [distance to be specified] of the treated field.	n.a.	-
Close hives 1 day before spraying	BM	• Physical protection of the hives during spraying activities • Implies an information of the beekeeper prior to applications	3	EL	See SPe 8		-
Permission by bee-	BM	• Implies an information	3	FI, DE	An alert of beekeepers	n.a.	

keeper needed		of the beekeeper prior to applications			is recommended		
Removal of flowering weeds	BM	• Removal of flowering weeds prior to applications in order to limit the exposure of pollinators • Potential conflict with preservation of biodiversity in cropped lands	3	BE, CZ, ES, HU, IT, UK	n.a.	n.a.	Not necessary – a note proposing a risk-benefit analysis is included below
Specific regulation or suspension of pesticide	Regulatory	• Restriction of uses in the registration certificate or decision notification	4	IT, SI, UK	n.a.	n.a.	No

as based on the questionnaires and further discussions

[3] Status:
1. Not to be promoted
2. Under development
3. Needs consolidation or research
4. Promising tool implemented in some Member States
5. Well established tool implemented in most Member States.

[4] In fruit crops (e.g. before / after 1st of May)

6.2.1 Buffer zones and field margins

6.2.1.1 Generic buffer zones

Generic buffer zones, not wind or temperature related [5], are the most common risk mitigation measures implemented in the EU. Buffer zones have first been set for the management of transfers to surface water via spray drift in almost all countries in the EU. Later on they were progressively used to protect non-target plants and non-target arthropods (13 countries reported the use of buffer zones and of the related SPe3 phrase for that purpose).

Buffer zones usually start at the edge of the field and are a defined width (1 to up to 100 m were mentioned). One country reported that the buffer zone could be located in-field cropped ("crop are allowed"), but defined them at the edge of the crop. Buffer zone widths are usually pesticide-specific. Buffer zones present the advantage of being easily used in the risk assessment and easily reported on product’s label. However, farmers report the lack of flexibility with regards to the width to be applied, which is fixed regardless of the way farmers manage their field margins. In France, it is possible to reduce the width of the buffer zone recommended on the label (e.g., from 50 m to 20 or 5 m, or from 20 m to 5 m) if the farmer uses additional spray drift reduction tools such as drift reducing nozzles or wind breaks (JORF 2006, see also Chapter 4.3). The width reduction depends on the number of measures the farmer applies to mitigate spray drift. The economic impact of buffer zones on growers (wheat, oil seed rape, and apple) was assessed for German conditions in Kehlenbeck et al. (2014).

No Member State reported specific buffer zones to protect landscape features such as hedgerows, flower strips, or wind breaks that the farmers plant themselves in-field for risk mitigation purposes. One Member State reported that no buffer zone applies to those features in order not to prevent farmers to establish them. When needed for the proper functioning of the feature itself, risk mitigation measures should be included in implementation directions, as for example in the UK (Natural England 2013). With the establishment of ecological focus areas (EC 2013) in or at the edge of the field, the landscape features above mentioned may gain additional interest to farmers, allowing them to manage specific requirements related to the use of products in compliance with the implementation of the greening aspects of the CAP.

The Directive “Natura 2000” (EC 1992) also recommends that the environmental protection of specific vulnerable areas and a variety of other areas may be defined at the national level, such as area used for drinking water supply, hospitals, etc. The protection of these areas involves diverse and country-specific approaches. Beside specific precautions regarding the use of the land in protected areas, some dedicated protections may be defined as, for example, specific buffer zones around houses, hotels, etc. Where the same level of protection is to be considered for all off-field areas, countries do not distinguish these areas from others (which are to be protected anyway). Member States did not specify the use of a no-spray zone, a buffer zone, or other, to explicitly protect biodiversity.

Overlaps were mentioned with measures implemented to prevent transfers of fertilizers. Overlaps with other legislation as, for example, in the context of the regulation on biocide products (EC 1998 and 2012) were reported in the only case where biocides are considered as part of pesticides (one country). Overlaps with measures being implemented for the protection of drinking water abstraction area where reported for one country. In some countries NAPs give buffer zones to areas used by population, as schools, hospitals, city parks, etc. (e.g., Italian NAP).

[5] Note that Good agricultural practices state a general maximum temperature and wind speed for spraying of PPPs

6.2.1.2 No spray zones based on local conditions

No spray zones based on local conditions have been reported in Sweden. This option provides more flexibility to farmers since they may adapt the recommendation to the current weather conditions, as well as to the rate of product they actually use. A user guide provides precise recommendation on the treatment conditions (Sakertvaxtskydd 2013). Since the level of risk reduction is available from the abacus provided in the guide, such measures may in principle be taken into account in the risk assessment in keeping the same risk reduction categories. The corresponding RMMTS may be found in Appendix 1.

6.2.1.3 Bare soil buffer zones (RMMTS #2)

Bare soil buffer zones (uncultivated buffer zones) are being used in the UK and in the Netherlands. As these buffer areas remain non-cultivated, their implementation becomes easier to verify than the previous types of buffer zones. However their popularity is affected by the fact they offer no filter or screen to drift, and do not represent a flexible option. The corresponding RMMTS may be found in Appendix 1.

6.2.1.4 Vegetated buffer strips (RMMTS #3 to 9)

Vegetated buffer strips have various functions and have been reported for the purpose of runoff management in some countries. Vegetated buffer strips dedicated to the protection of non-target arthropods or non-target plants are used in two countries so far. The advantages reported include the filter function they provide towards spray drift, and their easy implementation and verification in the field. The main disadvantage reported is again the lack of flexibility from farmers' point of view, since these vegetated strips are product-related and in theory offer little flexibility with regards to their width. An economic evaluation of buffer zones in Germany showed that for some crops a vegetated buffer strip can be economically more feasible than a no- spray buffer zone (Kehlenbeck et al. 2014). Also, when located in the field margin, they have shown diverse benefits over years.

The primary role of field margins was stock fencing and delimiting areas of ownership (Marshall and Moonen 2002). In addition, they can provide shelter for stock in adverse weather (heat, snow, wind), as well as windbreaks, and they are useful for preventing surface water flow and particulate water movement. They provide suitable habitat including for overwintering species that move into arable crops and are thought good place to locate beehives. They may also act as barriers to the movement of some pests between fields, but may also act as a source of pest in other cases. Since the 1990s, such field margins have been implemented in national plans as part of ecological compensation areas, as for example in Switzerland (see for example http://www.agroscope.admin.ch/oekologischer-ausgleich/index.html?lang=en).

