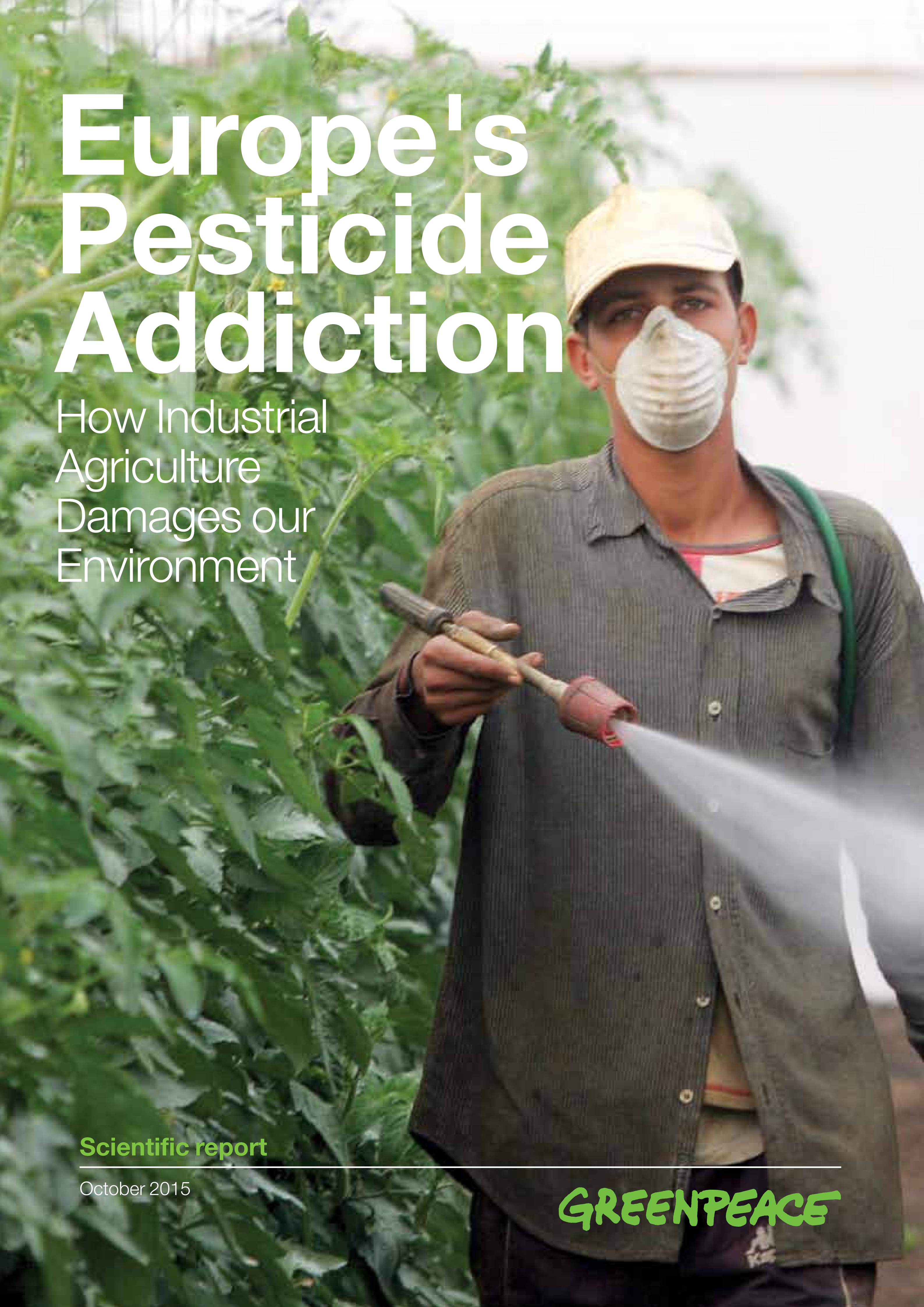

# Europe's Pesticide Addiction

## How Industrial Agriculture Damages our Environment

**Scientific report**

October 2015

GREENPEACE

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# Contents



# 01 Executive summary

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## Why it's time to break the vicious cycle of pesticides use

For almost half a century, the global agricultural system has relied heavily on the widespread application of millions of tonnes and hundreds of types of synthetic chemical pesticides to reduce crop losses. As most farmers are now treating their crops with a variety of pesticides on a routine basis, rather than as a last resort in rare cases of heavy pest infestations, this means that chemical inputs are applied multiple times to a crop throughout the whole growing season. As a result of our dependence on chemical pesticides, and because of their persistence and pervasiveness, almost every ecosystem on earth has already been negatively impacted by these harmful chemical compounds.

"*Europe's Pesticide Addiction: How Industrial Agriculture Damages our Environment*." examines the use of synthetic chemical pesticides in Europe, the widespread and severe environmental impacts they are having - including how they are degrading some essential ecosystem services and, the urgency of tightening the regulations that are supposed to control their use.

The production, sale and use of synthetic chemical pesticides has become a multi-billion euro industry dominated by a small number of agro-chemical businesses. In 2011, three European companies, Syngenta (Switzerland), Bayer CropScience and BASF (Germany), controlled 52.5% of the global pesticide market. Three US companies, Dow AgroSciences, Monsanto and DuPont, made up the list of the top 6 pesticide companies, which together accounted for 76% of global pesticide sales.[1]

Although the global pesticide market is growing fastest in Asia and South America, driven by large increases in use in China, India, Brazil and Argentina,[2] pesticide use in the more mature European market is still forecast to rise, due to increased use in the east of the continent and an increase in the frequency of pesticide applications. The concept of the "Treatment Frequency Index" as a metric of the number of pesticide applications per crop in a given growing season has been applied to some crops in some countries. This paints an alarming picture. For example, since 2001 in Germany this index has increased in arable crops such as rapeseed, cereals and sugar beet, and in fruit crops such as apples and grapes. In 2012 the index reached a value of 32 in apple orchards,[3] meaning that on average 32 full doses of pesticides were applied to apples during a single growing season. This intensive use of pesticides raises significant questions about the impacts on single species, whole ecosystems and biodiversity, as well as the way in which these chemicals are assessed, authorised and regulated in the EU.

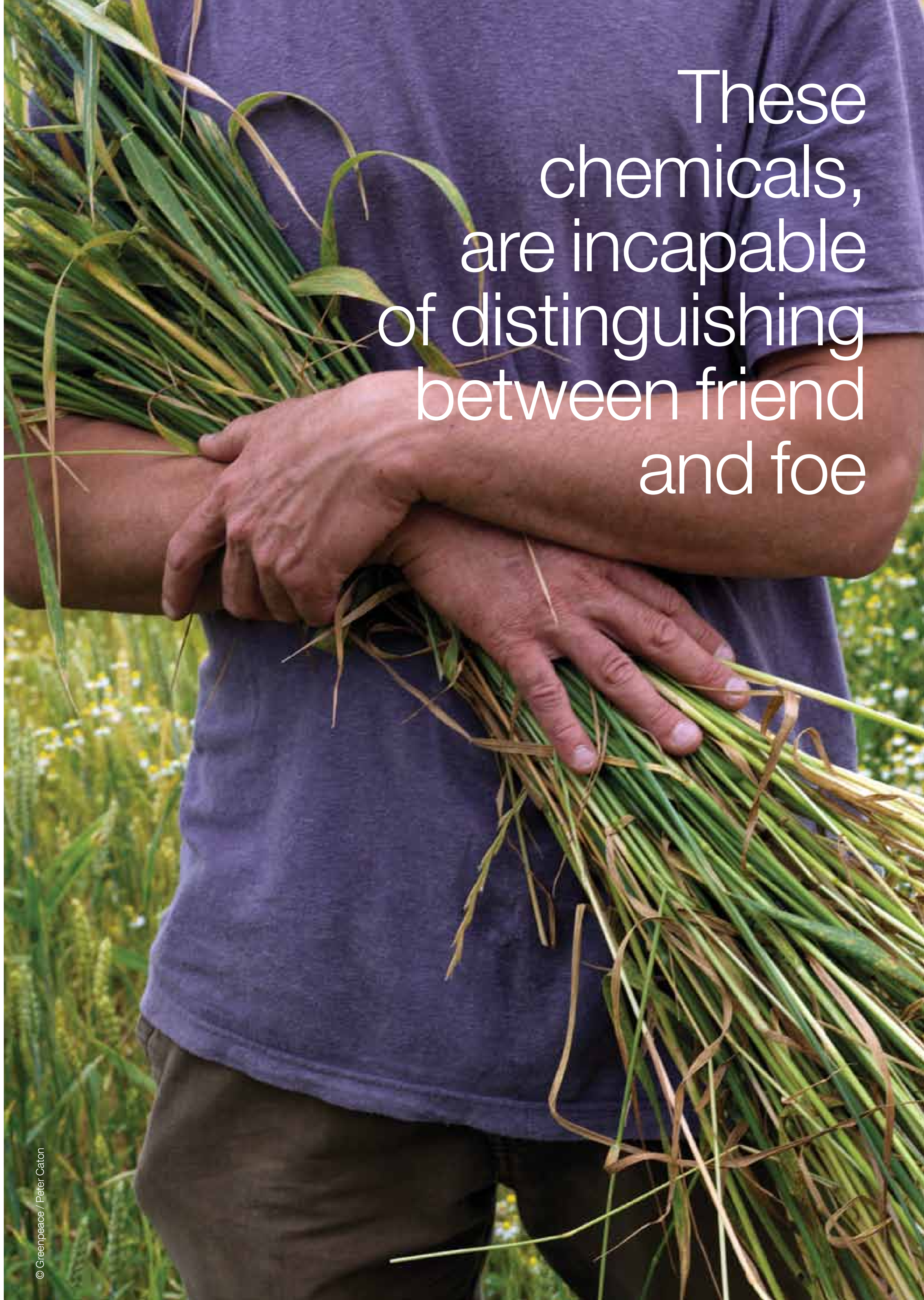
## Pesticides
## Missing the target

**The chemicals and compounds used in pesticides can affect all organisms, and the environments that they live in and depend upon, with potentially serious ecological consequences**. It has been known for a long time that the use of agro-chemicals is putting wildlife and natural environments at risk. Pesticides, in particular, are having a major impact on biodiversity losses - almost one in four (24.5%) vulnerable or endangered species in the EU are threatened by agricultural effluents, including the use of pesticides and fertilizers, like nitrates and phosphates.[4] European data also suggests a widespread decline in the diversity of wildlife species across all groups of organisms studied. For example, 27% of monitored mammal populations in Europe are in decline and even this figure could be masking a far worse trend, as the status of 33% of mammal species is unknown.[5] Highly vulnerable groups of species such as amphibians or dragonflies seem to be faring even worse. Despite the continually growing body of evidence about the serious problems being caused by chemical pesticides, no substantial policy changes have yet been made to reduce the impacts on the environment. This must be seen as a Europe-wide failure.

