An ecosystem services approach to pesticide risk assessment and risk management of non-target terrestrial plants: recommendations from a 1st SETAC Europe workshop

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This workshop report presents the results of the first workshop about non-target terrestrial plants that was held in Wageningen, The Netherlands, 1-3 April 2014. The workshop was held under the auspices of the Society of Environmental Toxicology and Chemistry (SETAC) Europe, with sponsorship from the European Crop Protection Association, the Dutch Ministry of Economic Affairs and participating stakeholder representatives.

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SUMMARY **(recommendations agreed by all workshop participants)**

1. The specific protection goals (SPGs) applied to infield/off crop areas is dependent on their primary purpose. In-crop SPGs are applied to areas whose primary purpose is mitigation of risks of PPPs (e.g. no-spray buffer zones). Off-crop SPGs are applied to areas whose primary purpose is enhancement of biodiversity.

2. The potential role of in-crop NTTPs for sustainability of the food web and provision of habitat was acknowledged, but the majority view was that compensation for these ecosystem services was not part of pesticide risk assessment.

4 The NTTP entity to be protected is the population or higher. Transient effects at a local scale are acceptable for some ecosystem services, but there should be negligible effects at either the landscape scale or in protected areas.

5 The extent to which the species currently tested are protective of wild species was evaluated by comparing the sensitivity of standard and wild species.

6 The extent to which current regulatory endpoints are protective of population effects should be evaluated. Do reproductive endpoints need to be included?

7 There is little knowledge, guidance, and experience for conducting field studies or other multispecies studies with NTTPs. There is a need to collate available information and exchange understanding, knowledge and protocols.

8 Relative importance of different exposure pathways to NTTPs is unclear. There is a need to collate and review available information.

SUMMARY **(conclusions and recommendations from follow up investigations)**

1. The evaluation of biomass-based ER25 and ER50 vegetative vigour endpoints revealed no consistent differences in sensitivity between wild plant species and crop species. Based on the most sensitive species, 20 quotients were > 1 and 19 were < 1 whereas for quotients based on the geometric mean, 21 were > 1 and 17 were < 1. Individual analyses of the ln-transformed endpoints of crop and of wild species indicated statistically significant difference in 13 out of 40 cases: wild species were more sensitive than crop species in 9 cases and crop species were more sensitive than wild species in 4 cases. Therefore, it was concluded there was no trend for any of the two to be more sensitive than the other. There appears to be no reason to include more wild species in standard ecotoxicity testing neither to extend the number of species to be tested in the first tier.
2. Available information and understanding, knowledge and protocols from field studies and multispecies studies were gathered from the literature and the expertise of workshop participants, showing a wide range of test approaches, test species and assessment endpoints. So far no agreed higher tier options have been established for non-target terrestrial plants. Higher tier testing of non-target terrestrial plants enable more realistic exposure and more realistic environmental conditions. Higher tier testing options provide a continuum from laboratory testing to greenhouse, semi-field outdoor tests and field-scale experiments and monitoring thereby increasing the level of biological organisation addressed in these studies (from single species to multispecies, populations and ecosystems). Higher-tier tests must be informed either from lower-tier tests or from monitoring studies. As higher-tier tests face an inherent

higher variability in the population and ecosystem level addressed, these higher-tier approaches need proper statistical designs and expectations. Also sub-lethal endpoints of plant growth and reproduction need to be addressed in order to adequately protect populations of non-target terrestrial plants. As higher-tier approaches are quite diverse, there is a need for further understanding, knowledge and protocols.

3. Spray drift was assumed to be the main exposure route for Non-Target Terrestrial Plants (NTTP) during the discussion and possible mitigation measured focused on it e.g. buffer zones, drift reducing technology including end nozzles, precision application intercepting drift in field with mesh screens, tall vegetation and hedges. Options for mitigating run-off were vegetative buffer strips, precision farming and adjusting the timing of application relative to weather conditions. For volatilisation, different types of formulation were mentioned. However, as the relative importance of run-off and other exposure pathways (e.g. volatilisation, airborne spray-drift) to NTTP with different physical structures could not be clarified at the workshop, information on the relative importance of different exposure pathways to NTTP and how to harmonize with other areas exposed to drift like Non-target arthropods was asked to be generated. A brief literature search yielded in literature about how to mitigate run-off especially for aquatic systems generated no information especially in terms of the relative importance of the exposure pathway run-off versus drift. It seems to remain an open research question to compare those fluxes to each other and to find out how run-off can affect NTTP. Thus, the follow up investigation report focused on drift reducing technology and buffer zones to reduce the exposure of Non-Target Terrestrial Plants. Different drift reducing measures and their efficacy are discussed in detail in the report e.g. buffer zones, low drift nozzles, boom height, different types of sprayers, precision application of PPP as well as vegetative barriers and windbreaks.

4. Test-substance - species combinations for which reproductive endpoints and vegetative vigour endpoints were available, were identified from open literature and from EU data and DAR reports. Multiple observations for a given test-substance - species combination were consolidated, so that just one quotient per endpoint type (ER10, ER25, ER50) and test-substance - species combination was obtained. Quotients were based on either a geometric mean or a worst case (minimum) overall measure of toxicity. As no consistent differences in sensitivity could be observed between greenhouse and field data, these data were pooled. The resulting ratios are presented in Table A.

Table A: Quotients obtained by dividing minima or mean vegetative vigour ERx endpoint by minima or mean reproductive ERx endpoint per substance/species combination. Censored values were either excluded, or the values (i.e. tested rates) included with a factor of 2 (in line with recommendations of the German UBA).

Effect level	Substance-species - combinations		Ratio VV/Rep	
	Censored values	n	minimum	mean
ER_{10}	*excluded*	23	0.97	1.88
	included with factor of 2	26	0.85	1.56
ER_{25}	*excluded*	56	1.43	1.95
	included with factor of 2	98	1.14	1.44
ER_{50}	*excluded*	71	1.22	1.87
	included with factor of 2	132	1.09	1.48

Based on this initial evaluation and including all data available to date, reproductive endpoints were generally somewhat lower than vegetative endpoints, i.e. the former were more sensitive by a factor of 0.9 to 1.9. However there were exceptions. In a few cases vegetative and reproductive endpoints were reported to differ by several orders of magnitude, possible causes of which are still being investigated.

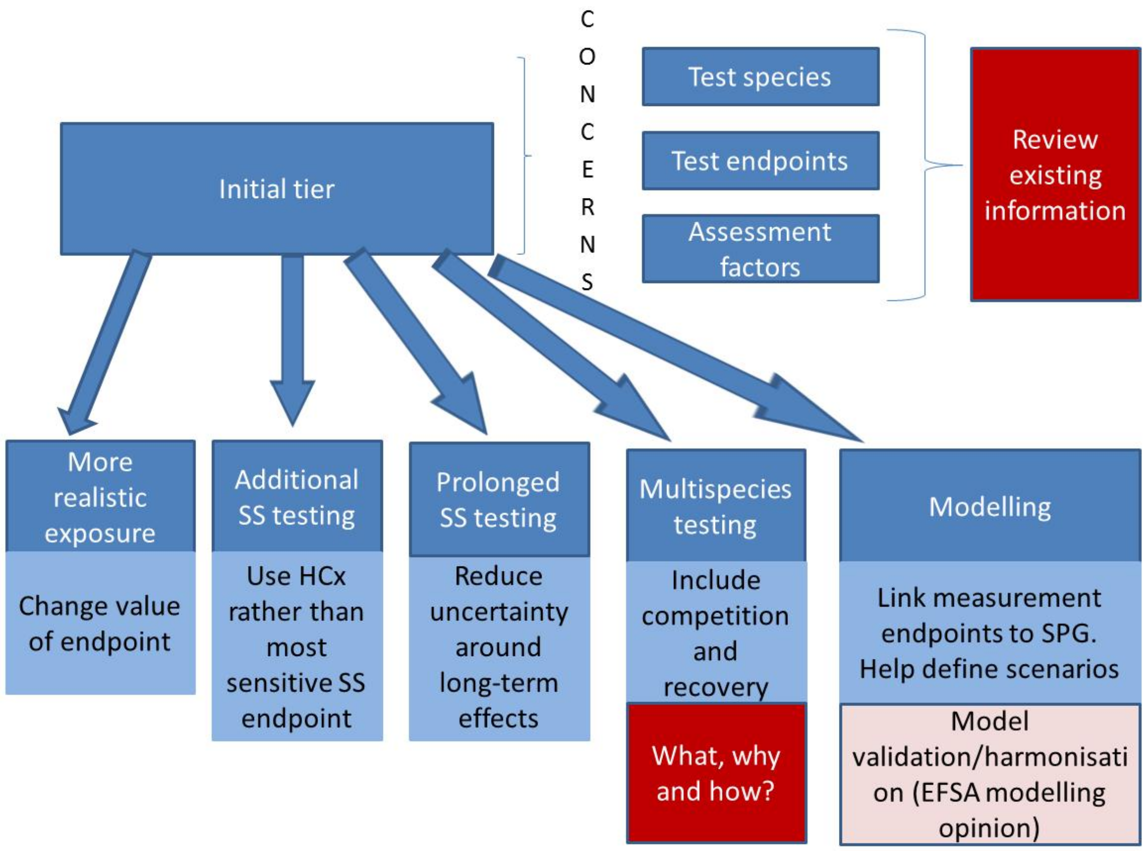
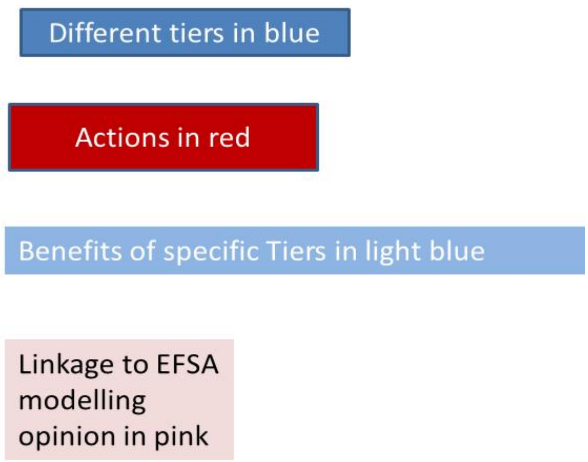


Figure A. Proposed higher tier options for NTTPs (dark blue boxes) and the associated benefits (light blue box below each option). Blue boxes highlight key concerns relating to initial tier risk assessment, which will be addressed in part, by reviewing existing information (red box). Legend:



Chapter 1 Introduction to the workshop

The registration of Plant Protection Products (PPPs) in the EU is under Regulation 1107/2009, which recommends a tiered approach to assessing the risk to non-target terrestrial plants (NTTPs). The tiered approach states that extended laboratory, semi-field and field studies may be conducted. However, little information is provided on how to perform and implement higher tier studies or how to use them to refine the risk assessments.