In order to gather a more comprehensive views on the possible benefits to be expected from field margins and landscape features, a review of field margins management and of their potential as risk mitigation measures suggested in the feedback provided by monitoring studies that investigated their effectiveness in the context of the implementation of Agri-Environmental Schemes. A variety of field margin types have been described such as natural regeneration areas, grass margins, wildflower margins, pollen and nectar or bird seed mix field margins, annual cultivation areas, and conservation headland. The benefits of these measures are documented in monitoring studies based on abundance and diversity indexes of in-crop and off-crop populations and communities. From these studies, the relative benefits for diverse aspects relative to the group of “organism of concern” was explored through an evaluation and ranking exercise reported in the table below:

Table 6.3: Evaluation and ranking of multiple benefits of different field margin types (NR = natural regeneration, GR = grass sown, WF = wildflower sown, P&N = pollen and nectar mix, WBS = wild bird seed mix, AC = annual cultivation, CH = conservation headland)

Environmental Benefit	Attribute	NR	GR	WF	P&N	WBS	AC	CH
Birds	Overall	2	2	2	1	3	3	1
	Summer - Seed & plant food	2	2	3	1	3	3	2
	Winter - Seed & plant food	1	1	1	1	3	3	2
	Invertebrate food	3	2	3	2	2	3	2
Mammals	Diversity	2	3	2	2	2	3	1
	Abundance	2	3	2	2	2	3	1
Pollinators	Food sources	2	2	3	3	1	2	2
	Species richness	2	2	3	3	2	2	1
	Abundance	2	2	3	3	2	2	1
	Hibernation sites	3	3	2	1	0	0	0
Non-target arthropods	Spiders	3	3	2	1	2	2	1
	Beetles	2	3	2	2	2	2	1
	Parasitic wasps	2	2	3	2	1	1	1
	Soil invertebrates	3	3	2	2	1	1	1
Plants	Overall	2	1	2	1	1	3	3
	Annual arable weeds	1	-1	-1	1	2	3	3
	Perennial wildflowers	3	2	3	1	1	1	1
Aquatic	Aquatic invertebrates	3	3	2	1	1	1	1
	Plants	3	3	2	1	1	1	1
Pest management	Weeds	1	3	2	1	1	1	1

	Invertebrate	2	3	3	2	1	1	1
Run-off	Pesticides	3	3	2	2	1	1	0
	Sediment	3	3	2	2	1	1	0
	Phosphorus	3	3	2	2	1	1	0
	Nitrogen	3	3	2	1	1	2	2
Spray drift	Pesticides	3	3	3	2	2	2	2
Soil	Soil erosion	3	3	3	2	2	1	1

It was agreed that this first analysis conducted in the context of this workshop was useful to obtain a first insight on the benefits each type of feature provides to specific group of organisms, but that more research was needed to refine the knowledge and allow their inclusion in the risk assessment. The importance to also develop the multi-functionality of field margins and thus optimize the land use by the farmers who implements them as risk mitigation measures was highlighted. Promoting the implementation of these types of field margins will be critical to rapidly observing the benefits they provide on the groups of organisms and processes listed above. As observed in the available studies, their benefits are more significant at a larger scale and landscape approaches may be more effective than field-scale implementation. This observation is important in deciding upon the policy level that is the most appropriate for their implementation in individual countries.

6.2.1.5 Multifunctional field margins

A possible way forward is the promotion of multifunctional field margins (MFFM), which would provide farmers a clear benefit as they address the types of risks where their farms show vulnerability. As an example, the use of insecticides on plots vulnerable to runoff could trigger the implementation of field margins, with an aim to stop runoff transfers and at the same time provide refuge, habitat, nectar, and pollen resources to pollinators and non-target arthropods. Recommendations exist regarding the implementation of effective field margins for the purpose of wildlife protection (Aschwanden et al. 2007, Askew et al. 2007, Burn 2003, Hoffmann et al. 2013, Macdonald et al. 2007, Shore et al. 2005, Vickery et al. 2009), invertebrate fauna (Blake et al. 2011, DEFRA 2007, Pywell et al. 2011b), including pollinators (Blaauw and Isaacs 2014; Carvell et al. 2007, 2011; DEFRA 2007; Osgathorpe et al. 2012; Pywell et al. 2005, 2006, 2008, 2011a, 2011b), non-target vegetation (DEFRA 2007, Marrs et al. 1992, Marshall and Arnold 1995, Pywell et al. 2011b) and soil organisms (DEFRA 2007), but also biodiversity (Berger and Pfeffer 2011, de Snoo et al. 1999, DEFRA 2007, Kleijn et al. 2001, 2006, Thomas and Marshall 1999), or to limit the transfer of pesticides via spray drift (Brown et al. 2004, Burn 2003, de Jong et al. 2008, de Snoo and van der Poll 1999, Longley et al. 1997, Miller et al. 2000, Wenneker and van de Zande 2008, van de Zande et al. 2000, 2004, 2010) or runoff (see Chapter 4.2), which may be adapted to provide multiple benefits (Marshall and Moonen 2002, Stoate et al. 2009, Hacket and Lawrence 2014). RMMTS #3 to 9 provide further recommendations for the implementation of multifunctional field margins. Appendix 9 proposes additional recommendations as regards flowering strips.

6.2.1.6 Landscape-dependant buffer zones (RMMTS #10)

Landscape-dependant buffer zones, developed in Germany, constitute an option to account for the landscape features in deciding about the risk mitigation measures to be implemented in the farmland (Gutsche et al. 2002, Golla et al. 2003, Enzian et al. 2004). With this option, farmers evaluate if their farmlands are in an area where semi-natural habitats are present, and if this is the case, they may apply more flexible risk mitigation (e.g., only SDRT without buffer) than if their farmlands do not fulfill the semi-natural habitat pre-requisites where, for example, SDRT and a no-spray zone is required. Flexibility is perceived as a clear advantage by farmers. However, only habitats, that may house the same species or provide the same benefits as managed field margins should be considered. In addition, the implementation of this option requires the generation of a robust and updated GIS-supported database and its access to farmers in real time.

6.2.1.7 Ecological focus areas

Ecological focus areas bring benefits for the environment, improve biodiversity, and maintain attractive landscapes (such as landscape features, buffer strips, afforested areas, fallow land, areas with nitrogen-fixing crops, etc.).

Ecological focus areas are a higher level option in landscape management proposed in the CAP (EC 2013). This option is described in the CAP, using Germany as an example, and consists of implementing ecological focus areas (e.g., land lying fallow, buffer strips) at farm level, which can serve as additional recovery areas in the landscape where these are not considered as sufficiently present. Although they do not represent a risk mitigation option strictly speaking, the benefit of implementing recovery area in the landscape is obvious and may represent more flexibility to farmers who need to compensate for specific vulnerability in their farmland.