### Pesticide effects: Acute, sub-lethal and indirect effects on individuals, populations and ecosystems

Pesticides can cause acute toxic effects in both target and non-target organisms, with direct acute mortality being the most common impact examined and reported. In some cases, the secondary toxic impacts are recognised as significant, such as in predatory birds feeding on small mammals poisoned with rodenticides, or on insects targeted with insecticides. Quite apart from these relatively obvious toxic "endpoints", pesticides can exert a variety of subtle and complex, sometimes delayed, effects. Immunotoxicity and disruption of endocrine systems are two comparatively well-known examples of such effects where organisms are made more susceptible to disease, or where reproductive or other functions are disrupted.

The translation of these individual and sometimes subtle impacts on populations and whole ecosystems may be extremely challenging to detect and quantify, and may only be detectable over a long period of time. Attribution of impact is made more difficult by the innate complexity of ecosystems and ecosystem interactions. One relatively obvious potential impact is the reduction of food sources as a result of pesticide use. Essential components of the food web, and the parasitoids and other predators feeding on these organisms, are affected, as well as



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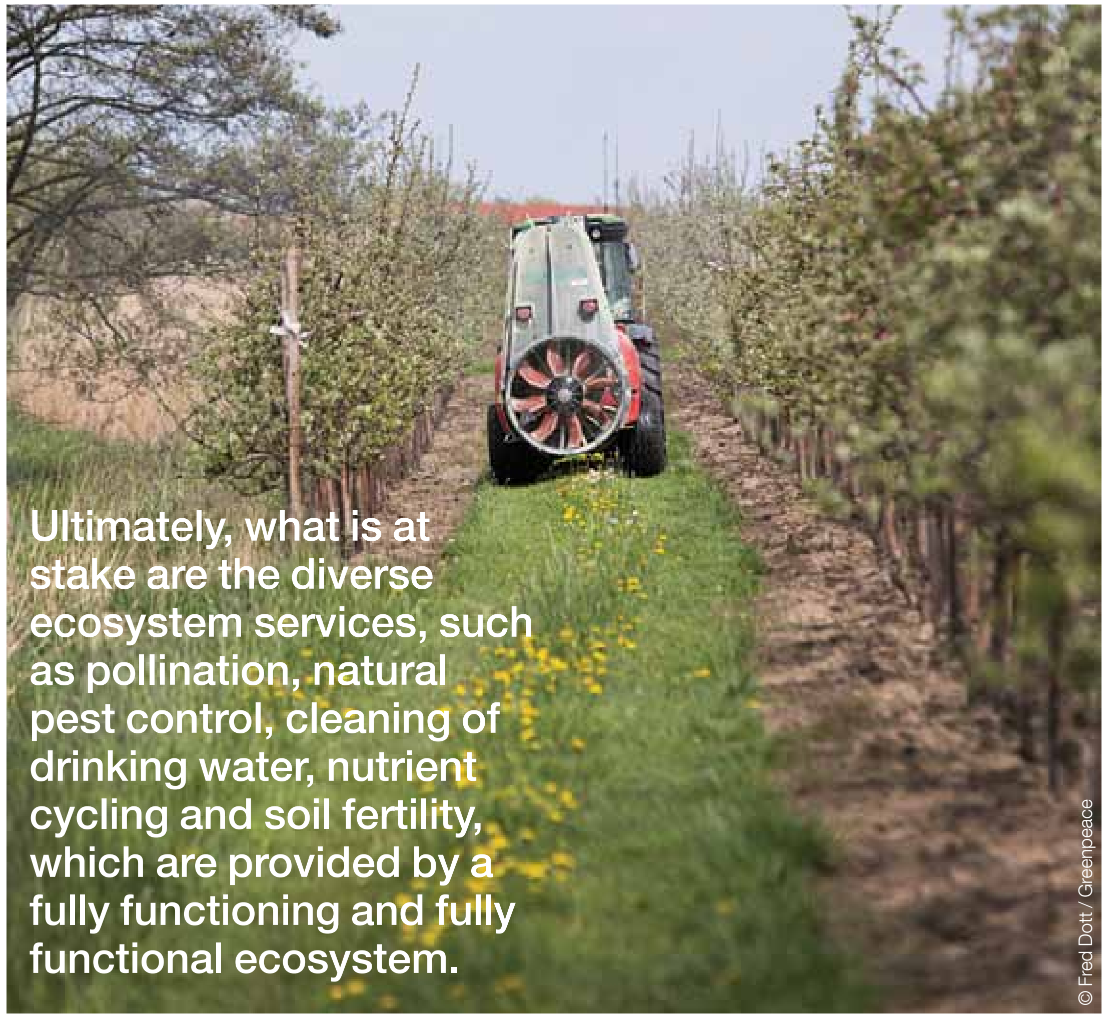
other organisms feeding, in turn, upon them. A partial collapse of the food web could result from this. The complexities are well illustrated by the widely documented decline of farmland bird species over the last three decades in Europe. Direct poisoning of birds plays a role, as does the reduction in their food sources. Insectivorous bird species have been impacted by reductions of arthropod prey populations. But herbicides can also affect birds by reducing the availability of seeds as a food source. Reductions in plant biodiversity and favourable habitat have also had a considerable impact on the decline of farmland bird species.[6]

**Ultimately, what is at stake are the diverse ecosystem services, such as pollination, natural pest control, cleaning of drinking water, nutrient cycling and soil fertility, which are provided by a fully functioning and fully functional ecosystem**. Also at stake is the resilience of disturbed systems to climate and weather extremes. Broadly speaking, the more diverse the ecosystem - the greater its resilience to such impacts. "*Europe's Pesticide Addiction: How Industrial Agriculture Damages our Environment*." considers just a few of these ecosystem services and their immense economic importance. It must be realised, however, that any monetary valuation placed on ecosystem services is held hostage to the fact that many are in effect irreplaceable, and once they are lost then their value quickly becomes immeasurable.




# Exposure to pesticides
## No Escape

Pesticides can be found widely distributed in the environment, and can be transported significant distances from the areas in which they were originally applied; via the atmosphere, in water, and even in the tissues of living organisms.

Samples of ground and surface water analysed for pesticides in surveillance monitoring are regularly found to be contaminated. A recent five-year survey in Germany showed that pesticides or their metabolites had reached the ground water at 60% of the 2280 sampling points.[7] In the Netherlands, 65% of surface water samples taken from sampling stations in 2013 contained 30 or more insecticides.[8] Even more pervasive pesticide contamination has been identified in surface water, even though, in general, only a narrow spectrum of chemicals is monitored such as those specified in the EU Water Framework Directive.[9] Failings in the EU's regulatory system also mean that monitoring efforts tend to lag significantly behind the introduction of new pesticides, so problems may not be identified in a timely manner. Finally, monitoring efforts focus largely on single substances, whereas pesticides are present in the environment as mixtures of active agents, their metabolites and other chemicals.[10]

The toxicological behaviour of these mixtures has been, and remains, very poorly researched.

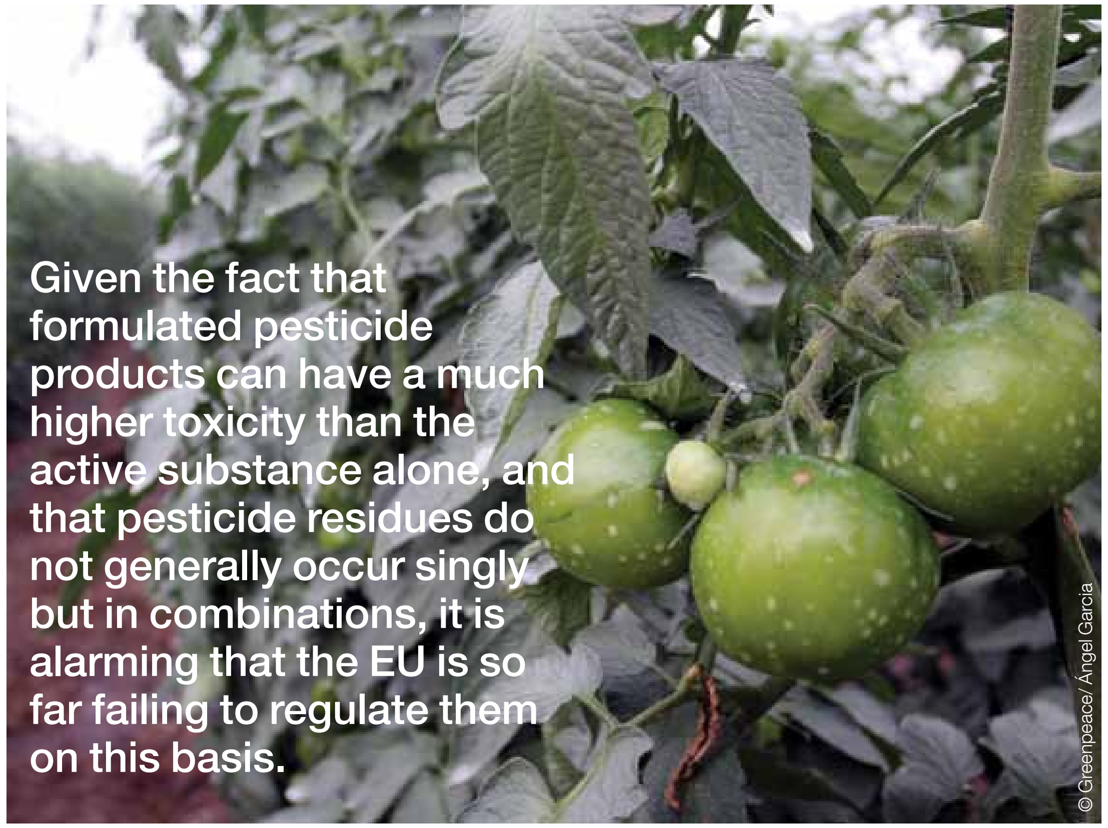
# Europe is failing to effectively regulate chemical pesticides