EFSA are in the process of developing guidance to support Regulation 1107/2009. One of the main objectives of this workshop is to consolidate scientific, technical and regulatory expertise as input for the further development of robust, reliable and usable NTTP testing and assessment procedures. There is also a need for clear guidance on how results from a tiered assessment procedure for non-target terrestrial plants may be interpreted or linked to the relevant ecosystem services.

In addition, there is a need to promote better understanding among different stakeholders of the state-of the art scientific knowledge relevant to terrestrial non-target plants risk assessment and the sustainable use of PPPs. There is also a need to use this understanding to agree on suitable risk management strategies.

Here we report on the outcome of a recent workshop that begins to address this need for non-target terrestrial plants in agricultural landscapes. The workshop was held under the auspices of the Society of Environmental Toxicology and Chemistry (SETAC) Europe, with sponsorship from the European Crop Protection Association, the Dutch Ministry of Economic Affairs and participating stakeholder representatives. The Steering Committee was convinced that via the collaboration of SETAC and ECPA this stakeholder workshop on Terrestrial Non-Target Plants was organized in an optimal way, where representatives from academics, regulatory bodies and business were invited and the proceedings/recommendations of this workshop were published and submitted to EFSA for possible inclusion in the revision of the Terrestrial Guidance document and were intended to be used in a 2nd follow up workshop with EFSA.

The overall aim of the workshop was to develop a framework for a higher-tier approach for assessing the risk of plant protection products to non-target terrestrial plants (NTTP) in off-crop areas.

Based on this overall aim, the objectives of the workshop were:

1. Consider the application of protection goals as defined in the EFSA opinion to NTTP risk assessment and testing.
2. Evaluate methods for lower and higher tier.
3. Define what approaches and information are needed to conduct higher-tier risk assessments for NTTPs.
4. Consider how modelling of single and multiple NTTPs can be implemented in the risk assessment.
5. Discuss approaches for mitigation of risk to NTTPs from different exposure routes.

Approximately 25 - 30 participants were invited, with equal representation from academic, business and regulatory communities. All participants were expected to have a working knowledge of either non-target terrestrial plant research and testing or the regulation of plant protection products in Europe.

The workshop provided the following deliverables:

- A set of recommendations agreed upon by all participants and laid down in a published paper.

- Expert opinion and advice as input for the ongoing revision of the terrestrial ecotoxicology guidance document and NTTP risk assessment procedures as laid down in this report and in 4 working group reports.
- A proposal for a clearly defined tiered approach for NTTP studies and risk assessment based on a structured and scientifically sound approach as laid down in this report.

Chapter 2: Specific Protection Goals for Non-Target Terrestrial Plants

2.1 Abstract of keynote presentation: Agricultural landscapes, terrestrial plants and ecosystem services. Lorraine Maltby (University of Sheffield), Gertie Arts (Alterra Wageningen University and Research Centre)

Ecosystems provide a variety of benefits to humans that are underpinned by biodiversity. These include: the provision of food, clean water and fibre; the regulation of climate, pest and disease populations; the detoxification of waste and alleviation of floods; as well as the production and retention of soil and soil fertility. These benefits are termed ecosystem services and understanding how they are impacted by agricultural management practices is fundamental to achieving sustainable intensification; a strategy for meeting the increased food demand of our still growing global population.

Pesticides can play an important role in addressing the food security challenge by enhancing crop yields, but they may also have effects on non-target organisms that are important in delivering ecosystem services, including those that benefit crop production (Figure 1). The challenge of sustainable intensification is to identify options that maintain or enhance provisioning services (e.g. crop production), whilst protecting or enhancing regulating (e.g. pest control), supporting (e.g. nutrient cycling) and cultural (e.g. aesthetics) services. Here we explore how the ecosystem services concept can be used in the management of pesticides and consider the role of terrestrial plants in ecosystem services delivery.

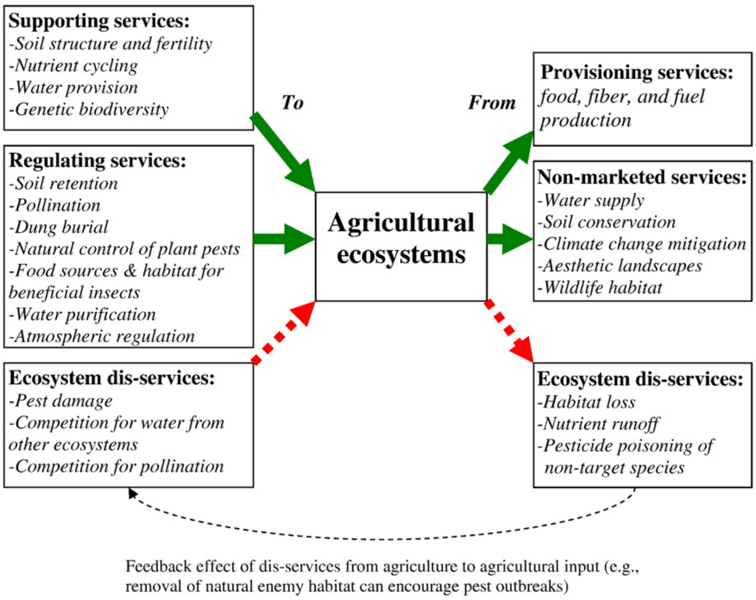


Figure 1: Agricultural systems rely on and provide bundles of ecosystem services. Agricultural practices also have adverse impacts on the ecosystem and the services it provides (ecosystem dis-services). From Zhang et al. 2007.

Terrestrial vascular plants are fundamental to most ecosystems. They provide food and habitat for animals and resources for microorganisms. Those that photosynthesise, regulate climate by releasing oxygen, absorbing carbon dioxide, and sequestering carbon in biomass. In addition, plants influence water quality, soil fertility and stability. Humans have relied on plants for thousands of years for food, shelter, fuel, fibre, clothing, medicines and ornaments. Life on Earth as we know it would simply not be possible without vascular plants. Table 1 lists the ecosystem services provided by terrestrial plants.

Table 1: Ecosystem services provided by terrestrial plants, classified according to the Millennium Ecosystem Assessment (MEA, 2005) typology. Supporting services are the ecological structure and processes underpinning the production of provisioning, regulating and cultural services.

Service Groups	Ecosystem services
Provisioning	Food, fibre, fuel, genetic resources, medicine and biochemical products, ornamental resources, biological products
Regulating	Pest and disease regulation, soil bioremediation, climate regulation, bank and soil stabilization, hydrological regulation, pollination, invasion resistance,
Cultural	Education, inspiration, aesthetic values, recreation and tourism, spiritual and religious values, cultural heritage
Supporting	Soil formation and structuring, photosynthesis, primary food production, nutrient cycling, decomposition and mineralization, food web control mechanisms, habitat and shelter supply

Non-target terrestrial plants (NTTP) are those plants growing within fields and outside fields that are not subject to direct control. NTTP comprise a range of growth forms and physiological adaptations to the biotic and abiotic conditions in vegetation complexes with and outside agricultural fields. They include different growth strategies (annual, bi-annual or perennial) and are classified into monocots (grasses) and dicots (broadleaf species). Annual plants develop their full growth cycle from seed to flower and seed again within one growing season. Biannual plants grow during their first year and produce flowers and seeds in their second year. Perennial plants grow from permanent structures in the soil (roots, rootstocks, etc.) and can reproduce every year under optimal circumstances. Some plant species that have adapted to living in arable landscapes pose little threat to crop production. On the contrary, many may be beneficial by fixing nitrogen, providing food for pollinators and habitat for predators of crop pests.

2.2 Ecosystem services and pesticide risk assessment

An essential requirement for effective risk assessment and risk management is a clear articulation of what is to be protected, where and when. General protections goals for use in regulating plant protection products (PPPs) are outlined in European legislation. However, these protection goals are only broadly defined, e.g. described in terms of “no adverse effects on” and more specific protection goals are required to enable robust and effective ecological risk assessment and regulatory decision making (Nienstedt et al. 2012). In 2010, the European Food Safety Authority (EFSA) published an opinion outlining how an ecosystem services framework could be used to establish specific protection goals for plant protection products (EFSA 2010), an approach that has been endorsed at a recent EFSA Scientific Colloquium (EFSA 2014). However, this colloquium also highlighted further work that was needed to make this approach operational, including translating protection goals into measureable assessment endpoints.