As previously mentioned, this option relates to the CAP and may also be considered in a more targeted way with the implementation of multifunctional field margins (see above), provided that the latter are designed as permanent measures.

In Ireland, the presence of recovery area in the farmland is appreciated using a set of characteristics, which help compensate for in-field effects and safeguard biodiversity, as for example in Ireland (box below):

Characteristics of the farmland landscape in Ireland that support ecosystem resilience and biodiversity:

1. Overall land-use pattern - a high proportion of Irish agriculture is low-input grassland farming, with very low levels of PPP use.
2. Large areas of monoculture are not a feature of Irish agriculture. The reasons for this are as follows:

   2.1. Small average farm size.

   2.2. Small average field size.

   2.3. A high degree of fragmentation of farm holdings.

   2.4. Widespread short-term renting of land.

   Large areas of contiguous land are very unlikely to be treated with the same PPPs. Land treated with any given PPP is very likely to be adjacent to land not treated with that, or any, PPP. This greatly increases the potential for recovery of populations of non-target species.

3. The Irish landscape is characterized by an abundance of hedges, and in particular large volume hedges, which serve as habitats for many species.

Several countries report that recovery areas in the farmland may not be sufficiently represented, as for example in intensive cropping area. In the Netherlands, an option proposed in the context of the Sustainable Crop Protection (2013-2023) to revert the situation is to stimulate farmers to grow flower strips, on a voluntary basis and if possible, with financial compensation from the common agricultural policy (EC 2013). In the Czech Republic it is intended to use tools proposed in the context of the CAP to improve the level of environmental protection in farmlands.

6.2.2 Spray drift reduction technologies

Spray drift reduction technologies (SDRT) correspond to a range of equipment and machinery that aim to target sprays on the crop and limit losses via spray drift. The benefits of their use is generally easy to verify, and they represent a range of options to farmers who may use them on a generic way once they are equipped. In some cases, they may compensate the implementation of buffer zones as for example in France, Germany, and the Netherlands (TCT 2014). Many of these equipments (drift reducing nozzles, reflection shields, boom height adaptation) are cost-effective, though others such as tunnels or band sprayers, still represent an expensive investment. Drift reducing nozzles are being used in 13 European countries so far and the level of drift reduction achieved by these nozzles is being determined on a certified basis (http://sdrt.info/). Advice for farmers is needed for these SDRT tools, either through training or information leaflets. More details on the efficacy of these tools at reducing spray drift may be found in Chapter 4.3 (RMMTS # 11 and 12, in Appendix 1). Each tool associated to quantified drift reduction rates may be used in the risk assessment.

Precision treatment represents an option that allows the farmer to restrict applications to the sole area of the crop that can receive the treatment.

This option is supported by GPS and sensor technologies incorporated into the sprayers. The sprayer is then automatically set up to perform precision applications. In addition to the benefit of saving application volumes this option may offer flexibility to the farmer and be used in a generic way. The related costs need further investigation (further details are provided in Chapter 4.3).

6.2.3 Adaptation of the conditions of use

The adaptation of Good Agricultural Practices (GAP) associated with a product (doses, timing, frequency, period of application) represents a set of options that are easy to implement on the labeling and the benefit of which can be taken into account in the risk assessment. In many countries, GAPs are adapted for the purpose of reducing risks to non-target arthropods, pollinators, and non-target plants, with preferences for an adaptation of the application period (9 countries), application frequencies (6 countries), or doses (7 countries). The benefit to farmers is a reduction of treatment costs and the flexibility related to other risk mitigation measures. The compliance is generally less easy to verify compared with SDRT and vegetated buffer strips and MFFM. However, advice to farmers is needed as modification of the recommendations related to a product may result in the development of resistance of pests or diseases, which need to be taken into account.

6.2.3.1 Adaption of the application dose

In the interests of reducing exposure to products in the environment, it is important to ensure that only the minimum dose is applied to achieve the desired effect. In order to establish the minimum effective dose, it is necessary to conduct trials that show whether doses lower than the recommended dose provide an inferior level of effectiveness compared with the higher dose, an inferior persistence of effect compared with the higher dose, or a control less than that intended or desirable for the target pest. In addition, the potential for resistance, the safety of the product to the crop, and other aspects of efficacy are also considered, e.g., yield. The minimum dose resulting from the efficacy evaluation is compared against the maximum dose rate that can be used safely by humans and in the environment. The authorized product label will specify the maximum dose that can be used in any particular situation or crop. A maximum number of treatments or maximum total dose may also be specified and this will restrict the total amount of product that may be applied to a specific crop or situation per crop or year.

6.2.3.2 Adaptation of the application frequency and interval between applications

Risk assessments may indicate that some non-target populations are initially affected by a product use, but that the population quickly recovers to pre-spray levels. In these instances it is possible for the regulatory authority to specify an application frequency or a minimum interval between applications.

6.2.3.3 Adaptation of the application timing or period of application

Specific application timings may correspond to the latest timing at which a product may be applied to a specific crop or situation, in which case it is often driven by consumer risk assessment. However, application timing may also be adjusted to fit outside the reproductive period of birds or outside the flowering period, in which case it is driven by the outcome of the risk assessment. It may be specified as a date (usually specified as 'in the year of treatment' 'or 'in the year of harvest'), the crop growth stage or as a number of days or weeks before harvest, or other as appropriate.

6.2.3.4 Exclusion of some application techniques

The exclusion of some application techniques, such as cannon applications, for example, is a specific situation where such restrictions are recommended after a dedicated risk assessment. These restrictions usually relate to a product and appear on the label. This is also linked to the labeling instructions regarding application methods and reduction of spray drift via spray drift technologies.

6.2.4 Risk mitigation tools for seed treatments

With regards to seed treatments, recommendations have been developed that define conditions of use for seeds coated with pesticides and of granule formulations that limit the amount of seed dusts being produced and spread out of the cropped area (SANCO 2014). Recommendations relate to the conditions of drilling and to the preparation and handling of coated seeds and granules so that the amount of dust to be expected at drilling is reduced to a minimum. Such measures are being used in several countries already and a guidance document of the European Commission is being developed to further harmonize the conditions of use of coated seeds in the EU (SANCO 2014).