Given the well known potential hazards associated with pesticides which are used openly in the environment, all pesticides have to go through an authorisation process before they can be used. The procedure consists of an effect assessment, which is based on toxicity tests, and an exposure assessment that relies largely on modelling of various scenarios. Mathematical modelling is used as field data are not usually available for the assessments. Pesticide risk assessments and authorisations have sometimes proven problematic or inaccurate in some way and, in some cases, adjustments have had to be made retrospectively and decisions revisited. A recent example of EU restrictions concerns some systemic insecticides of the neonicotinoid family.

On 1 December 2013, a number of uses of three neonicotinoid insecticides, thiamethoxam (produced by Syngenta), imidacloprid and clothianidin (produced by Bayer), were banned in the EU following a growing body of scientific evidence countering the initial positive assessment these systemic insecticides, instead showing serious negative impacts on honey bees and other pollinators.

A further illustration is provided by the ongoing debate around the re-authorisation of the herbicide glyphosate, and the widely differing conclusions that different institutions have arrived at - with the World Health Organisation's International Agency for Research on Cancer (IARC) classifying glyphosate as a "probable carcinogen" despite other scientific authorities giving a green light to the same chemical. This shows not only how difficult the assessment of even a single chemical can be, but also that even when a chemical has been subjected to much scrutiny, evidence may emerge much later, which requires an extensive re-think of the authorisation decision.

**While improvement of the EU authorisation process for pesticides has been, and continues to be a work in progress, there still appear to be major gaps in assessment, authorisation and subsequent surveillance monitoring**. Currently, almost 500 pesticide active ingredients are authorised for use in the EU. The number of commercially available pesticide




formulations, is actually much higher, since pesticides are sold as variously formulated products. Pesticide formulations usually contain not only the active substance, but also additives like solvents, surfactants and emulsifiers, designed to make them work more effectively (e.g. to assist penetration of cell membranes). Only the active ingredients are authorised, however, rather than the whole formulated product.

Given the fact that formulated pesticide products can have a much higher toxicity than the active substance alone, and that pesticide residues do not generally occur singly but in combinations, it is alarming that the EU is so far failing to regulate them. Although both the additive and synergistic effects of pesticides are described in the scientific literature, such effects are currently not taken into account in risk assessment procedures. Although there have been long running discussions about standardised methods for assessing mixtures, nothing has yet been agreed.

In addition to the EU's failure to address combinations of pesticides, some specific properties are also poorly addressed. For example, human endocrine disrupting properties have been a criterion potentially excluding chemicals from authorisation in the EU since 2009.

**Not one authorisation has so far been withdrawn because of the endocrine disruption threat and, despite the very serious human health risks involved, standardised methods for quantifying such properties are still under discussion**. This critical failing should be viewed against the very high probability that taking endocrine disrupting properties into account in the authorisation process would result in a number of substances being withdrawn from the market, making it more difficult for new substances to gain authorisation.

Setting aside the relatively new concerns around mixtures and additional modes of toxicity, even the long-used and accepted test methods applied in the authorisation process have a lot of demonstrable shortcomings. Usually, only effects on a few "standard" test organisms are tested for. The generally low susceptibility of these test organisms throws into question the degree to which they really reflect likely impacts on other individual organisms and real ecosystems. Some groups of organisms, such as amphibians, are not represented in the tests. Moreover, it is highly questionable whether the suite of lethal and sub-lethal effects used as test endpoints can ever truly represent the full range of possible impacts and some known and likely significant potential toxic endpoints are simply not evaluated at all.

The flaws extend to potentially serious conflicts of interest within the assessment process, as it is the applicant (usually the agro-chemical company) that has to perform and report on the standardised tests. Moreover, only summaries of the test results are published, not the full results, which are often only available upon request. This makes it impossible to discuss findings or to replicate the tests independently.

For many substances, particularly those which have been on the market for a longer period of time, scientific data can be found in open literature. These studies often have a markedly different scope to prescribed tests, investigate different effects and endpoints, or seek to answer more complex questions about sub-lethal and chronic effects. Additionally, they may be performed under less artificial conditions. According to EU guidelines, these studies, where they exist, have to be considered in the authorisation process, but in reality this rarely happens, because such studies are usually not considered to be relevant by either applicants or regulatory authorities.

It is also true that the wider environmental effects of pesticides are somewhat more difficult to assess than the "simple" toxicological ones. In many cases, instead of "real" data, assessments use a standard procedure involving the prediction of environmental concentrations and their effects by mathematical modelling. Studies have shown, however, that measured insecticide concentrations in the field can exceed the calculated ones by up to 78%. Therefore, under such circumstances modelling can considerably underestimate the real threat of pesticides to ecosystems. On top of this, some pesticides show unexpected "behaviours" in nature. As an example, chemicals thought to be "immobile" in soil are detected in water samples, which they were not originally expected to reach. Finally, in the EU, monitoring itself has major deficiencies. The spectrum of pesticides tested for is very narrow, and seems to focus largely on substances listed in EU regulations, namely the Water Framework Directive. A lot of substances, particularly newer pesticides like neonicotinoids, are not monitored as extensively as they should be given their widespread use. This means that pesticide regulations are currently not designed to allow a serious evaluation of the full impact of pesticides on the environment.[11]

These examples not only demonstrate the obvious failure of the EU´s pesticide approval process, they also strongly point to the serious lack of implementation of one of the fundamental principles of EU environmental law, the "Precautionary Principle". As defined in the 1992 Rio Declaration on Environment and Development, the Precautionary Principle requires that, where there are threats of serious or irreversible damage, "lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation". In other words, protective actions must be put in place whenever risks are identified, even if there is no full scientific certainty about them. In the case of pesticides several risks have been identified, indicating the need for a more a rigorous application of the Precautionary Principle.

# Jumping off the pesticide treadmill
## Shifting to ecological agriculture

**The over-reliance on chemical inputs, particularly of pesticides, has the potential to cause collateral damage to ecosystems precisely because they are designed to be toxic to a variety of organisms**. Pesticide use, even in accordance with regulations, not only endangers single species, but ultimately can put at risk essential ecosystem services. Paradoxically, this services include natural processes of pest control.

The problems caused by the control of pest organisms through the use of chemicals are, to an extent, self-reinforcing under current agricultural practice. The farming of relatively few species and varieties, effectively in monocultures, increases their vulnerability to fungal diseases, and to insects and to weed infestations. Low diversity at all levels (species, varieties, crop rotation) supports the development of, and subsequent pressure, from all kinds of pests, which are currently controlled using pesticides.

**In order to solve the problems caused by pesticide dependency, the current agricultural paradigm needs to be radically shifted towards viable, chemical-free, ecological agriculture methods**. Such methods make full use of ecosystem services, including natural pest control. The development and selection of disease resistant varieties helps to reduce, and even eliminate, insect and fungal pests. Carefully designed crop rotation, as well as diversification of agricultural systems and use of di- or poly-cultures, can enhance yields markedly, and buffer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against heavy pest infestation. Protecting soils and enhancing their organic matter, thus boosting fertility, also plays a fundamental role in managing pest infestation and ensuring plant resilience. Finally, the replacement of synthetic pesticides is already being successfully carried out via biological control, which makes use of natural enemies to control pests.

**The shift from a chemical-intensive agriculture system to an ecological farming model requires significant political and financial support**. Only by systematically putting in place effective support mechanisms, will the majority of farmers be able to adopt ecological farming practices. Most farmers are currently involved in a system that promotes the further industrialisation and specialisation of agricultural holdings, often disregarding the serious economic and environmental impacts. This effectively prevents the long-term development of rural communities. Adequate economic incentives are essential to create the paradigm shift to ecological farming. Billions of euros of taxpayers' money currently supporting unsustainable conventional farming systems and agro-chemical R&D, should be spent instead in promoting the rapid development and uptake of ecological farming practices, with their clear benefits for the environment, but also benefits for consumers, producers and rural communities.



# KEY FINDINGS

- The current destructive model of industrial agriculture depends on high levels of chemical use, particularly pesticides.
- Data shows that pesticide use continues to increase in the EU.
- Pesticides are found everywhere in the environment, they are distributed in many ways and can harm organisms far away from their point of application.
- Pesticide contamination is rarely due to a single substance. Mixtures or cocktails of pesticides are found most frequently in environmental samples.
- Acute toxicity of pesticides is often the most obvious hazardous effect, but subtle, sub-lethal effects may also take place and can include impacts on immune and endocrine responses, development, orientation, mating or foraging behaviour.
- Pesticides miss the target. They are not a precise tool targeting single pest insects but can cause severe damage to other, often 'beneficial', organisms.
- Pesticides cause biodiversity losses reducing populations of several organisms in agricultural ecosystems, even of animals on high trophic levels, such as birds of prey.
- Pesticides also have serious indirect effects on ecosystems, including the disruption of food webs and the destruction of habitats, and can already be linked to the decline of farmland bird species and arthropod populations, which many organisms feed upon.
- Pesticides can significantly affect fundamental "ecosystem services" like pollination, natural pest control, cleaning of drinking water, nutrient cycling and soil fertility.
- The EU is failing to control pesticides:
    - "Cocktail effects" of mixtures of pesticides are not routinely assessed;
    - Adverse effects, particularly sub-lethal ones, are too often overlooked, even on important pollinators like honey bees;
    - Only the active ingredients of pesticides are assessed, not the formulations applied in practice;
    - Endocrine disruption is not adequately assessed, despite being a criterion for the rejection of pesticide authorisations since 2009;
    - Assessment of sub-lethal effects is inadequate;
    - The authorisation process is not transparent and is dominated by industry information, particularly in relation to the studies used to inform it;
    - Organisms used in standard tests are often "robust" ones, thus not representative of naturally occurring organisms;
    - Independent studies are generally not taken into account, although they often find subtle impacts on certain species or the wider environment;
    - Modelling of pesticide contamination in the environment underestimates the real concentration of pesticides, even though it is integral to the authorisation process;
    - For many pesticides environmental monitoring is not currently foreseen.
- Powerful political and financial support is urgently required to support the shift from the current destructive chemical-intensive industrial agriculture system to ecological farming.