Many human activities may influence the delivery of ecosystem services and the potential impact of toxicants on ecosystem services was recognized over two decades ago (Cairns and Niederlehner 1994). The quantitative assessment of the risks of chemical exposure to ecosystem service delivery requires an understanding of the ecological components producing ecosystem services (i.e. service providing units) and their responses to chemical exposure (Forbes and Calow 2013, Maltby 2013). The structure and functioning of terrestrial plants underpins the delivery of many ecosystem services (Table 1) and EFSA (2010) identified non-target vascular plants as one of the key drivers of ecosystem services to be included in the risk assessment for PPPs. However, some terrestrial non-crop plants reduce food production by competing with crop plants within agricultural fields. Their abundance, therefore, is controlled in agricultural systems, often through the use of PPPs. Because PPPs are potentially harmful to non-target species, the challenge is to control target plants within the field that adversely affect crop production, whilst minimizing the effects on the crop and other NTTPs that provide important ecosystem services.

2.3 NTTP in agricultural landscapes

Discussions at the workshop focussed on vascular plants, of which there are more than 20,000 species in Europe (Bilz et al. 2011). Terrestrial plants are a highly diverse with species classified into three groups based on their anatomy and mode of reproduction: non-vascular plants (bryophytes), vascular seedless plants (lycophytes, pteriophytes) and vascular seed plants (gymnosperms, angiosperms). Angiosperms (flowering plants) have been traditionally divided into monocots (monocotyledons) and dicots (dicotyledons) based mainly on the number of cotyledons in the embryo. However, molecular data indicate that, whereas monocots form a distinct clade, dicots are polyphyletic, with the vast majority of species forming a large clade known as eudicots (Simpson, 2010).

In agro-ecosystems, vascular plants, may occur as NTTP both within (in-field) and outside managed fields (off-field). In arable fields, NTTP may occur within (in-crop) or outside (off-crop) the cropped area (Figure 2). Relevant areas for PPP risk assessment can then be defined as: in-crop, in-field but off-crop, and off-field (no crop).

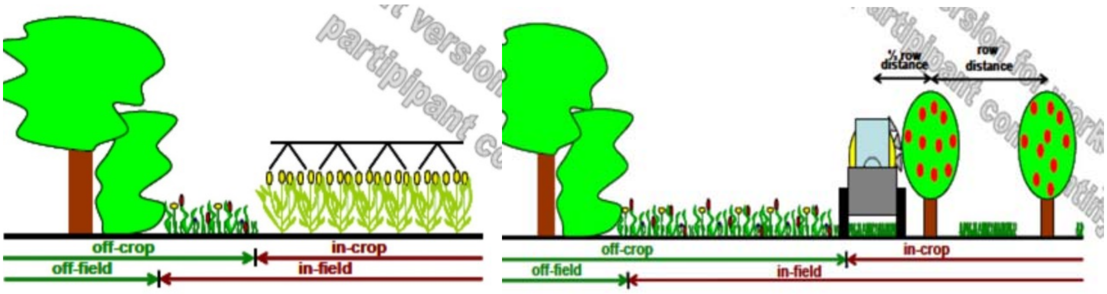


Figure 2. Schematic presentation of potential locations of NTTP in an arable crop situation (left) and a fruit crop situation (right) (after Escort 3, Alix et al., 2012)

2.4 Ecosystem services and specific protection goals for NTTP

Specific protection goals (SPGs) for ecosystem services specify which attributes of service providing units need to be protected, and at what spatial and temporal scale. The specific protection goal list from EFSA (2010) was adopted by the workshop as baseline for the further discussions (Table 2).

Table 2: Specific protection goals (SPG) for NTTPs specified by EFSA (2010). Ecosystem services of relevance to NTTP in agricultural landscapes and potentially at risk from exposure to PPPs are grouped into two bundles. Each bundle of services is associated with a SPG stating the ecological entity to be assessed, the attribute of that entity to be protected, and the magnitude and scale of impact that is acceptable in order to meet the legal requirement.

efsa — Specific protection goals for ERA of pesticides

key driver	ecosystem service	legal requirement	specific protection goal	ecological entity	attribute	scale		
						magnitude of impact	spatial scale of impact	temporal scale of impact
non target plants (aquatic and terrestrial)	- primary production - nutrient cycling - water regulation - provision of habitat -food	no unacceptable lethal and sublethal effect	no to short term effect on biomass of functional groups and keystone species	population to functional groups	biomass as affected by survival and growth	negligible to small effect (population dependent)	edge of field to landscape/ watershed	days to weeks in edge of field to no to days in protected areas and watershed
non target plants (aquatic and terrestrial)	- genetic resources - education and inspiration - recreation and ecotourism - aesthetic values	no decrease in biodiversity	no decline in biodiversity in the watershed/ landscape	metapopulation to community	diversity and population abundance/ biomass, visible phytotoxic effects	locally small to medium effect but negligible effects in protected areas and landscape / watershed	field to landscape / watershed	days to weeks in fields and edge of field to no to days in protected areas and landscape/ watershed

There was general agreement among workshop participants that the ecological entities to be protected in NTTP risk assessment should be populations and communities rather than individuals, with the possible exception of endangered species. Protecting populations was considered adequate to protect functional groups. Given that population endpoints depend on survival, growth, and reproduction, the latter was considered important to ensure the maintenance of populations. Participants agreed with the ranges given in Table 2 for the magnitude and duration of effects, and highlighted that large in-crop effects on NTTP are unavoidable if intensive agriculture is to be allowed in the EU. For most off-field areas, small to medium effects at the local scale during days to weeks should be acceptable. In the case of off-field protected areas and also at the landscape level, risks to NTTP should be negligible. This is in agreement with other regulatory frameworks operating at the landscape scale such as the Water Framework Directive (WFD; EC 2000).

NTTPs provide a wide range of ecosystem services within agro-ecosystems, however, the type and relative importance of ecosystem services will differ between different areas (i.e. in-crop, in-field but off-crop, and off-field). The use of ecosystem services-based SPGs therefore requires the prior definition of the areas where different protection goals become applicable. The EFSA PPR Panel recommended that in-crop SPGs are applied to field margins (i.e. in-field but off-crop) whose primary purpose is PPP risk mitigation whereas off-crop SPGs are applied to field margins whose primary purpose is enhancement of biodiversity (EFSA 2010; 2014). This recommendation implies that SPGs are different in-crop and off-crop, and that SPGs applied to field margins depends on their primary purpose. The workshop participants endorsed this recommendation.

Within in-crop areas, the dominant ecosystem service is provisioning by the crop species. The objective of using PPPs, and most other management practices, is to enhance this service. The potential role of in-crop NTTPs (other than the crop species) for support of the food web and provision of habitat was acknowledged and there was agreement that the effect of PPPs on such supporting services could be compensated by assigning areas for protection at the field, farm or landscape level. The majority view was that this compensation was not part of pesticide risk assessment, but should be captured by other policy instruments (e.g. agri-environment schemes, greening policies etc.), and incorporated into an integrated pest management approach.

At the edge of the field (in-field but off-crop), the main ecosystem services provided by NTTP are regulating and supporting services (e.g. reduction of erosion, runoff and PPP drift; soil conservation, water regulation, nutrient cycling). This area of the field is managed by the farmer and farm management practices often mean that endangered or rare species are seldom found in these areas. Workshop participants agreed that the promotion of rare weed[1] species is not compatible with intensive agriculture and that there was a need to distinguish between endangered species and species growing just outside of their habitat range (i.e. locally rare, regionally abundant).

Ecosystems services associated with off-field areas, and in-field but off-crop land managed for conservation by farmers in return for payments, include: soil conservation, water regulation, nutrient cycling, pollination, provision of habitat and genetic resources. These

[1] Following Boutin and Jobin (Ecological Applications, 8(2), 1998, pp. 544–557): Herbaceous species were classified as weeds if identified as such in the Noxious Weed Act (Anonymous 1981: Loi sur les abus pre´judiciables a`l'agriculture) and cross-checked with weed surveys performed in the area (MAPAQ 1987, 1989). Lythrum salicaria, although not listed in the Noxious Weed Act, was assigned to the weed category because of its invasive propensity (White et al. 1993).

areas are also acknowledged to be important for food web support and biodiversity conservation.

2.5. Conclusions

Workshop participants were generally supportive of the ecosystem services approach to setting SPGs proposed by EFSA (2010). They supported that view that the NTTP entity to be protected was the population or higher, and that transient effects at a local scale were acceptable for some ecosystem services. However, there should be negligible effects of PPPs on ecosystem services provided by NTTP at either the landscape scale or in protected areas. Participants acknowledged that the suite of ecosystem services provided by NTTPs is different in different parts of the agricultural landscape and that the SPGs applied to in-field but off-crop areas (i.e. field margins) are dependent on the primary purpose of these areas. In-crop SPGs are applied to areas whose primary purpose is mitigation of PPP risks (e.g. no spray buffer zones), whereas off-crop SPGs are applied to area whose primary purpose is enhancement of biodiversity. The potential role of in-crop NTTPs for the sustainability of the food web and provision of habitat was acknowledged, but the majority view was that compensation for these ecosystem services was not part of pesticide risk assessment. The regulation of trade-offs between crop production and other ecosystem services require wider management programs that operate at appropriate landscape scales (i.e. farm scale and above).

Chapter 3: Regulatory risk assessment for non-target plants

Current state-of- the- art risk assessment for non-target terrestrial plants was presented in detail including mitigation measures in case of risk identification.

3.1 Abstract of Keynote presentation Regulatory risk assessment for non-target plants

Véronique Poulsen (Anses) and Eva Kohlschmid (Agroscope)

1. Data requirements

Regulation (EC) 1107/2009 (EC 2009) concerns the placing of Plant Protection Products (PPP) on the market. At the time of writing two data requirements are in force:

1) Old data requirements: Commission Regulations (EU) 546/2011 (Active Substances, AS) and 545/2011 (PPP) implementing Regulation (EC) 1107/2009.
2) New data requirements: Commission Regulations (EU) No 283/2013 (AS) and 284/2013 (PPP) setting out the data requirement in accordance with Regulation (EC) 1107/2009.

Until January 1st 2016 new PPP can be submitted according to the old data requirements. For new active substances and for the renewal of active substances the new data requirements are mandatory.