6.2.5 Risk mitigation measures for aerial applications

With regards to aerial applications, general concerns have been raised in European countries about the pressure exerted on the environment resulting from applications via aircraft and helicopters. These application techniques usually respond to a specific demand (use of products on forests to control specific caterpillars presenting a threat to populations, or difficulty to apply products in certain area due to the slope, as observed in certain vineyards, for example) or to the height of the crops (maize, sugarcane, banana, for example). In this context, the use of aerial applications is restricted to situations where there is no alternative treatment device that can provide a lower level of risk (EC 2009). National authorities have developed additional precautionary measures limiting the area to be sprayed and sparing forest edges, as for example in the case of forests in Germany (see chapter on spray drift). These measures correspond to a generic approach to reduce application volumes and related pressure on the environment. More dedicated measures are not proposed in this manuscript since the level of management that is deemed necessary in European countries will remain country-specific, as it applies on a practice being already regulated.

6.2.6 Risk mitigation measures to protect pollinators

With regard to the protection of pollinators, and more specifically, to managed bees such as the honey bee, Regulation (EU) No. 547/2011 provides a set of risk mitigation measures aimed at reducing the exposure during and following sprayed treatments (SPe8 phrases) (EC 2011). The option to restrict applications out of the flowering period, which is being used in most European countries, is potentially beneficial to other pollinating species and is directly deduced from the risk assessment. The SPe8 phrase also contains options to remove or cover hives during the treatment, or close the hive one day before the treatment in order to keep bees from foraging on the treated crop. The latter being reported in 2 countries and implies the involvement of beekeepers who keep their apiaries in the farmland during the treatment process.

Finland reported an agreement with the beekeeper as a pre-requisite to proceed to an application. Similar agreements are reported for Germany. Within a radius of 60 m around a bee hive, dangerous pesticides may be applied within the period of daily bee flight only with agreement of the beekeeper. For compliance reasons, such a measure requires a communication between farmers and beekeepers, and more particularly that farmers inform beekeepers about the treatments that are planned on the farmland and that beekeepers inform farmers on the location of their apiaries. Tools can help support this communication, e.g., via internet or SMS (see Chapter 10).

Information on applications is promoted so that beekeepers may implement protection measures (cover hives, etc.) through communication leaflets. As an example, the British Beekeepers Association recommends to inform beekeepers directly or to contact the local beekeeping association 48 hours before applications (British Beekeepers 2010). In France, informing beekeepers of upcoming applications is recommended through a leaflet prepared by a collective work of all stakeholders (AFPP 2010). In Germany, communication between farmers and beekeepers is supported via an internet tool (BLE 2014). General communication to the public may be requested for specific cases such as aerial applications for sanitary reasons as recommended by the FAO (2001).

The early provision of information to beekeepers about applications is critical to help them implement the appropriate protection measures (cover, remove hives, or any other measure they wish to implement) and thus respect the precautionary recommendations of the SPe8 phrase that involve beekeepers (EC 2011). In turn, measures that may help farmers to be informed of the presence of apiaries in the vicinity of their farms would facilitate this communication. Local contacts or in future the availability of GPS localization of apiaries (of registered beekeepers in a national registration database, for example) would provide assistance in this respect.

Another option, which may also limit the exposure of other species, consists of the removal of flowering weeds under the crop to be treated (e.g., in orchards or vineyards) or in the field margins (all crops). This practice is reported in 5 countries, but remains controversial since the removal of flowers may in turn directly influence the frequency of occurrence of pollinators and other invertebrates in farmland and therefore affect biodiversity. Further considerations on this option are proposed in a note below.

6.2.7 Note on flower removal before pesticide application (pollinator protection)

The removal of flowering weeds in order to limit pesticide exposure to bees and other pollinating insects is one of the options proposed in the safety phrase 8 of Regulation (EU) No. 547/2011 –relevant for the protection of pollinators:

SPe 8:

Dangerous to bees./ To protect bees and other pollinating insects do not apply to crop plants when in flower./ Do not use where bees are actively foraging./ Remove or cover beehives during application and for (state time) after treatment./ Do not apply when flowering weeds are present./ ***Remove weeds before flowering****./ Do not apply before (state time).*

This option may apply to understory flowers in perennial crops as orchards or vineyards, but has also been mentioned in field margins (for all crops) and its implementation on product labeling is reported in 5 countries.

This measure remains controversial, since the removal of flowers may affect populations of pollinating insects as well as other flower visitors and therefore affect biodiversity. In an attempt to gather further details on the relationship between the presence of flowers on the farm and the presence of pollinators, an analysis of monitoring studies undertaken to describe the influence of farmland management was performed to look at the impact of the presence of non-cropped area, dedicated field margins such as wild flower sown mix or nectar and pollen sown mix, on pollinator populations or communities. The inventory captured studies published between 2000 and 2014 and covered 12 different countries.

No study describing the effects of flower removal as a risk mitigation measure in conventional crops on pollinators could be found. Rather, monitoring studies generally describe the effects, and in all cases the benefit of non-cropped land and diverse types of dedicated field margins involved in Agro-Environmental Schemes (AES) on pollinators as observed in studies on the benefits of AES on pollinator species richness (DEFRA 2007, Kleijn et al. 2001, 2006). In honey bees, benefits of surrounding features were highlighted through food shortage events that were reported between crop flowering events where these features are absent or under represented, as crops may not be sufficient to provide food resource over the whole season (Odoux et al. 2014). In bumble bees, the presence of flowers in field margins and natural regeneration strategies was an effective strategy for providing habitat (DEFRA 2007, Pywell et al. 2005). Higher species richness and forager density were recorded on conservation flower mixture patches than on existing non-crop control habitats. The proportion of arable land in the surrounding landscape was also found to influence bumble bee presence (Carvell et al. 2011). Open herbaceous vegetation proved to be valuable in conserving long-tongued species (Kells et al. 2011). Track edges and road verges with presence of flowering plants were shown to provide an important source of forage (Osgathorpe et al. 2012). In butterflies, positive effects of wildflower strip were recorded on communities (Haaland and Bersier 2011). Looking at pollination services, isolation from natural habitat appeared potentially to be more important to native bees than that of management where organic and conventional farms were compared (Kremen et al. 2002). In a recent study in cider apple orchards in the UK, flowering strips resulted in increased pollinator visits to the apple blossom compared with orchards without flowering strips (Campbell et al. 2013). Similar benefits towards wild bees were observed when forage habitat was provided adjacent to pollinator-dependent crops (Blaauw and Isaacs 2014).