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# Recommendations

**A wide body of empirical scientific research, already provides irrefutable evidence of the environmental impacts that pesticides cause.** This indicates once more the urgent need to move away from the current chemical dependency of industrial agriculture. The widespread presence of pesticide residues in ecosystems, with its both, known and as yet unknown consequences, makes it obvious that the only way to avoid the risks and dangers posed by pesticides use is to phase out their use in agriculture. Non-chemical alternatives to pest management are already available to farmers but need the necessary political and financial support to be mainstreamed.
**Only by reducing pesticide use and ultimately converting farming systems to ecological farming practices will it be possible to address the ecological and economic problems that agriculture currently faces.**

In order to drive the needed change the following measures must be put in place as a priority:

- **Breaking the vicious circle imposed by pesticide use.** Focusing on functional agro-biodiversity is a key element. Choosing resistant varieties adapted to local conditions, setting up serious crop rotation schemes, diversifying agricultural systems at field and landscape level, improving soil management methods and implementing biological control of pests can replace pesticide use in agriculture.

- **Ensuring proper implementation of the directive on the sustainable use of pesticides.** As required by EU law, member states should put in place concrete measures and targets leading to a substantial reduction in pesticide use.

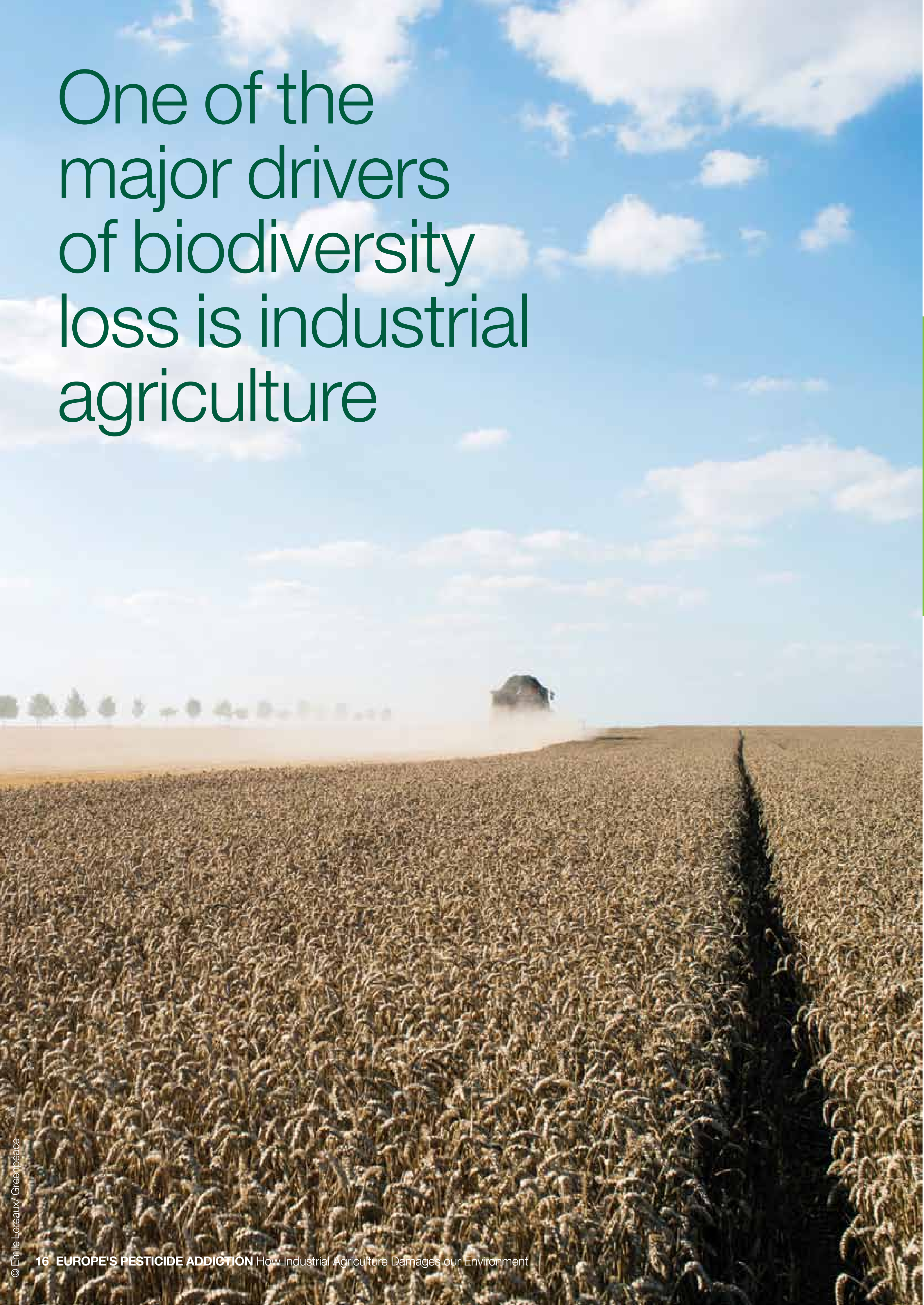
- **Overhauling regulatory controls for pesticide risk assessment.** In particular, investigating and monitoring the effects that the exposure to cocktails of chemicals can have on human health and the environment. The specific pesticide formulations used in the field should also be subject to testing and rigorous scientific assessment rather than the active ingredients alone. In addition, all available independent scientific literature should be taken into account as part of risk assessment processes, and all studies and data used in the assessment should be made publicly available. Once an authorisation has been granted, if scientific evidence emerges bringing additional information that could put into question the conclusions of the risk assessment process a re-evaluation of the active substance and the formulations should immediately take place.

- **Shifting towards ecological farming needs political and financial support.** Public research must be re-focused on ecological farming practices, and plant breeding should address the needs of ecological farmers, by delivering robust and locally adapted varieties, in participation with farmers.

- **Abolishing subsidies that promote the maintenance and upscaling of industrial agriculture practices.** Billions of euros of taxpayers' money is being poured into a broken system that continues to cause serious environmental and economic impacts. Public subsidies must instead be targeted to farmers to support the implementation of environmentally friendly farming methods. This would mean radically reforming the EU's Common Agricultural Policy (CAP) by phasing out subsidies promoting environmentally destructive practices, and making rural development subsidies conditional on the development and implementation of ecological farming methods.

- **Phasing-out synthetic chemical pesticides by prioritising chemicals with particularly hazardous properties.** This would mean banning pesticides that have bee-harming properties, are carcinogenic, mutagenic and toxic to reproduction, or which interfere with the hormone system (endocrine disrupting substances) as well as neurotoxic substances.

- **Introducing fiscal measures discouraging the use of pesticides and promoting the implementation of ecological farming practices.**



# One of the major drivers of biodiversity loss is industrial agriculture

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# 02
# Introduction

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Biodiversity - the extraordinary variety of ecosystems, species and genes that surround us - is not only important in its own right, it also provides society with a wide range of ecosystem services upon which we depend, such as food, freshwater, pollination, protection against floods, etc.

Biodiversity is however in crisis. In Europe, almost a quarter of wild species are now threatened with extinction and the majority of ecosystems are degraded to the point where they are no longer able to deliver their valuable services. This degradation represents enormous social and economic losses for the EU.

## EU Biodiversity Strategy to 2020

The trends in the status of these ecosystem services are to a large extent negative (Fig. 1). Since 1990, over 30 essential ecosystem services have been degraded (European Environmental Agency - EU 2015a). For some ecosystems like grasslands or lakes and rivers, nearly all services have been degraded.

Fig 1: **Trends in the status of European ecosystem services (EU 2015a)**

| Ecosystems Services | Agro ecosystems | Forests | Grasslands | Heath and scrubs | Wetlands | Lakes and rivers |
|---|---|---|---|---|---|---|
| **Provisioning** | | | | | | |
| Crops/timber | ↓ | ↑ | | | = | |
| Livestock | ↓ | = | = | = | ↓ | |
| Wild Foods | = | ↓ | ↓ | | = | |
| Wood fuel | | = | | = | | |
| Capture fisheries | | | | | = | = |
| Aquaculture | | | | | ↓ | ↓ |
| Genetic | = | | ↓ | = | | |
| Fresh water | | ↓ | | | ↑ | ↑ |
| **Regulating** | | | | | | |
| Pollination | ↑ | ↓ | = | | | |
| Climate regulation | | ↑ | | | = | = |
| Pest regulation | ↑ | | = | | | |
| Erosion regulation | | = | = | = | | |
| Water regulation | | = | | ↑ | ↑ | = |
| Water purification | | | | | | = |
| Hazard regulation | | | | | | = |
| **Cultural** | | | | | | |
| Recreation | ↑ | = | ↓ | ↑ | ↑ | = |
| Aesthetic | ↑ | = | = | = | ↑ | = |

**Status for period 1990-present**

Degraded Mixed Enhanced unknown Not applicable

**Trends between periods**

↑ Positive change between the periods 1950-1990 and 1990 to present

↓ Negative change between the periods 1950-1990 and 1990 to present

= No change between the two periods

Biodiversity is crucial for maintaining the ecosystem services (CBD 2000). These provide basic "services" which are essential for human existence, e.g. crop pollination or water purification. Wildlife species in Europe are declining in a "continuing and serious" manner, according to the European Environment Agency (EU 2010). A baseline summary of the status of wildlife species in Europe in 2010 found that 25% of marine mammals and 15% of terrestrial mammals, 22% of amphibians, 21% of reptiles, 16% of dragonflies, 12% of birds and 7% of butterflies are threatened with extinction (EU 2015a). An analysis of population trends for amphibians and reptiles showed that nearly 60% of amphibian species and 42% of dragonfly species were in decline (Fig. 2).