According to the old data requirements for AS (annex point 8.6) and PPP (annex point 10.8) a summary of available data from preliminary tests which provide information with respect to possible impacts on non-target flora, shall be provided.

In the new data requirements for AS (annex point 8.6.1) and PPP (annex point 10.6.1) screening data with six plant species from six different families including mono- and dicotyledons is required. In case of herbicidal or plant growth regulatory activity a dose response test on a selection of 6 to 10 monocotyledon and dicotyledon plant species providing an ER50 value shall be conducted (annex points 8.6.2/10.6.2). Routine testing with non-target terrestrial plants is done in highly standardized greenhouse studies.

For PPP extended laboratory studies following a more realistic exposure are asked for if a high risk has been identified (annex point 10.6.3). Semi-field and field tests on plant abundance and biomass production at different distances from the crop are set out under annex point 10.6.4 for PPP. As there are no standardized tests available, the type and conditions of these studies shall be discussed with the national authorities (see also chapter 4).

2. Guidance document

The Guidance Document on Terrestrial Ecotoxicology (EC, 2002: SANCO/10329/2002) was established under Council Directive 91/414 EEC. As no specific data requirements has been set out (see old data requirements) a tiered approach is suggested, starting with the available data and if needed to proceed with further studies. For Tier 1 screening data, for Tier 2 bioassays on terrestrial plants (if more than 50% effect were identified at Tier 1), and for Tier 3 field or semi-field studies are proposed.

3. Toxicity assessment

a) Tier 1 effect assessment

Two test guidelines are used for testing toxicity of PPP in laboratory conditions:

- OECD 208 (Seedling Emergence and Seedling Growth Test), which aims at assessing effects on seedling emergence and early growth of higher plants following exposure to the test substance in the soil, during 14 to 21 days after 50 % emergence of the seedlings in the control group.

- OECD 227 (Vegetative Vigour Test), which aims to assess effects on vegetative vigour and growth of terrestrial plants following above-ground exposure, during 21 to 28 days from treatment. As such it does not cover all chronic effects or effects on reproduction (i.e. seedset, flower formation, fruit maturation).

Both tests are conducted in controlled conditions of temperature, moisture and light, and usually on artificial soil.

The effective concentration ECx or effective application rate ERx (e.g. EC25, ER25, EC50, ER50) are determined for the most sensitive parameter(s) of interest, i.e.:

- emergence, biomass and/or visual effects compared to unexposed controls for the seedling emergence test,
- biomass of surviving plants, height of the shoots, as well as abnormalities in appearance of the young plants, stunted growth, chlorosis, discoloration, mortality, and effects on plant development for the vegetative vigour test.

Many species can be used for plant testing, either crop or non-crop. Table 3 lists species that are historically used in plant testing. It is however often questioned whether wild plant species could be more sensitive to plant protection products than the standard test species. A literature review has therefore been conducted to compare the sensitivity of terrestrial plant species (crop-species and wild species) (see paragraph 6 of this chapter).

Table 3: Species historically used plant testing.

Family	Species	Common names
DICOTYLEDONAE		
Chenopodiaceae	*Beta vulgaris*	Sugar beet
Compositae (Asteraceae)	*Lactuca sativa*	Lettuce
Cruciferae (Brassicaceae)	*Sinapis alba*	Mustard
Cruciferae (Brassicaceae)	*Brassica chinensis*	Chinese cabbage
Cruciferae (Brassicaceae)	*Brassica napus*	Oilseed rape
Cruciferae (Brassicaceae)	*Brassica oleracea var. capitata*	Cabbage
Cruciferae (Brassicaceae)	*Brassica rapa*	Turnip
Cruciferae (Brassicaceae)	*Lepidium sativum*	Garden cress
Cruciferae (Brassicaceae)	*Raphanus sativus*	Radish
Cucurbitaceae	*Cucumis sativa*	Cucumber
Leguminosae (Fabaceae)	*Glycine max (G. soja)*	Soybean
Leguminosae (Fabaceae)	*Phaseolus aureus*	Mung bean
Leguminosae (Fabaceae)	*Pisum sativum*	Pea
Leguminosae (Fabaceae)	*Trigonella foenum-graecum*	Fenugreek
Leguminosae (Fabaceae)	*Lotus corniculatus*	Birdsfoot trefoil
Leguminosae (Fabaceae)	*Trifolium pratense*	Red Clover
Leguminosae (Fabaceae)	*Vicia sativa*	Vetch
Solanaceae	*Lycopersicon esculentum*	Tomato
Umbelliferae (Apiaceae)	*Daucus carota*	Carrot
MONOCOTYLEDONAE		
Gramineae (Poaceae)	*Avena sativa*	Oats
Gramineae (Poaceae)	*Hordeum vulgare*	Barley
Gramineae (Poaceae)	*Lolium perenne*	Perennial ryegrass
Gramineae (Poaceae)	*Oryza sativa*	Rice
Gramineae (Poaceae)	*Secale cereale*	Rye
Gramineae (Poaceae)	*Sorghum vulgare*	Shattercane, Grain sorghum
Gramineae (Poaceae)	*Triticum aestivum*	Wheat
Gramineae (Poaceae)	*Zea mays*	Corn
Liliaceae (Amarylladaceae)	*Allium cepa*	Onion

b) Tier 2 effect assessment

Glasshouse or field studies might be used to study the effects observed on non-target plants during realistic applications. These studies are not standardized and protocols are usually proposed by notifiers and might be discussed with national agencies.

4. Exposure assessment

The risk assessment for non-target plants is conducted for off-field non cropped areas. Therefore for this off-field exposure assessment the drift models from Ganzelmeier et al., 1995, updated by Rautmann et al., 2001 are usually used (see Table 4). The initial assessment was supposed to be conducted for a distance of 1 m from the edge for field crops, vegetables and ground applications and 3 m for other crops.

Table 4: Drift expressed as the applied dose (from Ganzelmeier et al., 1995, updated by Rautmann et al., 2001)

Basic drift values for one application Ground deposition in % of the application rate (90[th] percentiles)									
Distance	Field crops	Fruit crops		Grapevine		Hops	Vegetables Ornamentals Small fruit		Field crops
[m]		Early	late	Early	late		Height < 50 cm	Height > 50 cm	Water > 900 l/ha
1	2.77						2.77		4.44
3		29.20	15.73	2.70	8.02	19.33		8.02	
5	0.57	19.89	8.41	1.18	3.62	11.57	0.57	3.62	0.18
10	0.29	11.81	3.60	0.39	1.23	5.77	0.29	1.23	0.05

5. Risk assessment

a) Deterministic approach

The TER (toxicity exposure ratio) value is calculated using the toxicity value for the most sensitive species out of the minimum 6 species tested. It is compared to the trigger value of 5, and should be greater than 5 to consider that effects on non-target plants are acceptable.

Equation 1: TER calculation

$$TER = \frac{ER_{50}}{Exposure}$$

b) Probabilistic approach

When 6-10 species are available, a probabilistic method based on species sensitivity distribution might be used. If the HC5 for is below the highest predicted exposure level, the risk for terrestrial plants is assumed to be acceptable.

c) Higher tier risk assessment

The higher tier risk characterisation is a case-by-case analysis. The ecological relevance of the observed effects, consequences on soil functions, and the potential for recovery are key elements for the assessment. Common tools are refinement of exposure estimates and more realistic test setup from extended lab tests to field tests

Ecological models are tools that might be used as third tier risk assessment. However, further development is needed as very few validated and widely used models are available.

3.2 Uncertainties in lower-tier risk assessment for non-target terrestrial plants

During the discussions in the workshop, the uncertainty in sensitivity comparing wild plant species to tested crop species was one of the main topics emerging as an important point of attention and therefore meriting further action and research. Therefore this topic was included as one of the recommendations emerging out of the workshop. The results of broad literature and data research are included in the next par. 3.3.

3.3 Sensitivity of wild plant and crop species in the context of 1107/2009

Abstract from report by Heino Christl (Christl 2015)

In order to test the hypothesis that wild plant species could be more sensitive to plant protection products than the standard test species, published literature, and unpublished data generated in the course of the registration of PPPs, were collated and reviewed to compare the sensitivity of terrestrial crop species and wild plant species (Christl 2015). A database of

2084 data sets (species – test combinations) was compiled. The data were very heterogeneous and many of the endpoints were censored. Often endpoints of wild species would stem almost exclusively from field tests, whereas the majority of crop species endpoints would come from lab/greenhouse experiments. Furthermore it was noted that there were many cases of multiple testing, i.e. the same species had been tested repeatedly on a given active substance. Considering only numeric endpoints and merging multiple endpoints of equivalent substance-species-test system combinations (multiple testing of same species) resulted in 658 numeric ER25 and 670 numeric ER50 endpoints.

The largest homogeneous data set was used for the final evaluation: endpoints from vegetative vigour studies, ER25 or ER50 endpoints and biomass data. This resulted in a total of 535 crop and 602 wild species endpoints. Active substances were classified according to mode of action and ERx endpoints were normalised based on the geometric mean of all plant endpoints of a particular compound. Quotients were calculated (a) based on the most sensitive species in each group and (b) on the average sensitivity of each group, always dividing the crop species endpoint by the wild species endpoint. Quotients above 1 indicate that the wild plant species were more sensitive than the crop species.

The evaluation of biomass-based ER25 and ER50 vegetative vigour endpoints revealed no consistent differences in sensitivity between wild plant species and crop species. Based on the most sensitive species, 20 quotients were > 1 and 19 were < 1 whereas for quotients based on the geometric mean, 21 were > 1 and 17 were < 1 (Figure 3). Individual analyses of the ln-transformed endpoints of crop and of wild species indicated statistically significant difference in 13 out of 40 cases: wild species were more sensitive than crop species in 9 cases and crop species were more sensitive than wild species in 4 cases.