The relationship between bee species abundance or richness and plant coverage seems to be species-dependent and not necessarily linear, thus indicating that other elements of the landscape interact, such as crops (Calabuig 2000), latitude, local land use intensity, connectivity, and geographical location of study fields (Conception et al. 2012a, 2012b). A strong influence of connectivity and corridors on species richness is observed, but effects are habitat dependent. Even small patches of dispersed natural habitat may support high abundance in honey bees and wild bees, in landscape with a low proportion of natural habitat (Winfree et al. 2008). A study comparing the effects of AES in landscapes of different categories with regards to diversity indicated that positive effect of flower abundance observed in hoverflies and bees based on richness and abundance criteria, may be more intense in landscapes with few semi-natural habitats, as in diverse landscape the species richness and abundance are higher and less sensitive to the implementation of AES (Kleijn and Van Langevelde 2006). For some species like eumenid wasps, landscape that permits access to a multiple set of resources was critical to their maintenance (Klein et al. 2006).

On the other hand, the benefit of flower removal on the reduction of pollinator exposure to pesticides is, although intuitive, not fully established. In a review on the aspects determining the risk of pesticides to wild bees, the contribution of in-crop flowering weeds to pollinator exposure has been reported in one of three countries where data or feedback was recorded, and limited to apple orchards (Van der Valk and Koomen 2013). Effects of weeds removal, mechanically or by herbicide applications on pollinators were reviewed by Nicholls and Altieri (2013). Effects on wild bees, but also Coleoptera and Lepidoptera have been reported, and relate to the reduction of nectar sources, larval food sources, and safe sites. The magnitude of effects for pollinating species is related to the length of its seasonal flight period. Effects have also been reported on biocontrol agents such as predators and parasitoids, relating to the availability of floral resources. Weed removal through grazing intensity was found to result in differences in composition of insect-pollinated plants and therefore of bees species richness (Batary et al. 2010).

In view of the observations reported above, flower removal therefore could not be considered to be an appropriate measure to protect pollinators, as this creates gaps in foraging resources. The maintenance of flowering weeds or implementation of flowering margins is instead to be preferred, according to a management plan that does not affect crop yields where relevant (see Nicholls and Altieri 2013). The benefits are reported even for crop monocultures when surrounded by (semi-) natural habitats (Nicholls and Altieri 2013). The presence of flowering weeds in cropped fields also benefits wild bees and other insect pollinator communities (Nicholls and Altieri 2013). In addition, care should be taken to provide a continuous supply of nectar and pollen through the season (i.e., spring to autumn). With regards to flowering weeds in field margins, the introduction of wildlife seed mixtures has the potential for providing the best foraging habitat for as long as preferred forage species are introduced (DEFRA 2007, Pywell et al. 2005). Long-term management may also allow the formation of tussocks, which make nesting sites, as observed for *Osmia* spp, for example (Benedek 2008), and could be used as larval habitat for several species, provided the time span between sowing and ploughing of a strip was adequate (Haaland and Bersier 2011). Further details on dedicated field margins are presented in this chapter.

6.2.8 Risk management through regulatory decisions

Regulatory decisions that may involve restrictions of uses or product withdrawals remain an option for regulators. These options are not in the scope of this workshop and are not discussed further.

6.3 Additional recommendations to promote the implementation of risk mitigation measures in the farmland

The key to a successful implementation of risk mitigation tools by farmers relies on the capacity to deliver clear messages about their efficacy at fulfilling their function(s), their availability, and also on how these tools relate to the overall regulatory framework. This section proposes additional recommendations with regards to the appreciation and measurement of the risk mitigation measures tools' efficacy and side-effects, as well as ways to improve the implementation of these tools in the future.

6.3.1 Demonstrated efficacy and benefits of the risk mitigation measures tools

The demonstration of the efficacy of risk mitigation measures tools to reduce risks and present benefits for the environment is critical in their acceptance and implementation by farmers and all stakeholders. It is, however, easier to establish this efficacy in the case of risk mitigation measures tools that involve a technology or practice aiming to reduce exposure, such as spray drift reduction tools including SDRT, adapted GAP, or even buffer zones (vegetated or not) than for landscape features aimed at promoting wildlife and biodiversity. Indeed the efficacy of such a technology or practice can only be measured through appropriate trials, or through a certification process, as for low spray drift nozzles or sprayers (ISO 22866 2005, BBA 2000, CIW 2003), for example, whereas the efficacy of a flower strip to promote a group of organism requires dedicated monitoring strategies.

As stated earlier a number of studies have attempted to quantify the benefit of landscape features such a field margins and usually confirm positive effects. A review for flowering strips has been proposed by Dicks et al. (2013), which is reproduced in Table 6.4:

Table 6.4: Outcome of 80 studies on the effects of flowering strips on wildlife and biodiversity, adapted from Dicks et al. (2013). Sixty-four studies showed some benefits to one or more wildlife groups. Note that numbers do not sum up as effects could be positive, negative, or neutral on different species or groups in the same study:

Wildlife Group	Number of Studies Demonstrating Positive, Neutral, or Negative Effects of Landscape Features as in AES on Wildlife and Biodiversity			Parameters Monitored
	Positive Effects	**Neutral Effects**	**Negative Effects**	
Invertebrates (65 studies)	50	6	15	Abundance, species richness/diversity Foraging, flower visits
Plants (21 studies)	17	4	4	Plant cover, number of flowers, diversity, species richness
Birds (7 studies)	4	2	1	Abundance, density, species richness
Small Mammals (5 studies)	5	-	-	Abundance, density, species richness
Biodiversity (22 studies)	19	3	3	Indices of biodiversity

As shown in Table 6.4, the presence and implementation of field margins and recovery areas exert positive effects on all groups of organisms as well as on biodiversity, provided that some recommendations with regards to their implementation are respected (see for example, Pe'er et al. 2014, Stoate et al. 2009). These recommendations may relate to the geographical scale at which the measures are implemented as well as on the time scale needed for the benefits to be actually observed (Pe'er et al. 2014).

Using pollinators as an example, it was observed that both landscape- and local-scale factors influence wild bees assemblages and may interact (Kennedy et al. 2013). Habitat diversity and field-level diversity both promote abundance and richness, and at landscape-scale, the diversity of habitats at bee foraging ranges is a driver of bee abundance and diversity.

Landscape parameters are also critical in the efficacy of a mitigation measure to exert the expected effects. Beneficial effects of AES were more effective in landscapes with intermediate levels of heterogeneity, as previously described in Stoate et al. (2009) and Tscharntke et al. (2012).