For mammals, the situation is not much better, with at least 27% of species in decline as the population trend of one third of mammal species is unknown (Fig. 2).

The European Commission stated in 2010 that the current rate of biodiversity loss is putting the future well-being of citizens in the EU and worldwide at risk (EU 2015b).

One of the major drivers of biodiversity loss is industrial agriculture, which is exerting considerable pressure on the environment due to land use changes, despite the application of mitigation measures and the steady increase in organic farming (EU 2010).

**Figure 2: Population Trends**
Amphibians and reptiles in Europe (EU 2015a)

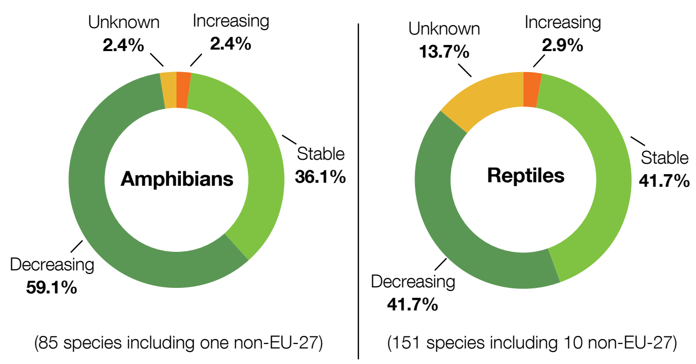
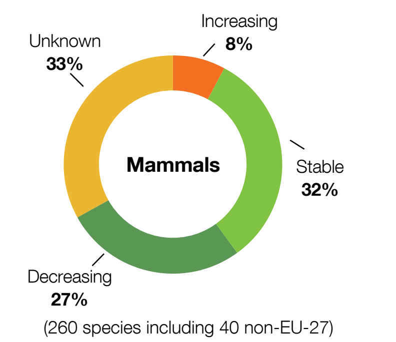



**Figure 3: Population Trends**
European mammals (EU 2015a)




Effects of industrial agriculture include:

- Reduction, fragmentation or elimination, eutrophication of habitats.
- Intensification of grassland use.
- Abandoning of traditional and extensive land use measures.
- Land utilisation (field, grassland as meadow, pasture).
- Crop rotation (e.g. restriction of crop rotation).
- Infiltration by invasive species.
- Deployment and more frequent use of heavy machinery.
- Reduction and elimination of food supply for wild species e.g. through plant protection measures.

Pesticides play a major role in many of the above effects. Almost one in four (24,5 percent) vulnerable or endangered species in the EU are threatened by agricultural effluents, including the use of pesticides and fertilizers, like nitrates and phosphates. (IUCN 2015). Habitat destruction and deterioration with the increased use of pesticides has diminished the abundance and diversity of many insect pollinators (EASAC 2009). Thus, it is possible that a threshold in pollinator species exists below which pollination services become too scarce or too unstable. Such a tipping point can occur when pollinator habitat is destroyed to such an extent, by reducing landscape diversity and increasing land-use intensity, that a population crash in multiple pollinator species becomes evident (EU 2015a).

In this report Greenpeace summarises the multiple threats of pesticides to nature and includes examples of some of the impacts. We also examine the current status quo of pesticide use and evaluate the quality of environmental risk assessments used for the approval of pesticides. Our report concludes with strong policy recommendations for alternatives to the current use of conventional agricultural pesticide to be implemented at both policy and farm levels.

# Pesticide use in Europe

The number and frequency of pesticide applications by farmers depends on many variables.[1] The number of applications (measured as Treatment Frequency Indicator)[2] between farmers growing the same crop in the same country can vary by a factor of 10 (Roßberg 2013).

A number of EU countries conduct pesticide use surveys over many years, including UK and Germany, however, only Slovakia and the Czech Republic maintain a pesticide use reporting system where farmers (with farms above a certain size) are legally required to report each use to authorities. Most countries assess pesticide use by the amounts of pesticides sold, and Regulation (EC) No 1185/2009 concerning statistics on pesticides use requires that Member States survey pesticide use on major crops over 5-year periods. The first survey results are expected in late 2015.

Therefore, it is impossible to conduct a European pesticide use trend analysis over the last 10 years. The total amounts used by use type (sales of herbicides etc.) are of little value, because changes in cropping area or pesticides' efficacy (e.g. substitution of high dose with low dose pesticides or vice versa), will always distort any analysis of highly aggregated sales data.

## What are Pesticides?

***Pesticide*** - Synthetic chemical pesticides are chemical substances or mixtures used to control pests, including insects, fungi, moulds and weed plant species. These substances are also commonly known as 'plant protection products'.

They are often categorised according to the target pest, for example:

***Insecticides*** - to control insect pests

***Herbicides*** - to control weeds

***Fungicides*** - to control fungal pests

Together, these groups cover a very large number of individual active ingredients, formulations and brand names. Pesticides are also categorised by their chemical class or by effects/mode - for example, organophosphorous (OP pesticides), organochlorine pesticides (OC pesticides), carbamates, neonicotinoids.

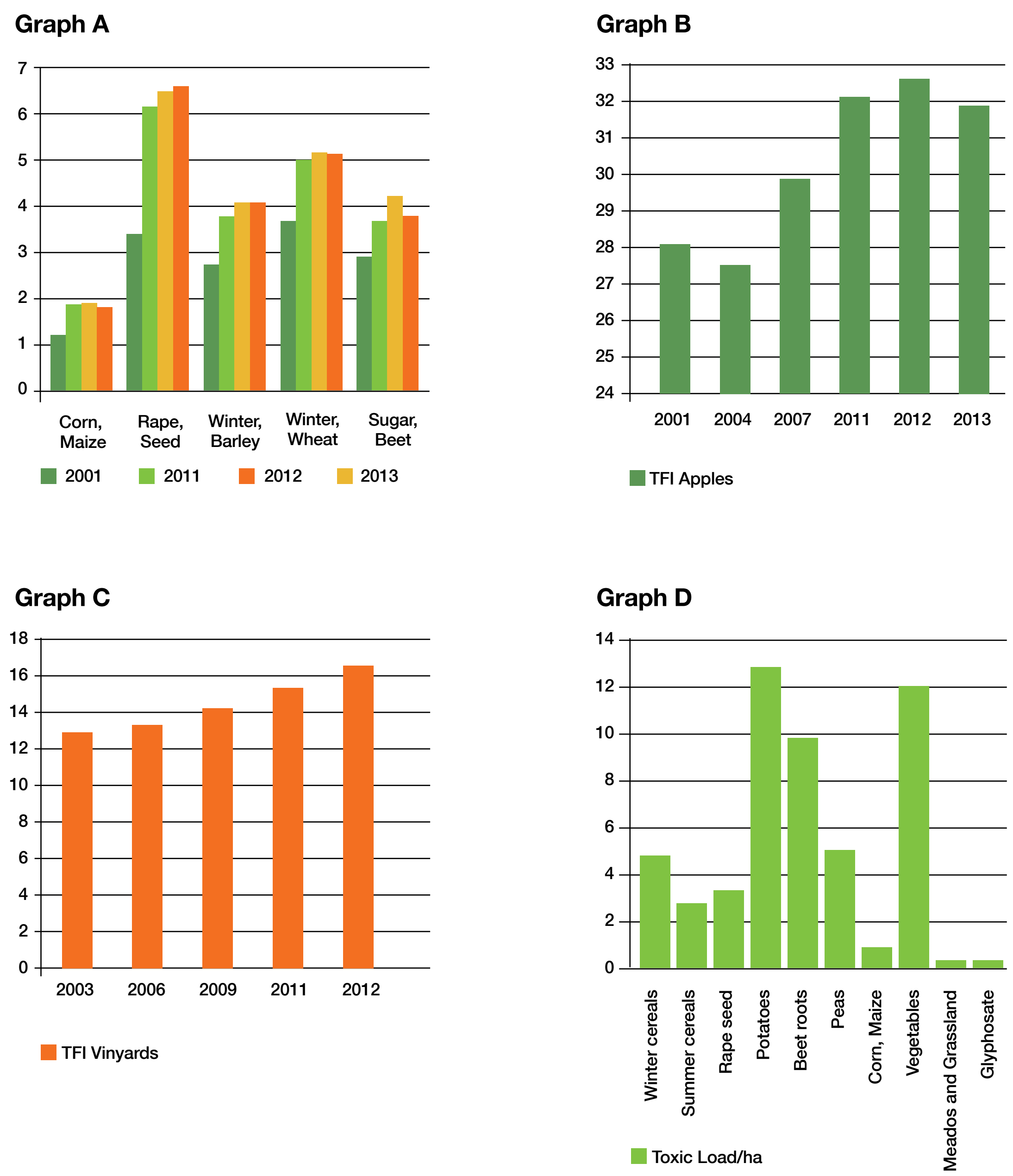
More reliable data about the number of treatments per crop is shown in Fig. 4. Such data is only available for a few EU member states and for a limited number of years. The Treatment Frequency Indices (TFI) in Fig.4 are probably somewhat representative for the specific crop, whereas the type of pesticides used may change depending on different climatic and regional conditions.