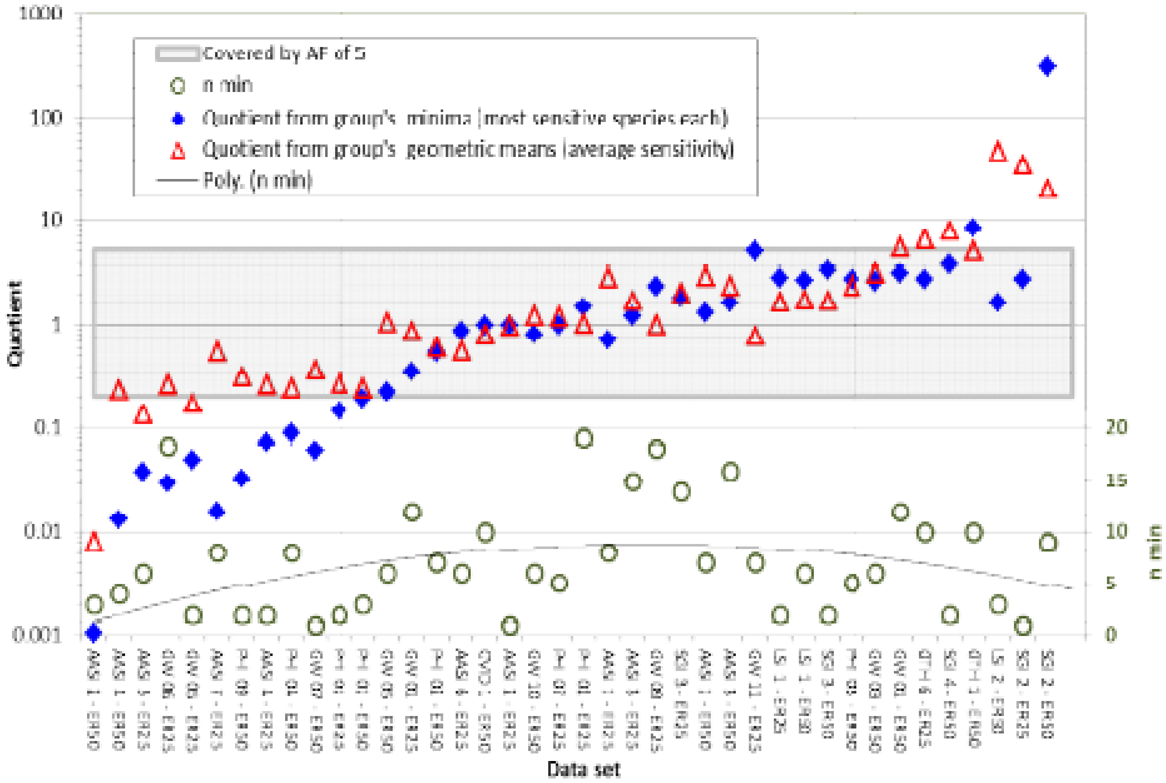


Figure 3 Quotient (triangles and rhombi) of the individual cases on a log scale, sorted by average quotients in ascending order. Circles indicate the number of species (lower n of the compared groups, secondary ordinate). The trend line illustrate that the datasets at the far ends are those with a lower n and hence lower reliability. Data set codes indicate MoA of the active substance: amino acid synthesis inhibitors (AASI), seedling growth inhibitors (SGI), growth regulators (GW), photosynthesis inhibitors (PhI), lipid synthesis inhibitors (LSI), cell membrane disrupters (CMD), Acetyl CoA inhibition (ACI), inhibition of cell division (ICD) and other (OTH)

[2]. Therefore, it was concluded there was no trend for any of the two to be more sensitive than the other. MDD-analysis and multivariate regression analysis of manipulated data sets indicated that for the dataset of this size and heterogeneity, differences between crop and wild species would have been detected as statistically significantly different if they had differed by a factor of 1.5 or more.

[2] Data of seedling emergence studies (seedling emergence, survival, shoot height, vegetative vigour, biomass), and other endpoints from vegetative-vigour-like studies (such as survival, measured shoot height etc. were available for some active substances and were initially assessed as well. They did not show a fundamentally different pattern, but added further uncertainty; and were too few to be analysed on their own. For the final analysis of this report it was decided to analyse and present only vegetative vigour data, the largest subset of data.

3.4 Conclusions from Heino (2015) and consequences for risk assessment

Thus it can be concluded that for the taxonomic groups for which data were available there is no consistent difference between crop species and wild plant species. Testing 6 to 10 crop species as model organisms in standard toxicity tests is by far more extensive than standard testing in any other ecotoxicology area and covers a range of uncertainties versus testing only one representative organism as usually performed for risk assessment. Thus it seems to be a pragmatic and cost-effective approach as some basic requirements of the testing guideline can be fulfilled by cultivated species and not by wild species such as the requirement for at least 70% germination or germination within a short timeframe to allow for all plants to be at the same growth stage during application. Based on the subset of endpoints with most data[3] there appears to be no reason to include more wild species in standard ecotoxicity testing or to add an additional uncertainty factor for studies where only crop species have been tested.

3.5 Comparison of reproductive versus vegetative endpoints

Following recommendations of the SETAC workshop on "Non-target terrestrial plants" one literature review was performed to answer the question if reproductive endpoints are more sensitive endpoint than the standard vegetative vigour endpoint available from tier1-tier2 tests. Test-substance - species combinations for which reproductive endpoints and vegetative vigour endpoints were available, were identified from open literature and from EU data and DAR reports. Multiple observations for a given test-substance - species combination were consolidated, so that just one quotient per endpoint type (ER10, ER25, ER50) and test-substance - species combination was obtained. Quotients were based on either a geometric

[3] While the assessment of other endpoints (listed in the previous footnote) was not presented in detail in this paper, the assessment of ER25 and ER50 endpoints of vegetative vigour (the largest fraction) is considered to allow also the more categorical conclusion given here.

mean or a worst case (minimum) overall measure of toxicity. As no consistent differences in sensitivity could be observed between greenhouse and field data, these data were pooled. The resulting ratios are presented in Table 5.

Table 5: Quotients obtained by dividing minima or mean vegetative vigour ERx endpoint by minima or mean reproductive ERx endpoint per substance/species combination. Censored values were either excluded, or the values (i.e. tested rates) included with a factor of 2 (in line with recommendations of the German UBA).

Effect level	Substance-species - combinations		Ratio VV/Rep	
	Censored values	n	minimum	mean
ER_{10}	*excluded*	23	0.97	1.88
	included with factor of 2	26	0.85	1.56
ER_{25}	*excluded*	56	1.43	1.95
	included with factor of 2	98	1.14	1.44
ER_{50}	*excluded*	71	1.22	1.87
	included with factor of 2	132	1.09	1.48

Based on this initial evaluation and including all data available to date, reproductive endpoints were generally somewhat lower than vegetative endpoints, i.e. the former were more sensitive by a factor of 0.9 to 1.9. However there were exceptions, in a few cases vegetative and reproductive endpoints were reported to differ by several orders of magnitude, possible causes of which are still being investigated. Further analysis is ongoing and focuses on comparison of reproductive ER10, ER25 and ER50 endpoints with corresponding vegetative vigour endpoints of plants of the same age/growth stage/duration of exposure. Generally reproductive endpoints appeared to be somewhat lower than the corresponding vegetative vigour endpoints, with a few large deviations in both directions. On the other hand standard tier1/tier2 vegetative vigour endpoints are also distinctly lower than the vegetative vigour endpoints generally used for the comparison above.

Chapter 4: Higher tier approaches for non-target terrestrial plant testing and risk refinement

4.1 Higher tier approaches for non-target terrestrial plant testing and risk refinement

Hugo Ochoa-Acuña (DuPont Crop protection) and Margit Dollinger (Bayer CropScience)

So far no agreed higher tier options have been established. A review of experiences with higher tier testing of herbicides on non-target terrestrial plants is summarised in this chapter (par 4.3). First, some examples of higher-tier testing are discussed. The first example involves the testing of effects of herbicide exposure at different growth stages to determine potential effects on reproduction. The second example presents a straightforward higher tier approach based on a plant testing cascade for non-target terrestrial plant testing.

In recent years, there has been concern as to whether potential effects on reproduction of terrestrial non-target plants are adequately evaluated using the standard regulatory testing (seedling emergence and vegetative vigour tests following OECD guidelines 208 and 227, respectively). The objective of these studies was to evaluate whether reproductive effects (reduction in number of seeds and/or number of seeds and vigour of resulting seedlings) occurred at rates lower than the rates used for risk assessment (the lowest endpoint from seedling emergence and vegetative vigour tests on a set of 10 species).

Treatment groups in the field study were assigned to plots and sub-plots, respectively, according to a randomized split-plot experimental design. Applications were made at four soybean growth stages in both the greenhouse and field studies: seedling stage (V2), pre-bud initiation (V5), flower bud initiation (R1), and beginning pod set (R3). Parameters measured were: vegetative vigour at 21 days after application, vegetative vigour at the R7 (late reproductive stage), number of pods/plant at maturity, total yield at maturity, weight of 1000 seed batches where possible to determine effects on seed size, and seed moisture at maturity. In addition, follow-up germination and growth testing with seed from both the field study and the greenhouse study was conducted to determine any potential for effects on germination, emergence and early seedling vigour.

No adverse effects were observed in the field study or the greenhouse study on germination, viability, and growth of seedlings harvested from treated soybean plants regardless of the application timing and rate. The relative exposure rates impacting yield and vegetative vigour at 21 days after application from the most sensitive growth stage were within the same range in both the field and greenhouse studies, although these rates were lower under greenhouse conditions. The greenhouse study determined the lowest ER25 for seed yield to be 0.0387 g a.s./ha when application occurred at the R1 stage. The lowest ER25 for yield in the field study was 0.198 g a.s./ha for application at the R3 stage. The lowest ER25 value recorded was for 21-d post-application dry shoot weight for applications at the V2 stage. This application and endpoint correspond to the test design of the standard vegetative vigour regulatory test. These results demonstrate that effects on vegetative vigour and seed yield occur at similar exposure levels, and that risk assessment based on current vegetative vigour endpoints from regulatory testing are protective of potential effects on reproduction.