Similar observations were reported by Kennedy et al. (2013), Kleijn and van Langevelde (2006), Oppermann and Hoffmann (2012), Scheper et al. (2013), and Winfree et al. (2008). Also, habitat fragmentation as compared with the scale at which landscape features are implemented is critical, as observed for example for pollinators, which implies to consider both pollen and nectar resources and nesting habitat for an optimized effectiveness of the measures implemented (Wright et al. 2015).

The implication of the influence of spatial-scale on the efficacy of AES is that although recommendations on their implementation are useful at the farmland scale (i.e., as for example in the recommendations provided in RMMTS #3 to 9 for field margins), an additional level of verification is necessary at a larger scale in order to adjust these recommendations at the relevant local or regional scales. Similar recommendations have been published by Dicks et al. (2013), on the basis that landscape-related factors are implicated in the level of environmental status and biodiversity that is expected in first place, and, therefore, to be promoted or preserved. This was reflected in the outcome of studies AES implementation and efficacy as a function of landscape heterogeneity reported above. GIS-supported landscape descriptions that are in development in some European countries could be a basis for such recommendations as they could help define the relevant scale at which a specific risk mitigation measure may be implemented on a specific way (e.g., field margins of a specific length or width, or of a specific type).

Time-scale effects have finally been reported. The percentages of food plant species being useful to butterflies and birds were found to increase with the age of set-aside fields, and this was accompanied with an increase in the percentage of bird and butterfly species for which larval food plants were present (Stoate et al. 2009). The rapidity with which effects are observed depends on growth traits and competitiveness between the species in an assemblage. The recommendations published in the UK thus propose a multi-year management of field margins in order to promote long lasting effects on wildlife and biodiversity (Natural England 2013). In Switzerland, further work has lead to the development of “improved field margins” (Jacot et al. 2007). These field margins are a species-rich mixture designed to establish a long-lasting, floristically diverse and flower-rich vegetation, which provides multiple benefits to the typical fauna of crop-dominated landscapes, such as shelter, food, or suitable microclimate and they are managed as (semi) permanent landscape features.

Thus, in spite of the difficulty to quantify the level of risk reduction achieved through the implementation of a dedicated field margin for the purpose of risk mitigation issues, it is possible to appreciate the benefit of specific field margins on groups of organisms or on the factors driving the abundance of these groups (e.g., food resource, hibernation sites) through the use of indices (see RMMTS #3 to 9 in section 3) (Hackett and Lawrence 2014). Approaches to quantify the effectiveness of natural areas at mediating effects of harmful pesticides on non-target species are just being initiated as for wild bees for example, which showed a buffering effect providing that the surface represented by these natural areas compared with the cropped surface is important enough (Park et al. 2015).

The benefits of AES measures on wildlife and biodiversity are assessed via monitoring studies, comparing abundance and diversity in one or several groups of organisms in agricultural systems (measured in-crop and off-crop) presenting diverse degrees of implementation of these measures. These studies have been reviewed in several meta-analyses and confirm positive effects of AES measures on all groups of organisms, even in conventional farming, thus demonstrating compensating effects on the overall reduced biodiversity that occurs in intensive systems where no or limited AES are implemented (DEFRA 2007, Dicks et al. 2013, Kennedy et al. 2013, Scheper et al. 2013, Stoate et al. 2009, Schneider et al. 2014). Using pollinators as an example, a review of 39 studies investigating the impact of landscape- and local-scale factors revealed that vegetation diversity in conventional crop fields had similar effect on abundance as organically managed fields with low vegetation diversity, which indicates a potential for compensation mechanisms through the availability of refuges, habitat, and food resource (Kennedy et al. 2013). Similar conclusions were reported by DEFRA (2007), Park et al. (2015), Scheper et al. (2013), Stoate et al. (2009), and Winfree et al. (2008). Kennedy and collaborators (2013) suggested that with a 10% increase in the amount of high-quality habitat in a landscape, wild bee abundance and richness may increase on average by 37%. Even narrow margins (<3 m) are reported to be beneficial to wildlife as for arthropod predators or butterflies (Hahn et al. 2014). However, as stated above, the implementation of farmland features needs to account for diversity in habitat and habitat scale and for an optimizised effectiveness on biodiversity (Kleijn et al. 2015, Park et al. 2015, Wood et al. 2015, Wright et al 2015).

There is a need to develop monitoring strategies that are able to appreciate the benefits of field margins implemented on the groups of organisms concerned (Pe'er et al. 2014). Existing studies use ecological indices such as species richness, abundance, and density indices, but also foraging or visits and plant cover to quantify the effects induced (see Table 6.4). Metrics to inform about species biodiversity in cultivated areas are developed and tested for their capacity to provide useful measurement of the contribution of a farm or a group of farms to the overall biodiversity of an area (Luscher et al. 2014). Recommendations on the spatial- and time-scales to be respected in ecological monitoring would be useful and are under development in the Society of Environmental Toxicology and Chemistry (SETAC) advisory group Environmental Monitoring of Pesticides interest group (http://www.setac.org/group/SEIGPest). Examples of monitoring in birds, invertebrates, or pollinators are available (Hoffmann et al. 2013, see also more references in the introduction to RMMTS #3 to 9 in section 6.3), as well as stewardship initiatives reported in the related chapter. For some species, food resource may also be used as reliable indicator of their presence as for birds, invertebrates, and pollinators, for example Marshall et al. (2001). In addition, the efficacy of a nectar and pollen strip to fill the needs of pollinators may be estimated in calculating the food resource they provide, as for example in Lemoing and Pasquet (2011) (see Appendix 9).

Besides studies that would provide detailed feedback on the effect of risk mitigation measures on the different groups of organisms, simple tools designed to be used by farmers to appreciate the results of their management work would be very useful. This recommendation rejoins previous recommendations to provide farmers with ecological training

(Pe'er et al. 2014). Simple indices have been developed for plants (Abadie et al. 2008) and butterflies, (see PROPAGE, developed by the French national museum of natural history [http://propage.mnhn.fr/]), which allow for a fast appreciation of the flora or fauna frequenting fields. Limitations of these indices compared with comprehensive taxonomical monitoring have been pointed out (see for example, Krell 2004; Ward and Stanley 2004), however, they are valuable for global comparisons of trends in space and time and do not require the involvement of a scientist. This level of monitoring is critical as it presents the double benefit of a tool that may be implemented at a large scale together with an easy mean for self appreciation of mitigation results.