The graphs in Fig. 4 (A, B, C) show that in Germany the Treatment Frequency Index has risen considerably since 2001 for arable crops, apples and grapes (JKI 2015, Roßberg 2013). The same trend was observed in Denmark (The Danish Government 2013).

The information presented in Fig. 4 (A, B, C) coupled with a crop specific toxicity index would be of best value for analysing pesticide use trends. In Denmark, the toxicity and environmental fate of pesticides - what happens to a pesticide once it enters the environment e.g. dispersion or persistence - is now incorporated in the pesticide use analysis. The new index is called pesticide load. Fig. 4 (D) shows the pesticide load per hectare for different crops in Denmark (Miljøstyrelsen 2014).

Figure 4: **Treatment Frequency Index** (TFI)

In Germany over time (Graphs A, B, C) and pesticide load (toxicity & fate x amounts sold) per hectare in Denmark 2013. The TFI reflects the number of applications at full recommended dose. A higher TFI shows higher pesticide use intensity.



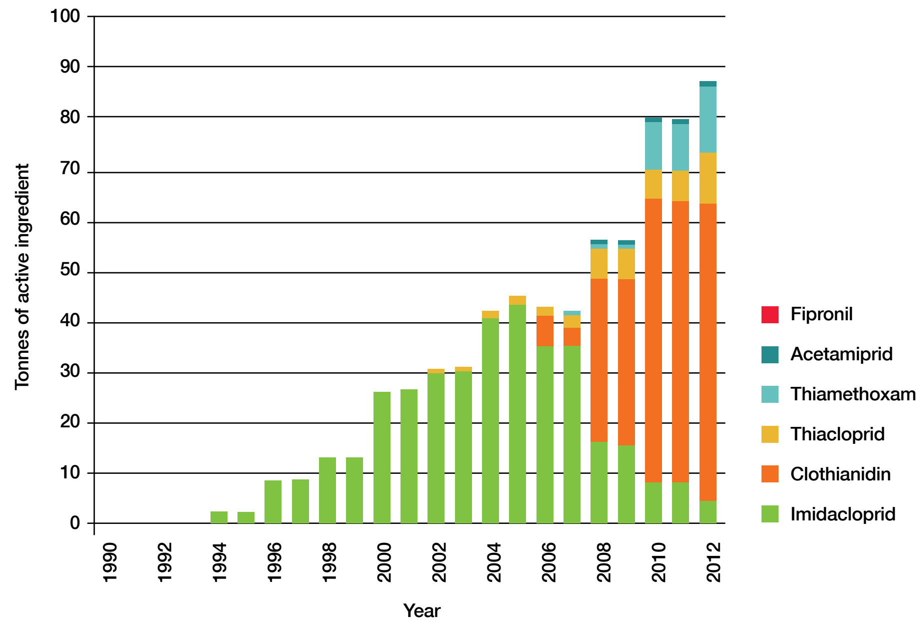
1. Due to the re-authorisation process, which began in 1991, the number of available pesticide active ingredients in the EU has decreased by about 50% since 2001. Currently about 500 active ingredients are authorised in the EU compared to about 650 in 2004 (Neumeister 2014).
2. Many pesticides with a high degree of acute toxicity to birds and mammals that have many cases of resistances (e.g. organophosphates, carbamates) have been substituted by other pesticides, mainly neonicotinoids (Fig. 5)
3. In order to save labour and fuel costs many farmers adopted conservation tillage and no-tillage practices. However, an overall reliance on agricultural chemicals and without other elements of ecological agriculture in place, farmers appear to have relied on increasing herbicide treatments.
4. The EU patent for glyphosate, which is a non-selective, systemic herbicide, expired in 2000 and became cheaper. In combination with a higher share of reduced tillage, where glyphosate replaces ploughing as a weed control measure, it became the most used pesticide globally (by volume).
5. The introduction of genetically modified crops started, but mainly due to public opposition such crops are not widely planted.
6. While demand for organically grown food rose significantly in some countries, this does not yet represent a major shift in consumption. The area under organic production is still small (5.7% in the EU)[3] and in some areas the lack of financial support has forced organic farmers to shift back to conventional production.

A variety of changes have also taken place at national policy level. Some countries (Denmark) continued, started (France, UK) and abandoned and restarted (Germany) pesticide use reduction programmes. New EU member states underwent a large transition period also affecting agriculture and pesticide use. With the implementation of the Framework Directive on the sustainable use of pesticides some activities within National Action Plans[4] are planned.

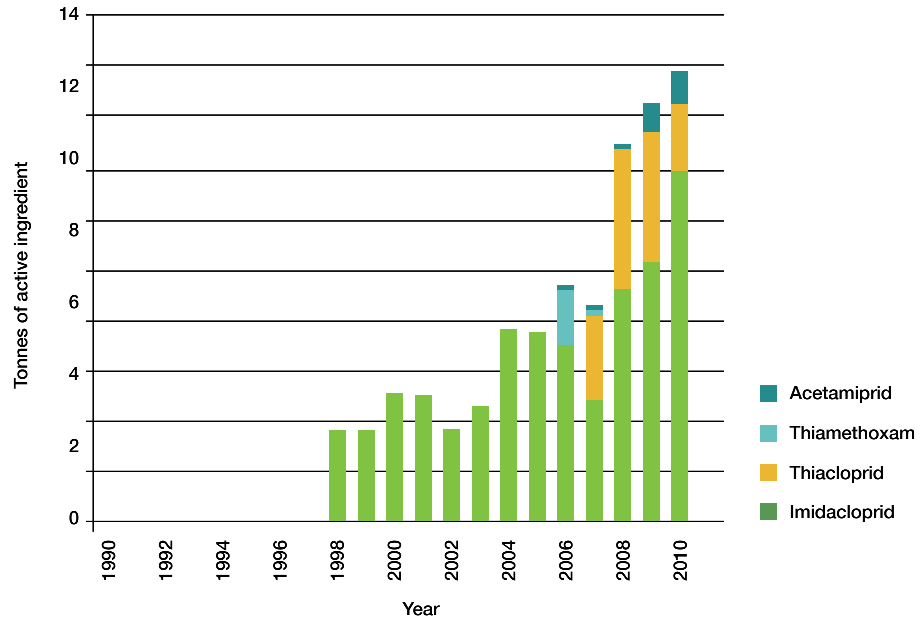
Figure 5: **Neonicotinoids and fipronil**

The rise of neonicotinoids and fipronil in Great Britain (Graph A) and Sweden (Graph B). Simon-Delso et al. (2015). Neonicotinoids largely replaced the use of other insecticides, specifically carbamate and organophosphates.

**Graph A**




**Graph B**



# The Authorisation of Pesticides
## Failure of the registration process

The Authorisation of pesticides in the EU is performed according to Regulation EC 1107/2009, which demands that pesticides "shall not have any harmful effects on human health, including that of vulnerable groups, or animal health or on groundwater". The registration procedure consists of an effect assessment, which is based on toxicity tests, and of an exposure assessment, which relies on modelling, as usually no field data is available.

The registration process is severely limited by a lack of scientific knowledge and also by systematic process weaknesses.

## Endocrine disruption not considered

There is sufficient evidence of the effects of endocrine active pesticides in invertebrates, reptiles, fish, birds and mammals, as reviewed by Mnif et al. (2011). Despite the alarm bells about endocrine disrupting chemicals first being rung decades ago, endocrine disrupting properties are still not considered in the EU's pesticide authorisation process.

While under the pesticide authorisation guideline EC 2009/1107, endocrine disruption properties are now an exclusion criterion for authorisation, the actual criteria in the guideline for identifying endocrine properties are provisional and most likely incomplete. Standardised and harmonised test methods are still in discussion and an end of the process is not expected in the foreseeable future.[5]

## Combination effects not considered

Additive and synergistic[6] effects of pesticide combinations in the environment are described by different authors (e.g. Zhou et al. 2011, Laetz et al. 2009, Phyu et al. 2011) and has been reviewed in a report commissioned by Greenpeace Germany.[7] For years now, research and discussion processes for detecting and evaluating these effects, and how to integrate them into the Risk Assessments, are ongoing in Europe.[8] Since no standardised test methods are yet available, these properties can not be considered in the pesticide authorisation process.

## Population effects based on behavioural changes not considered

Many studies report about the effects of pesticides on insect behaviour, with most focused on honey bees.

In a review by Blacquiere (2012), low-dose effects on bees were reported for:

- Imdiacloprid; on learning, medium term memory, delay in returning time to feeding place and locomotor activity.[9]
- acetamiprid; on long term memory and locomotor activity.
- Thiamethoxam; on orientation.

Nevertheless, in (semi-) field studies,[10] not all of these effects could be confirmed. One of the reasons could be that bees change their behaviour in response to pesticide perception. They reject contaminated sugar solutions resulting in a significant reduction of the foraging activity, and this behaviour contributes to a decrease in general fitness of the bees by 6-20% (Cresswell 2011).

Further behavioural effects of pesticides on invertebrates in sub-lethal doses were reported for mobility, navigation/orientation, feeding, oviposition, or learning (Desneux et al. 2007).

These behavioural effects are reported in open scientific literature and are not detected by the prescribed tests of the current pesticide authorisation process.

# Flawed testing

Under EC guideline 1107/2009, the active ingredient of a pesticide is tested extensively. In the field, however, this active ingredient is always applied in a formulation also containing the so-called "Inert Ingredients". These include solvents, surfactants, and emulsifiers, which have a variety of functions such as preventing caking or foaming, extending product shelf-life, or allowing herbicides to penetrate plants with the general aim to maintain and enhance the effect of the active ingredient.Therefore, pesticides are always applied as chemical mixtures and should also be treated as such in effect assessment. Any formulation is approved by each EU member state following guideline EC 284/2013. According to the guideline, the formulation is not to be tested as intensively as the active ingredient.

# Shortcomings of the EU's pesticide testing failure include:

Generally, experimental data on **formulations** are only to be performed if 'its toxicity cannot be predicted on the basis of data on the active substance. It may be sufficient to test the plant protection product with that species of a group that was most sensitive with the active substance.' (EC 284/2013).