In the second example, seven sensitive species from a greenhouse vegetative vigour study were tested in a newly developed semi-field design. Plants were grown in polyethylene containers under outdoor conditions. Application was conducted simulating normal field application at drift relevant levels. For two days after application, the containers were kept under a UV permeable roof to ensure full penetration of the product without exposure to rain. Afterwards the plants were exposed to real environmental conditions. Assessments of phytotoxicity were made on days 7, 14 and 21 after application. Plant survival and shoot dry weight were determined at test termination.

As in the greenhouse trial, the most sensitive parameter under semi-field conditions was shoot dry weight. For most species, dry weight inhibition was distinctly more pronounced under greenhouse than under semi-field conditions. With regard to phytotoxicity, the recorded symptoms were similar; however, the severity of the symptoms under semi-field conditions was overall lower than in the greenhouse.

Since the higher tier study delivered endpoints for seven species, it was possible to calculate a species sensitivity distribution from which an HR5 was obtained. The probabilistic non-target plant risk assessment based on this new endpoint resulted in a distinct reduction of required mitigation measures if compared to the outcomes of the standard risk assessment approaches.

The method presented here proved to be suitable for higher tier non-target plant testing. While increased realism in ecotoxicological studies is usually linked to larger variation, here a high level of reproducibility could be kept due to the straightforward and standardized test design. This approach is also suitable to adapt further to more realistic testing conditions (e.g. natural and biological active soil, growth stage of plants during application, type of application, etc) or to run prolonged studies with non-target plants (Dollinger et al., submitted).

4.2 Uncertainties in Higher Tier Risk assessment for non-target terrestrial plants

Participants agreed that non-target terrestrial plant field tests are complicated to perform and guidance how to conduct such tests is currently missing. Many uncertainties were raised in the context of higher-tier tests with non-target terrestrial plants. What is the uncertainty of these higher-tier tests ? Efficacy data already show a high variability. Such experiments are often conducted at the highest application rates, so at lower rates variability is expected to increase. What is the representativeness of different field studies ? Participants expressed a need for protocols and experimental outlines. As a highest tier, monitoring was suggested (either instant-monitoring or long-term monitoring). Also field studies and datasets are needed for the calibration / validation of models. Participants held the opinion that semi-field and field tests are important to address recovery.

It was concluded that there is little knowledge, guidance, and experience for conducting field studies or other multispecies studies with NTTPs. Therefore, there is a need to collate available information and exchange understanding, knowledge and protocols (see par. 4.3).

4.3 Abstract of Report Review of Multispecies and Field Testing in Assessing Risk of Chemicals to Non-Target Plants in Agricultural Landscapes

A review was conducted for multispecies and field testing in assessing the risk of chemicals to non-target plants in agricultural landscapes (Krueger, 2015). Multispecies testing can be defined as testing a few up to many species that are not necessarily in the same general taxonomic grouping. Multispecies testing is typically done in the field but may be done in the laboratory (e.g. aquatic microcosms, soil TMEs), with a few species to better understand a problem identified in the field. Multispecies testing allows us to analyze effects of PPP on NTTP under more realistic conditions with respect to exposure, growth conditions, competition, recovery and indirect effects than single species tests. Experimental options of different complexity and realism are available which have to be selected carefully based on the specific question to be addressed. Until now there is not much experience and no guidance on how to conduct multlspecies tests with NTTP. However, they should be considered as a higher tier option similar as for soil invertebrates, non-target arthropods and aquatic communities. A simulated field study is a controlled experiment that typically results in some form of randomized plot design that maintains independent replicates, minimizes edge effects of sampling, and minimizes the potential for cross contamination. Plants are planted in plots to meet the experimental configuration or plots are set up in large fields and treatments are randomly assigned to plots. The simulated field study is more of a hybrid between the laboratory and the field that has the advantage of being a controlled experiment under field conditions. Highest tiered field studies involve replicates of agricultural fields that have adequate separation to maintain independence of the populations being monitored. Testing at different scales and with differenct complexicity is illustrated in Figure 4.

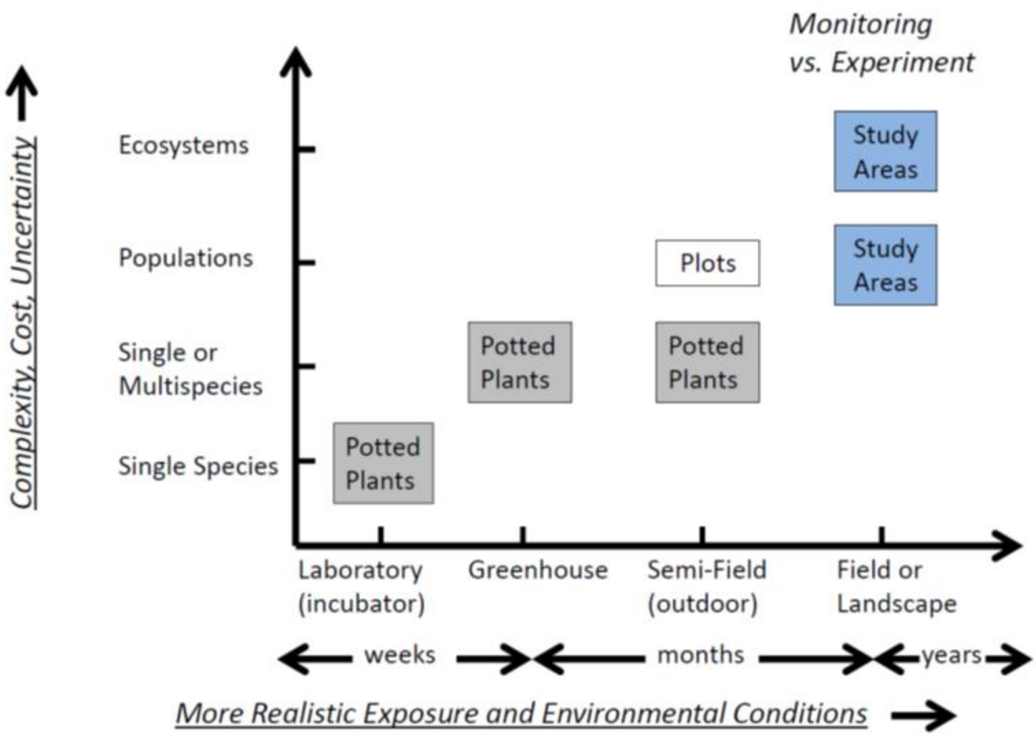


Figure 4: Relationships between types of laboratory and field studies in reference to the experimental units, levels of biological organization, and experimental conditions that trend towards more realistic exposure and environmental conditions (Krueger 2015).

Krueger (2015) gives a number of recommendations, listed below:

- Studies must address concerns identified from lower tier tests or from incident reports from the field;

- There is a need to simulate realistic exposures from drift events in large scale field or monitoring studies or to set concentrations in plot experiments. Current technologies in spray drift application equipment (including drift reduction nozzles) should also be considered in the experimental design.

- There is a need for a proper statistically experimental design with adequate statistical power to insure that there is high certainty in the validity of the results. Field studies are not expected to produce the precision and accuracy achievable in the laboratory. Obtaining EC10 or EC 20 values is unrealistic. Definition of reference sites or controls must be established in conducting field studies. If the evaluation is based on NOECs the minimum detectable difference(MDD) should be reported in addition tot he NOEC value.

- Determining effects of a single chemical may be confounded by other chemicals or nutrients (fertilizers) used in the study area. Care must be taken to minimize the effects of these variables in field test maintaining similarity among plots. When conducting large scale field or monitoring studies these are variables that need to be measured.

- Plant multispecies and field studies may need to be conducted in multiple sites depending on the geographic range in which a chemical is used.

- There is a need to address sub-lethal endpoints of plant growth and reproduction to determine population level effects on multiple species.

- There is a need to address how changes in plant population dynamics are affecting ecosystem level endpoints such as biodiversity, nutrient cycling, energy transfer, primary production, and habitat. Alterations to plant community structure may result in adverse effects on organisms at higher trophic levels that represent other key drivers of the ecosystem. However, if there are little or no adverse effects on growth and reproduction on plant populations one might be able to assume that the ecosystem services are also protected.

- There is a need to clearly identify the resource at risk in the context of protection goals, ecosystem services, and key drivers. How ecosystem services are prioritized and weighted is important. Does the risk to plants within one meter of the field edge outweigh the benefit of a crop?

- There is a need to collate and exchange understanding, knowledge and protocols for field studies and multispecies studies, as well as develop new approaches to the problem.

- There is no reason to perform multispecies tests without knowing how the results will be used by regulators in their evaluation of risk and whether the results will be used to offset the hazardous effects that may have been identified in lower tier tests.

4.4 Conclusions

So far no agreed higher tier options have been established for non-target terrestrial plants. A review of experiences with higher tier testing of herbicides on non-target terrestrial plants is summarised in this chapter. Higher tier testing of non-target terrestrial plants enable more realistic exposure and more realistic environmental conditions. Higher tier testing options provide a continuum from laboratory testing to greenhouse, semi-field outdoor tests and field-scale experiments and monitoring thereby increasing the level of biological organisation addressed in these studies (from single species to multispecies, populations and ecosystems). Higher-tier tests must be informed either from lower-tier tests or from monitoring studies. As higher-tier tests face an inherent higher variability in the population and ecosystem level addressed, these higher-tier approaches need proper statistical designs and expectations. Also sub-lethal endpoints of plant growth and reproduction need to be addressed in order to adequately protect populations of non-target terrestrial plants. As higher-tier approaches are quite diverse, there is a need for further understanding, knowledge and protocols.