6.3.2 Controlling weeds and pests

The presence of field margins can influence the crops they are boarding through diverse processes (Marshall and Moonen 2002). In principle they may:

- Constitute a reservoir of seeds and contribute to the spread of weeds into the crop
- Create microclimate conditions or compete for light, moisture, and nutrients
- Constitute a habitat for pests; but also for beneficial insects, with consequences to the crop that depend on the balance between the two groups

With regards to weeds, studies on the location of plants at arable field edges show four distribution patterns for plant species: (1) limited to the crop area, (2) some ability to spread into the crop, (3) limited to the off-crop area, and (4) highest density in crop edges, or in headlands (Marshall and Moonen 2002). The ability of plant species to spread into the crop would be more limited in Northeastern Europe than in other areas. In warmer Mediterranean conditions, the flora may behave very differently to the moist Atlantic areas, where competitive exclusion by perennial species in general reduces annual weeds.

Among species presenting a propensity to spread are annuals *Anisantha sterilis*, or *Bromus sterilis* and *Gallium aparine*, perennials such as *Elytrigia repens* (current name *Elymus repens*), and biennials such as *Heracleum sphondylium.*

A comparison of the hedge-bottom vegetation of two neighboring farms in Wiltshire, UK gave insight on the influence of field margins on the presence of some grass species (Moonen and Marshall 2001). One farm was sown with 2–20m wide grass strips and the other farm was sown with 0.5m wide sterile strips. The abundance *of B. sterilis* in the hedge-bottom was significantly reduced where grass strips were present. The mechanism is believed to be a protection from disturbance afforded by the introduced grass margins. This is in line with further observations from a review that the disturbance of the field margin and removal of perennials species may promote annual species capable of colonizing the field (Marshall and Moonen 2002).

Another outcome of the above study was that sown grass strips had a positive influence on species richness (Moonen and Marshall 2001). Grass and wildflower strips can prevent spread of *B. sterilis*. Other studies also showed that sown perennial grasses can significantly reduce the growth and spread of rhizomes of *E. repens*, a perennial weed of field edges (Marshall and Moonen 2002). A variety of weeds, including *H. sphondylium*, *Urtica dioica*, *B. sterilis,* and *Cirsium arvense* have been observed to be significantly reduced by sowing grass or grass and flower mixes. Overall, data indicate that where a field margin contains less desirable plant species at the outset, these are likely to increase where natural regeneration is used to create extended margins. Sowing will reduce these species although they might not eliminate them.

With regards to pests, the presence of field margins with diverse flora is theoretically expected to favor pest abundance and thus increase pest pressure in the crops. However, few examples of this phenomenon are described in the literature, as such. Certain pest species are associated with plant species in the field margin, as for example black bean aphids and the shrub *Euonymus europaeus* (Marshall and Moonen 2002). The spread of molluscs has also been observed into crops consecutively to the implementation of field margins (Marshall and Moonen 2002). Field margins may also be as a source of damage from zoophytophagous predatory bugs in species who may survive by feeding on the crop.

Vegetation diversity may however have a suppressive effect on pest abundance through bottom-up mechanisms that disrupt the pest's ability to locate or access the host plant (Marshall and Moonen 2002). In a study comparing sown flower strips to semi-natural habitats, sap sucking insects were found to be more abundant in flower strips, although crop damage was found to be lower suggesting that flower strips may act as trap-crop (Balzan and Moonen 2014).

But the most described mechanism by which vegetation diversity influences pest presence is the promotion of natural enemy populations. In their study, Balzan and Moonen (2014) observed that the presence of flowers increased the parasitism rate in aphids in the crop, and a lower rate of damage related to Lepidopteran was observed. Lower level of crop damage was observed early in the season when semi-natural strips were present suggesting a role of crop colonization by natural enemies.

It has also been suggested that the presence of field margins with diverse flora would increase the abundance of natural enemies and thus lead to a better regulation of pest populations. Sown flower strips may enhance the abundance of parasitoids and generalist predators such as Coccinelidae, Nabidae, Syrphidae, Thomisidae (Marshall and Moonen 2002, Balzan and Moonen 2014). Indeed, natural enemy populations may be promoted by an adequate choice of flowers: most hymenopteran parasitoids and many predators have short mouthparts and feed on accessible sugar sources such as exposed floral and extra floral nectar (Marshall and Moonen 2002, Balzan and Moonen 2014). Thus, significant reductions in aphid populations have been recorded in cereal crops boarded with grass and flower strips in Germany, which confirm the potential to promote biological control agents (Marshall and Moonen 2002).

It is therefore possible to design field margins in a way to get the most positive effects related to the functions of field margins. Their size, composition, and management, as well as additional considerations relative to crops and the region may help limiting their impact on pests or grass spread into the cropped area while providing a suitable reservoir for wildlife and biodiversity, as well as providing protection functions of the off-crop area.

6.3.3 Build the confidence in risk mitigation measure's efficacy through the development of certified systems

Besides the generation of data through monitoring or dedicated studies, the promotion of certification systems may contribute to building awareness and confidence in the efficacy of a risk mitigation measure. As an example, sprayers and spray drift reducing nozzles may be verified through standardized methods such as ISO methods (ISO 22866 2005, ISO 22369 2006) so that their efficacy is guaranteed by manufacturers. Later on technical controls may be planned in order to verify the compliance with initial specifications, as recommended for sprayers for example (EC 2009). Most of spraying technologies could benefit of such systems. Similarly for sown field margins, seed mixtures fit for purpose could be standardized and a certification process could be developed, which would contribute to facilitate their implementation.

6.3.4 Provide clear messages: Link to the regulatory framework of the Common Agricultural Policy

As previously mentioned field margins also appear as a farmland management tool of the ecological focus area described in the CAP Greening concept – see also below (EC 2013). The ecological focus area as proposed by the CAP represents at least 5% of the arable area of the holding for farms with an area larger than 15 hectares (excluding permanent grassland) – i.e., field margins, hedges, trees, fallow land, landscape features, biotopes, buffer strips, afforested area. This figure will rise to 7% after a Commission report in 2017 and a legislative proposal.

Some of these tools have been implemented in European countries since the 1990s. Grass margins, the most common of these risk mitigation measures, were for example implemented in Finland and in the UK as part of the AES, with a primary goal to mitigate erosion and pesticide drift into watercourses, although with a recognized added value to preserve biodiversity (Stoate et al. 2009). The benefits of field margins entering in AES programs in other countries have since been reported and published as described above (see for example, Conception et al. 2012a or b, Dicks et al. 2013, Kleijn and Van Langelvelde 2006, Kleijn et al. 2006, Pontin et al. 2006, Pywell et al. 2005, Stoate et al. 2009). Thus, these tools are already implemented in some countries as part of AES. It was therefore important to ensure that the recommendations regarding field margins proposed in this manuscript are practical to farmers in the context of the implementation of these AES and aligned with the Greening concept laid down in the CAP. The field margins and recovery areas described in the RMMTS above may be part of the 5% of the arable land dedicated to ecological focus areas while fulfilling their role of buffering chemical transfers and supporting biodiversity.