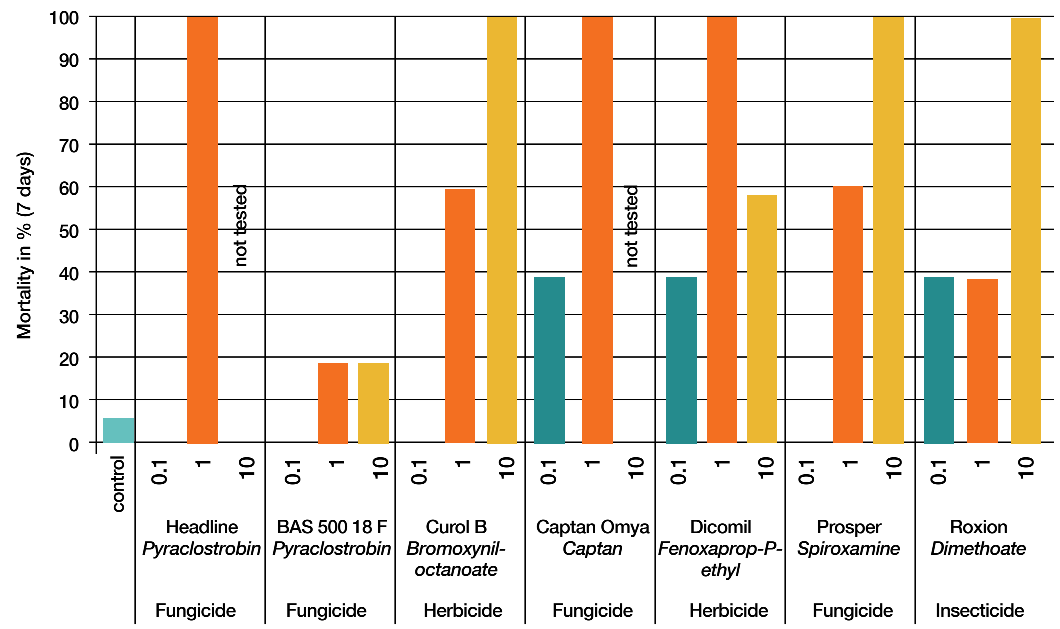
- For **birds, only one species** of quail was tested and, therefore, any interspecies variation in insecticide susceptibility may be underestimated (Gibbons et al. 2015).
- For **birds, mammals and fish, longer term tests are only to be performed when acute tests have shown higher acute toxicity** (for fish: 10-fold) compared to the active substance - so effects appearing over longer time periods are likely to be missed.
- For aquatic invertebrates, the large water flea, Daphnia magna, and one other not defined invertebrate species are tested; Daphnia is not the most sensitive species for all pesticides e.g. the neonicotinoids (Morrissey et al. 2015).
- For other organisms, **longer term tests** (including reproductive, behaviour and juveniles) are **only to be performed for honey bees, two arthropod species** (one mite and one aphid) and **earthworms**, so effects appearing over longer time periods in other species may be missed.
- Other insects are only investigated if the tests with the arthropod indicator species indicated a risk; so **beetles, other insects and spiders are not tested.**
- **Amphibians like frogs are not tested regularly**, only after discussion with the national authority.
- **Endocrine effects are not tested at all for pesticides.**

# Testing pesticide active ingredients misses effects of formulations

So-called "inert ingredients" in pesticide formulations can already have toxic properties. For example, the nonylphenol polyethoxylates, a class of serious endocrine disruptors or the solvent N-methyl-2-pyrrolidone, which is toxic to reproduction in humans[11] and highly toxic to bee larvae (Zhu et al. 2014). The wetting agents (organosilicones) showed toxicity on honey bee learning ability (Cjarlo et al. 2012). The adjuvants - agents that modify the effects of other agents - in the formulations, e.g. solvents, surfactants, and emulsifiers, can also have an important role in mixture effect assessment, for example when enhancing the entrance of the active ingredient into cell membranes like the surfactants do. So higher toxicities of the pesticide formulations compared to the contained active ingredient can appear as shown by Mullin et al. 2015, Clair et al. 2012, Demetrio et al. 2014, and Coalova et al. 2014. Some formulations showed up to 1000-fold higher toxicity in human cell lines than the active ingredient (Mesnage et al. 2014).

Fig 6: **Frog Mortality**

Mortality of juvenile European common frogs (Rana temporaria) after seven days following an overspray exposure for seven pesticides at 0.1×, 1× and 10× the label rate (formulation name, active substance and class are given). (Brühl et al. 2013)




Brühl et al. (2013) have recently shown that juvenile frogs oversprayed with a fungicide product at recommended label rates caused surprisingly high mortality rates. The commercially available product Headline (pyraclostrobin and 67% naphta solvent) caused 100% mortality just after 1 hour at the label rate, the formulation with the lower (< 25%) naphta content revealed 20% mortality at the label rate. Other products caused 40% mortality in even only 10% of the label rate.

Earlier investigations confirm the relatively high amphibian toxicity of certain strobilurin fungicides (Hooser et al. 2012; Belden et al. 2010). Both studies show the outstandingly high toxicity of the product "Headline".

Publicly available toxicity information for pesticide formulations is generally limited to some acute effects. Information about the inert ingredients in pesticide formulations is not publicly available due to corporate confidentiality. In the EU, only ingredients classified as dangerous substances according to EC regulation 1272/2008[12] have to be specified, e.g. in the Safety Data Sheet (SDS) of the formulation.

## Incomplete exposure scenario

A yawning gap in the pesticide authorisation process was identified in 2008. In the exposure assessment of the neonicotinoid clothianidin, a special insect exposure scenario had been overlooked. Although the abrasion issue had already been identified (Greatti et al. 2006), abrasion particles of corn seeds dressed with clothianidin were distributed into the environment using seeding machines, killing many thousands of bees in southern Germany.[13] As a consequence, the authorisation for 8 pesticide products was withdrawn in Germany. Previously these products had been classified as “not dangerous to bees”. This example clearly demonstrates the dangers of the current flawed testing regime and shows why tests need to be performed with more species or over longer time periods in the assessment of plant protection products according to EC-Guideline 284/2013.

## Calculated ‘Predicted Environmental Concentration’ (PEC) values too low

The environmental risk assessment for pesticides comprises the comparison of the regulated acceptable concentration (RAC) derived from toxicity tests with the calculated predicted environmental concentration (PEC). The PEC values for surface waters and sediments are calculated by the FOCUS exposure model of the Joint Research Center of the EU[14] using a 4-tiered approach. Knäbel et al. (2012) compared FOCUS PEC values with 122 insecticide concentrations found in surface waters with the result that measured insecticide concentrations in the field exceeded those calculated by FOCUS by up to 78% - the authors’ conclusion: The FOCUS modelling approach is not protective for insecticides.[15] Knäbel et al. (2014) repeated the same assessment with fungicides: Up to 43% of the predicted PECs were exceeded by field concentrations.

Dose-response models for the relationship of pesticide toxicity with the abundance of sensitive macroinvertebrate species showed significant differences to reference sites at 1/1000 to 1/10,000 of the median acute effect concentration (EC50) for Daphnia magna; about 50% of the sensitive species were not abundant any more at concentrations of 1/100 of the EC50 for D. magna. That means that effects well below the threshold of 1/100 of the EC50 for D. magna (incorporated in the EU Uniform Principles (UP) for registration of pesticides) appear and that this threshold is not protective for field communities subject to multiple stressors, pesticide mixtures, and repeated exposures (Schäfer et al 2012).

## Incomplete regulation of pesticide degradation products

During the authorisation process, metabolites are identified and classified as relevant or non-relevant. The EU authorisation directive demands:

*“A metabolite is deemed relevant if there is a reason to assume that it has intrinsic properties comparable to the parent substance in terms of its biological target activity, or that it poses a higher or comparable risk to organisms than the parent substance or that it has certain toxicological properties that are considered unacceptable.”*



# How much evidence is needed before a pesticide is regulated or banned?

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So in water legislation at EU and member state level, non-relevant metabolites of pesticides are either not specifically regulated or diverse threshold values are applied (Laabs et al. 2015). But from the perspective of drinking water hygiene, the often very water-mobile degradation products should be regarded as "relevant for drinking water" (Dieter 2010) because during oxidative drinking water processing like chlorination or ozonation, unexpected metabolites with critical toxic properties can occur (Schmidt and Brauch 2008). When "non-relevant metabolites" are found in drinking water, the procedure of what to do (reporting, measures) is not defined, yet a common European legal regulation for the "non-relevant metabolites" is demanded (UBA 2015, Laabs et al. 2015).

## Risk assessment for bees inadequate

The huge decline in Europe's honey bee population in recent years makes it even more evident that the pesticide risk assessment for honey bees is failing. A statement from the European Food Safety Authority (EFSA) from 2012 confirmed "considerable" effects of field realistic levels of neonicotinoids on honey bee colony stability and on bumble bees, found by free scientific literature and performed research on several bee-harming substances and on species other than the honey bee.[16] As a consequence, an EFSA guidance document for the risk assessment for bees was released in July 2013. The underlying EFSA study for this factor found sensitivity differences between honey bees and 18 other bee species by up to 10 for 95% of the investigated cases but 5% of the cases showed much higher differences, by up to 2000 (Arena and Scolastra 2013).

Chronic testing of bees and testing of larvae is now mandatory; a safety factor of 10 was introduced to extrapolate from honey bee tests to other bee species. Additionally, many studies report about behavioural changes in bees caused by pesticides (Chapter 6). The new EFSA must consider these studies as part of its new guidance.

In December 2013, the European Commission commenced a two year restriction for use of neonicotinoids on seed or soil treatment for some flowering crops. It was hoped that the restriction would result in better performance of bumble bee colonies in farmland over time as neonicotinoid residues fall. However, it is unfortunate that no regular monitoring is taking place that might detect such benefits (Goulson 2015a).