Chapter 5 Mitigation

Eva Kohlschmid (Agroscope)

According to the Guidance Document on Terrestrial Ecotoxicology (EC, 2002: SANCO/10329/2002) the options to reduce exposure of non-target terrestrial plants (NTTP) are similar to non-target arthropods (NTA) to protect off-field areas, e.g. buffer zones to sensitive areas and drift-reducing application techniques in the vicinity of sensitive areas.

In France risk mitigation measures for non-target terrestrial plants are in-field untreated zones of 5m, 20m, 50m. In Switzerland no risk mitigation measures are established until now. For NTA buffer zones of 6m, 20m, 50m, 100m and/or the obligatory use of drift reducing nozzles (75-90%) can be enforced to protect natural conservation areas which will be recommended for NTTP as well.

In addition, the establishment of multifunctional field margins can sustain abundance and diversity of NTTP. Regarding perennial plants, sown wildflower strips and natural regeneration areas are well suited, while annual cultivation and conservation headlands are best suited to support annual weeds.

5.1 Abstract of Keynote presentation: Drift Reducing Technology and buffer zones to reduce the exposure of non-target plants

Jan van de Zande, Wageningen UR-Plant Research International (WUR-PRI)

Drift reducing technology (DRT) is calibrated against standard drift curves. In The Netherlands, these standard curves are specified as derived from an XR11004 nozzle at 3 bar (medium spray quality; Southcombe et al., 1997), 0.5 m above a potato crop during the relevant period for fungicide treatments (half June – half September). Similarly, standard low drift nozzles were used to give a drift curve for a standard drift-reducing technique (preorifice nozzles DG11004 at 3 bar with an UB8504 end nozzle, giving 50% drift reduction (Porskamp et al., 1999; VW et al., 2000, 2007).

For various drift reducing spray techniques, drift reduction with respect to the reference spray technique is determined at a distance of 2-3 m from the last nozzle, taking into account that for many crop situations the actual location of the water surface or field edge differs from this range. Based on field data from 1995-2005, a new reference drift curve was established (van de Zande et al., 2012) and for various drift-reducing techniques the drift reduction was and classified as shown in Table 6.

Table 6. Downward directed spray drift reducing technologies and the drift reduction classes.

Drift reduction classes	Spray drift reducing technology in drift reduction class
50%	50% drift reducing nozzle types * Air-assisted boom sprayer + nozzles drift reduction class 0 Low-boom height (30 cm) conventional boom sprayer + nozzles drift reduction class 0
75%	75% drift reducing nozzle types * Band sprayer in maize + nozzles drift reduction class 0 Släpduk sprayer + nozzles drift reduction class 0 Hardi Twin Force air-assisted sprayer + nozzles drift reduction class 0
90%	90% drift reducing nozzle types Band sprayer in sugar beet + nozzles drift reduction class 0 Low-boom height (30 cm) conventional boom sprayer + nozzles drift reduction class 50 Air-assisted boom sprayer + nozzles drift reduction class 50 *
95%	95% drift reducing nozzle types Low-boom height (30 cm) air-assisted boom sprayer + nozzles drift reduction class 0 Low-boom height (30 cm) air-assisted boom sprayer + nozzles drift reduction class 50 Hardi Twin Force air-assisted sprayer + nozzles drift reduction class 50 Släpduk sprayer + nozzles drift reduction class 50 Tunnel sprayer for bed-grown crops + nozzles drift reduction class 0 Air-assisted boom sprayer + nozzles drift reduction class 90 *

* Representative curve for class.

For each drift reduction class an appropriate technique was selected (marked with * in Table 6) to calculate a drift deposition curve as a representative curve for that class. Typical curves obtained for the different DRT classes are given in Figure 5 for the cropped situation (crops > 20 cm high) and in Figure 6 for the bare soil or small crop situation (crops < 20 cm high: van de Zande et al., 2012). At the field edge, (0-2 m) drift reduction is limited as overspray occurs and this depends very much on the top angle of the outside nozzle. Therefore, drift deposition curves can cross in this area. The drift deposition curves are clearly shaped in two parts: a steeply declining part close to the crop edge and a constantly decreasing at a larger distance from the crop edge.

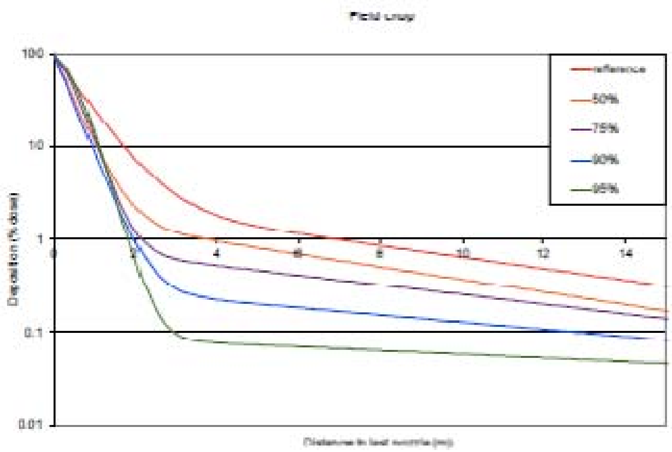


Figure 5. Spray drift deposition curves of the standard and 50%, 75%, 90% and 95% drift reducing technology spray techniques for downward directed spray applications (boom sprayer) in a crop situation (> 20 cm high).

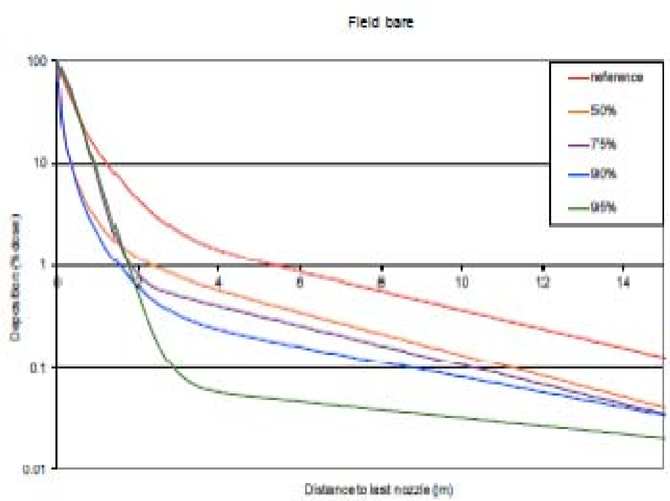


Figure 6. Spray drift deposition curves of the standard and 50%, 75%, 90% and 95% drift reducing technology spray techniques for downward directed spray applications (boom sprayer) in a bare soil – short crop situation (< 20 cm high).

It should be noted that not all drift reducing technologies lead to similar or stepwise decreasing spray drift exposure, especially when they are combined with different widths of crop-free zones. It was therefore decided to develop a matrix approach combining classes of Drift Reducing Technology and stepwise widths of crop-free buffer zones. A crop-free buffer zone is defined as the distance between top of bank of the surface water or field edge and the first plant row.

Figure 5 and Figure 6 show that spray drift deposition declines with increasing distance to the crop sprayed. This means that by enlarging the crop free buffer zone the drift exposure on surface water is reduced for all sprayers (Standard and DRT sprayers). This means that the estimation of spray drift deposition at the NTP evaluation zone can be evaluated in a matrix approach. The spray drift deposition can be estimated for the standard spray technique, secondly for drift reducing techniques and measures; thirdly for all spray techniques with step-wise wider crop-free buffer zones (Figure 7).

For each of the drift reduction classes standard, 50%, 75%, 90%, and 95% in combination with the different minimal agronomic crop-free zones the spray drift deposition can be calculated at the NTP evaluation zone.

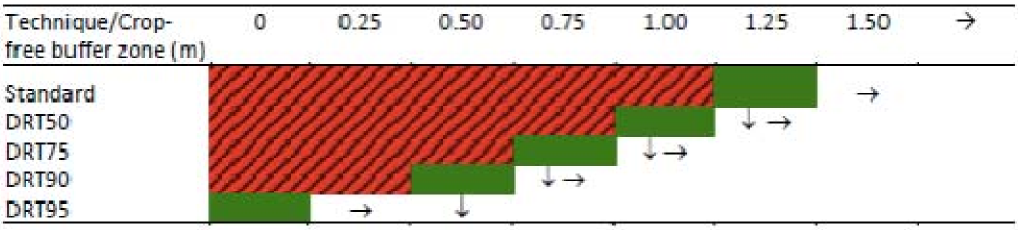


Figure 7. Evaluation matrix of combinations of drift reducing technology classes and width of crop-free buffer zones. Red means no authorisation possible because the resulting PEC exceeds the RAC. Green means authorisation possible because the resulting spray drift deposition is below the threshold value. Arrows show the direction of the evaluation.

5.2 Discussion on relevant exposure scenarios under the view of the agreed protection goals?

Different exposure routes to non-target terrestrial plants e.g. spray drift, airborne spray drift, run off and volatilization were mentioned during the discussions. Spray drift was proposed to be the main exposure route for Non-target terrestrial plants (NTTP). However, as the relative importance of run-off and other exposure pathways (e.g. volatilisation, airborne spray-drift) to NTTP with different physical structures could not be clarified at the workshop, information on the relative importance of different exposure pathways to NTTP and how to harmonize with other areas exposed to drift like Non-target arthropods was asked to be generated. Therefore, the workshop output concentrates on mitigation measures applying to Non-Target Terrestrial Plants.

5.3 What are the mitigation options or compensations to achieve these protection goals?

Spray drift

To mitigate spray drift, different options were discussed.

A common mitigation measure is to apply in-field buffer zones. These are no spray zones which are located either in-crop or off-crop to protect non-target terrestrial plants growing off-field. For example, the Netherlands have crop free zones instead of spray free buffer zones (Felsot et al., 2012).