6.3.5 Promote the availability of risk mitigation measures to farmers

Beside the lack of awareness on a risk mitigation measure or confidence in the efficacy of the measure, the non availability of the technology involved or financial issues associated with gaining access to this technology are often reported as reasons for not implementing a risk mitigation measure.

With regards to financial implications, participants to the workshop agreed to also include and promote in their inventory the risk mitigation measures that involve expensive technologies. For example, some sprayers with special high-tech equipment may enter in this category, and are thus not evenly distributed in European countries. However, the group considered the efficacy of a technology as a priority criteria, before financial implications for the reason that if that technology would represent a significant benefit in environmental protection, then it should be recommended as such to European authorities for them to consider the ways to facilitate the access to this technology in future. A similar reasoning was agreed with regards to measures that are not yet available in some countries.

6.3.6 Education and training

The lack of experience or practice with a risk mitigation measure may also prevent their implementation. Education and training are critical to communicating the correct messages about risk mitigation measures and building farmers' practice. Education and training with regards to the use of pesticides are part of the recommendations of the Directive of the sustainable use of pesticides (EC 2009).

However, training on the implementation of AES is less often reported, although stewardship initiatives proposing educational booklets, dedicated websites, and applications for mobile phones exist (see chapter on stewardship for further details). In addition, training to use dedicated technology, like spray drift reducing nozzles, may be easier than training to implement specific field margins, because the capacity of farmers to self-evaluate the efficacy of their work is easier with a technology than when ecological aspects are at stake. Recommendations to provide farmers with the minimum level of ecological expertise have already been made in relation to the CAP (Pe'er et al. 2014). This expressed need in education and training has consequence on the acceptance of these tools by farmers and thus their implementation. Examples of dedicated training may be found in Chapter 10.

The acceptance of risk mitigation measures by farmers may be assessed via questionnaires where farmers rank the attractiveness of risk mitigation measures and explain their responses. An example study has been undertaken by Jacot and collaborators (2007) with the aim of collecting farmers' opinions on the implementation of AES. Farmers' acceptance of field margins was observed to be related to crop yields and to the costs relative to the value of the crop. Flexibility in the implementation was also reported as a preferred criterion as for example, the possibility to adjust the width of the unsprayed edges. But encouragingly, the capacity to appreciate an increased biodiversity in the cultivated landscape was also a factor of acceptance of field margins by farmers (Jacot et al. 2007). Finally, the authors report that "the more species-rich a plant community is, the more it appealed to people" (Jacot et al. 2007). Intuitively, the capacity to appreciate the benefits of a management feature like a field margin on the mitigation of erosion or run-off, or on the frequentation of the farmland by butterflies or beneficial organisms, constitutes a convincing argument in favor of a practice, and the development of self-evaluation tools is considered as a priority among educational tools. Such tools could be simple ecological indices, such as those previously developed for flora or butterflies, which may be linked to more academic ecological indices in future. It is believed that a wide spread use of such basic tools would represent an important step forward to better awareness of the environmental dimension in a farmland, as well as to a better appreciation of its status within time.

6.4 Conclusions and recommendations

The toolbox for the protection of the off-field area contains a number of tools in the categories of buffer zones, field margins, spray and dust drift reduction technologies, and good agricultural practices. A total of 15 tools have been identified, 13 of which are further described in RMMTS to ease their implementation. Most of the risk mitigation tools we describe here and in the RMMTS above are well developed and many of them are already implemented in European countries (see Table 6.2 for details). Some of them, particularly when based on drift reduction practice (buffer zone) or technology (spray drift reduction technique), are already taken into account in the risk assessment, as the related reduction of risk through reduced transfers may be quantified and standardized. For risk mitigation measures related to field management features such as field margins or recovery areas, benefits have been described and may be quantified through indices and appropriate indicators or ecological modeling approaches, implying the implementation of dedicated monitoring. However their implementation should not be restrained as their contribution to compensate for potential effects of pesticides in conventional agriculture is significant, as indicated by current knowledge.

Although the toolbox offers a set of measures that present a significant potential impact, it is acknowledged that the key to sustainable environmental protection relies on the implementation of the tools (see van der Valk and Koomen 2013 for pollinators). For example, the implementation of field margins does not prevent the use of spray drift reducing technologies and combined effects are expected. In addition, it is often recommended to look for risk mitigation tools that allow a reduction of exposure in the first place, rather than concentrating efforts on compensatory tools only. A selection of complementary measures may help to achieve significant results soon after implementation and could be a way to include these measures into the standard practice in future.

Recommendations for future development are listed below, in order to complete the development or further improve the risk mitigation toolset for off-field protection. They complete the set of recommendations listed in Chapter 11 for the purpose of off-crop protection:

- Promote the implementation of buffer zones (bare soil buffer zones, wind or temperature dependant buffer zones) and field margins in Europe in order to improve their benefits at a larger scale
- Further develop the multi-functionality of field margins and adapt to Member States conditions in order to refine the related RMMTS and optimize associated benefits
- Further develop the standardization of seed mixtures used to implement field margins and develop related certification systems
- Promote the implementation of spray and dust drift reducing technologies through measures to encourage their use by farmers and their development by manufacturers
- Develop guidelines for monitoring in the farmland in order to get a set of tools to measure the ecological benefits of risk mitigation measures and refine them – in line with the SETAC Environmental Monitoring of Pesticides interest group
- Develop an abacus of spray drift reduction provided by the different types of field margins, as well as of combined spray drift reduction measures
- Develop simple indices to measure the benefits of risk mitigation measures in the farmland, by farmers and develop the communication

tools for education and training

- Develop GIS-based databases to appreciate the environmental status of a landscape in order to be able to refine the recommendations in the RMMTS relative to field margins and farmland landscape features to be implemented
- Develop scenarios to be applied in ecological modeling approaches to quantify benefits of (combinations of) risk mitigation measures for an extended understanding and optimization
- Develop a mapping of apiaries e.g., through national inventories and record of honey bee colonies, so that GPS coordinates would become available to farmers
- Develop a cooperation system (preferably web-based) for farmers and beekeepers to exchange relevant information (e.g., location of apiaries, insecticide treatment) while respecting data privacy among the partners
- Enable and promote the link to the regulatory framework of the CAP

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