The interception of drift deposition in field with mesh screens or tall vegetation like trees, shrubs or catch crops like *Miscanthus* species was highlighted. In a field trial, winbreak hedges minimized spray drift by 75%, a screen on the top of the orchard by 65% and a coarse-mesh screen at the edge of the field showed an effect of abot 20% drift reduction (Schweizer et al., 2013).

Precision farming technology for specific weeds e.g. volunteer potatoes was discussed. This technology offers the possibility to reduce target area of herbicide application without lowering efficacy. However, it was mentioned during the discussion that this technology might be too expensive for small scale famers. According to Schroers et al. (2010) this equipment requires sufficient machine utilization e.g. large scale farms (600-900 ha) or contractors with a good annual usage of the technology to achieve an economic benefit.

Regarding reducing target area of herbicide application another approach was considered e.g. adopting the dose to limited areas sprayed with herbicides e.g. orchards and vineyards if only strips of the tree rows are sprayed and not the whole area. Application rate per ha can be lowered by this way, but target area still receives the full dose.

Also splitting the application rate instead of 1 time into three times was mentioned as an option. But there will be problems arising due to resistance developing. Apart from this there would be problems with GAP and MRL if the product is only registered for 1 application.

For drift reducing technology several options were considered e.g. drift-reducing nozzles, end-nozzles and type of formulation (see van de Zande, 2015).

Volatilization

Formulations might lower drift of droplets and volatiles (e.g. Enlist(R)).Furthermore, volatilization can depend on the environmental conditions, but was not discussed further in this context.

Run-off

Mitigation measures for run-off vegetative buffer strips, precision farming and adjusting the timing of application relative to weather conditions were proposed. Integrated weed management like ploughing and crop rotation came also up during the discussion.

Compensation

Apart from risk mitigation single fields, compensation, i.e. preserving some parts and accepting direct and indirect effects (e.g. food web supply) in the field, could be an option (land sparing; separating landscape functions). But, the majority opinion was to put it on the management level and on the level of the ministry and not to make it part of the registration directive. The minority opinion was that it could be related to the pesticide Regulation. In the UK they are under the agri-environment scheme. The question remained if the Pesticide Regulation was the appropriate policy instrument to include compensation, or are there other policy instruments available, like set aside, agri - environment schemes (Regulation No 1698/2005), greening projects, birds (Directive 2009/147/EC) and habitat directive (Council Directive 92/43/EEC). In this context several programmes which might mitigate indirect effects were acknowledged – e.g. SAFFI project, wild flower pollinator mixes, beetle banks, skylark strips.

The report multifunctional role of field margins in arable farming by Hacket and Lawrence (2014) also addresses this issue.

5.4 Summary of follow up investigation: Drift Reducing Technology and buffer zones to reduce the exposure of Non-Target Terrestrial Plants

The report extends the already addressed issues of Chapter 4.1 and Chapter 4.3 spray drift reducing technologies and the drift reduction classes used in the Netherlands (Van de Zande, 2015).

Field tests were performed on spray drift in 1997, 1998 and 1999 to quantify the effect of two spray volumes using 'low-drift' nozzle types and air assistance. Low drift nozzles were compared to standard flat fan nozzles. The differences in the range of the droplet size resulted in drift reductions up to 85% when compared to standard flat fan nozzle.

In another experiments boom height was reduced to 0.30 m above crop canopy instead of the standard 0.5 m. Drift experiments were performed spraying a potato crop. It was concluded that lower boom heights at 0.30 m above crop canopy in combination with two types of drift reducing nozzles can minimize spray drift by more than 50% or even by more than 90% respectively compared to the reference system. The Släpduk system using a shield to float over crop canopy and the tunnel sprayer for bed grown crops can reduce spray drift between 75% and 90%, respectively.

A 90% drift reduction was achieved with a band sprayer compared to standard field sprayer when doing experiments in early growth stages of maize.

An end nozzle creates a cut-off spray fan preventing the overspray of the edge of the field with plant protection products. On 1-2 m distance this effect was 50% up to 80% with air assistance.

Precision application of PPP makes it possible for the farmer to restrict applications to the sole area of the crop where a treatment is needed. For example, in a 4 year field trial, herbicide use for grass weeds and broad-leave weeds with site specific weed control was diminished by 90% and 60%, respectively.

Several different types of vegetative barriers were mentioned in the report like elephant grass (*Miscanthus sinensis*) and common reed (*Phragmites* spp.). Elephant grass grown 0.5 m and 1.0 above crop height levels reduced spray drift by respectively 75% and 90%. Also hemp, maize, winter rye and triticale (later than 15 May) were considered potential barrier crops next to e.g. potatoes, sugar beet, onions and carrots. The combination of this different drift reducing technologies results in the drift reduction classes used in the Netherlands (see Table 6).

Spray-free buffer zones and crop-free buffer zones were mentioned in the report. If vegetation at the spray-free buffer zone is 0.5 m or 1 m higher than the sprayed crop, spray drift reduction at 1-5 m behind the vegetated buffer strip is about 80% or 90%, respectively. For vegetated buffer zones lower (<20 cm) than the sprayed crop the spray drift reduction is comparable to that of a crop-free buffer zone. This buffer zone is a non-cropped area and can be kept as a bare soil surface to prevent weeds entering the cropped area. Due to experiments between the years 2012 and 2014 a 1 m bare soil surface buffer zone reviled a reduction in spray drift deposition of at least 50%, a 3 m zone at least 75%, a 5 m zone around 90% and a 10 m zone around 95%. However, it should be noted that many EU member states do not allow combinations of SDRT to add to more than 95% total drift reduction.

Variable no spray zones (safety distances) which are based on local conditions instead of fixed buffer zones could be established. This is done by the Swedish authorities who consider for the so called “Hjälpredan” (engl. ‘The Helper) weather/climate conditions such as wind direction, wind speed and local temperature as well as used application technology and the dose of PPP to minimise risk to the environment.

The report also discussed the importance about airborne spray drift, as spray drift deposition in bushes and hedgerows cannot be estimated based on the current used spray drift curves predicting the spray drift deposition on soil surface. Thus, it was concluded to take airborne spray drift into account. However, this subject is very complex and only limited data on airborne spray drift is available and further work is needed???

5.5 Conclusions

Spray drift was assumed to be the main exposure route for Non-Target Terrestrial Plants (NTTP) during the discussion and possible mitigation measured focused on it e.g. buffer zones, drift reducing technology including end nozzles, precision application intercepting drift in field with mesh screens, tall vegetation and hedges. Options for mitigating run-off were vegetative buffer strips, precision farming and adjusting the timing of application relative to weather conditions. For volatilisation, different types of formulation were mentioned. However, as the relative importance of run-off and other exposure pathways (e.g. volatilisation, airborne spray-drift) to NTTP with different physical structures could not be clarified at the workshop, information on the relative importance of different exposure pathways to NTTP and how to harmonize with other areas exposed to drift like Non-target arthropods was asked to be generated. A brief literature search yielded in literature about how to mitigate run-off especially for aquatic systems (e.g. Reichenberger et al., 2007; Maetens et al., 2012, Focus 2001). But, NTTP were not a topic in these listed references, especially in terms of the relative importance of the exposure pathway run-off versus drift. It seems to remain an open research questions to compare those fluxes to each other and to find out how run-off can affect NTTP. Thus, the follow up investigation report focused on drift reducing technology and buffer zones to reduce the exposure of Non-Target Terrestrial Plants. Different drift reducing measures and their efficacy are discussed in detail in the report e.g. buffer zones, low drift nozzles, boom height, different types of sprayers, precision application of PPP as well as vegetative barriers and windbreaks.

Chapter 6: General conclusions, recommendations and outlook

NTTPs provide a wide range of provisioning, regulating, cultural and supporting ecosystem services (Chapter 1) and may occur in-field and off-field. The workshop participants agreed that the type and relative importance of ecosystem services provided by NTTPs differ between different areas both in field and off field. The key recommendations from the workshop are given in the Summary and the agreed outcome of the workshop is presented in Figure A. The figure highlights the higher-tier options, the benefits from these options, the concerns raised around these options and the actions taken in order to reduce uncertainty. For the initial tiers, concern was especially raised around uncertainty related to test species (are standard test species protective for wild species?) and endpoints (are current regulatory endpoints protective of reproductive endpoints ?). These questions were addressed by further research. The evaluation of the sensitivity of crop species versus wild plant species revealed no consistent differences in sensitivity between both groups of species. Therefore, it was concluded there was no trend for any of the two to be more sensitive than the other. In conclusion, there appears to be no reason to include more wild species in standard ecotoxicity testing neither to extend the number of species to be tested in the first tier. Based on the initial evaluation of reproductive versus vegetative endpoints and including all data available to date, reproductive endpoints were generally somewhat lower than vegetative endpoints, i.e. the former were more sensitive by a factor of 0.9 to 1.9. However there were exceptions. In a few cases vegetative and reproductive endpoints were reported to differ by several orders of magnitude, possible causes of which are still being investigated and work is still going on. For the higher tiers, the main questions focussed on how to perform higher tier studies. Available information and understanding, knowledge and protocols from field studies and multispecies studies were gathered from the literature and the expertise of workshop participants, showing a wide range of test approaches, test species and assessment endpoints. As higher-tier approaches are quite diverse, there is a need for further understanding, knowledge and protocols. So far no agreed higher tier options have been established for non-target terrestrial plants. The question of the relative importance of the exposure pathway run-off versus drift could not be answered by further literature research. It seems to remain an open research question to compare those fluxes to each other and to find out how run-off can affect NTTPs.

The outcome of the four specific actions as included in this workshop report and as summarized above, serve as input for the second workshop taken place in Wageningen, The Netherlands, 21-22 September 2015.

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