Most recently, EFSA has also confirmed a risk to bees by neonicotinoid pesticides applied as foliar sprays (sprayed on crops rather then applied e.g. as seed coating or into soil). EFSA will then review the material and offer conclusions concerning an updated risk assessment (EFSA 2015).

## Relevance of the shortcomings of the registration process for human health

Pesticides in plants and animals are also highly relevant for human health since many of them serve as food. Food often contains even multiple residues of pesticides (Fenik et al. 2011). The toxic effect of these mixtures is particularly poorly understood, though it is recognised that some substances can interact additively (1+1=2) and even synergistically (that means that their combined effect is even greater than additive effects (1+1=3 or more; Reffstrup et al. 2010).

Many of the shortcomings of the pesticide registration process are related to the human risk assessment. Endocrine disruption and combination effects are not tested at all, formulations and degradation products are barely tested. Moreover, there are critical toxicological human endpoints which are not tested yet: the developmental neuro- and immunotoxicity representing exposition in early life stages and of serious effects later in life (e.g. during growth or puberty) as reviewed by Bjørling-Poulsen et al. (2008) and Dietert (2014) respectively. One such example is the reduced drawing ability of children exposed to pesticides as reported by Guillette et al. (1998). A recent Greenpeace report, "Pesticides and our Health" (Greenpeace 2015a), has extensively reviewed the effects of pesticides on human health.[17]

## How much evidence is needed before a pesticide is regulated or banned?

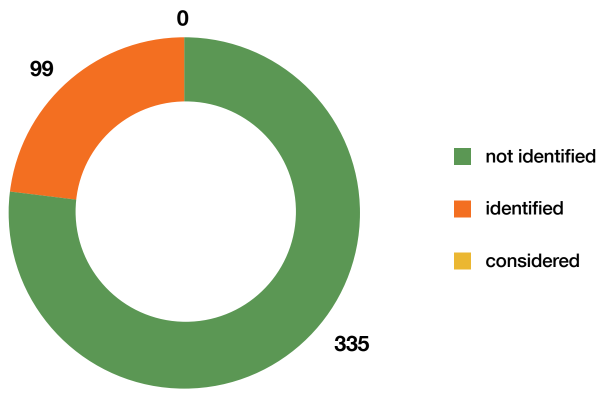
The herbicide, glyphosate, is currently one of the most frequently used pesticides worldwide. The International Agency for Research on Cancer (IARC) classified glyphosate in March 2015 as a 'probable carcinogen' (Class 2A) (Guyton et al. 2015). In sharp contrast, as part of the current European reassessment procedure for glyphosate, Germany as the Rapporteur Member State has assessed glyphosate as "unlikely to pose a carcinogenic risk in humans"[18]. However, independent scientists have severely criticised the risk assessment report prepared by Germany. They say the report omits a number of important studies, and the evaluation of the remaining, largely unpublished, studies is often questionable [19,20]. The European Food Safety Agency (EFSA) is currently undertaking a peer review of the German report. The EFSA´s opinion will then form the basis for the possible re-approval of glyphosate. This example illustrates several crucial issues in pesticide authorisation: How much evidence is needed before a pesticide is regulated or banned? How is the EU precautionary principle being applied? The German Federal Institute for Risk Assessment (BfR), responsible for assessing the health risks linked to glyphosate, has said: "The fact that different bodies assess issues differently due to differing information and assessments of experimental data is part and parcel of the risk assessment process."[21] This points to a further crucial authorisation issue: Who is able to interpret data and with which criteria?

## Scientific Literature – to be considered, but not in practice

For the authorisation process of a pesticide, the applicant - in most cases the manufacturer -has to perform studies on the effects of the pesticide on human health and the environment using standardised test methods. Currently these studies are usually either performed, or commissioned, by the applicant and are not publically available and the results are only available by request. According to the results of these studies, the approving authority decides which studies have to be performed additionally.

For many pesticides, even for those under re-authorisation processes, scientific data of the pesticide's effects is available in "open" scientific literature (e.g. independent studies not following test guidelines, which can be found in publicly accessible journals and databases). Often these studies have a different scope and show different effects and results than the applicant's studies. Under EC guideline 2009/1107, open literature has to be considered during authorisation, but in reality, many of these studies are not recognised and most of all are not accepted by the applicant or the authorities. One of the most common excuses given is that they do not fulfill GLP ("Good Laboratory Practice") standards. In an analysis of the risk assessments of seven pesticides authorised according to guideline 2009/1107, Tweedale (2014) discovered that of 434 important toxicity studies from academia, only 99 (23%) were identified by the applicant. Of those 99 studies, not one was seen as relevant and reliable enough to be used, generally because they were not performed according to OECD test protocols (including GLP). Tweedale (2014) also found critical doses in open literature studies being up to 1500-fold (!) lower than the established 'safe' doses in the EU pesticide Assessment Report.

Figure 7: **Scientific Literature in Risk Assessment**
Identification and consideration of 434 studies from open literature for seven pesticides by the applier in the according risk assessment (Tweedale 2014).




The studies were not even read but only checked for OECD compliance. This GLP criterion is based on a study by Klimisch et al (1997), employees of BASF. Nevertheless, not one EU rapporting member state, responsible for the evaluation of the applicant's test data, demanded the consideration of all studies in their Assessment Report (Tweedale 2014).

## Key toxicity results not sensitive enough

The key studies, following the standards of Good Laboratory Practice (GLP) and OECD testing guidelines (TG)[22] that are performed for pesticides, aim to find a threshold with no effect. Normally these chronic studies doing long-term testing. Since these chronic tests have to be performed to the GLP/TG standard, in many cases they do not find the lowest adverse effect level (LOAEL), as reported by Buonsante et al. (2014). One reason is that test animals are only kept alive for limited periods, so any long-term effects can not be detected. Another is that adequate negative and positive controls are not used. In addition, using light microscopes to identify tissue alterations is criticised for being outdated.[23].

The current risk assessment standard is to extrapolate high or medium dose toxicity results to a (low) dose with no effect (NOAEL) by using safety factors [24] and assuming a linear dose-response curve. But this 'safe' dose is rarely tested – based solely on the assumption that there are monotonic dose-effect relationships, and thus no adverse effects can occur below the NOAEL. But many examples, even for endocrine disrupting chemicals, show non-linear dose-response curves; in 20%-30% of the Bisphenol A literature, non-linear dose-response curves are reported (Vandenberg 2014). This means that effects can occur below the 'safe' doses.

## Risk assessments and known impacts of pesticides can change dramatically

Organochloride insecticides such as DDT were used all over the world before their persistence, bioaccumulation and disruptive impacts on ecosystem functioning were recognised, and they were subsequently banned in most countries.

Organophosphates have been largely withdrawn because of a belated acceptance by the chemical industry and governments that they posed great risks to human and wildlife health. (Van der Sluis et al.2015).

Identification of endocrine disrupting properties, first reported in the 1960's, only led to changes in pesticide authorisation criteria 50 years later, in EU Pesticide Directive 2009/1107.

The current discussion about the classification of glyphosate as a carcinogen shows that even the evaluations of specialist risk assessors can be extremely contradictory. It will be very interesting to see if the precautionary principle is factored in to the decision on whether or not to extend the glyphosate authorisation.

**Over recent decades, there have been examples of pesticide approvals being withdrawn based on scientific findings of environmental pollution:**

In 2010, the authorisation for the herbicide trifluralin was stopped because of the "high risk for aquatic organisms, especially fish, the toxicity of metabolites to sediment dwelling organisms, the consumer exposure for non-cereal applications, the high persistence in soil, the high potential for bioaccumulation, and the potential for long range transport via air". (EC 2010).

After frequent findings of atrazin in groundwater (Graymore et al. 2001), the EU Commission stopped its authorisation in 2004 (EC 2004a).

For amitraz, "the applicant has not demonstrated for the proposed uses that consumers might not be exposed to amitraz exceeding the Acute Reference Dose". The Commission ceased the authorisation in 2004 (EC 2004b).

In 2012, new scientific findings indicated that the neonicotinoid insecticides clothianidin, thiamethoxam, imidacloprid and fipronil showed high risks for bees. In 2013, the EU Commission restricted the use of these pesticides (EC 2013a; EC 2013b).

## New pesticides are not the solution

Neonicotinoids are a relatively new class of pesticides, being introduced into the market from 1991 on (Tomizawa and Casida 2011). Previously expected to exert only low toxicity on mammals, birds, and fish, because these compounds have a low affinity for vertebrates relative to insect nicotinic receptors (Tomizawa and Casida 2005), over the following two decades, these systemic pesticides and also fipronil have become the most widely used insecticides of the five major chemical classes on the global market (Jeschke et al. 2011). Today, several reviews are available proving the growing body of evidence that persistent, low concentrations of systemic pesticides pose serious risks of undesirable environmental impacts (Simon-Delso et al. 2015; Van der Sluis et al. 2015; EASAC 2015); several authors demand regulatory measures (Pisa et al. 2015; Van der Sluis et al. 2015) and reiterate that alternative agricultural and forestry practices exist (Furlan and Kreutzweiser 2014).

Although endocrine disruption is a new criterion for the authorisation according to the EU Pesticide Directive 2009/1107, not a single pesticide authorisation has been withdrawn for that reason.On the contrary, even after entry into force of directive 2009/1107, profoxydim, an EU Category 1 Endocrine Disruptor,[25] was approved in 2011.[26] Another widely used Category 1 Endocrine Disruptor, deltamethrin, is still authorised for use (EC 2007).

## There are no tests in open independent literature for new pesticides

For new pesticides, data not derived from the applicant/manufacturer is very sparse. For example, four new pesticides approved by the EU in 2014, benzovindiflupyr, rescalure, mandestrobin, and flupyradifurone, together only mustered eight hits on PubMed, one of the world's largest online databases for biomedical literature.[27] So, the only data for these substances (or products) is available in the Draft Assessment Report, which is mostly based on the manufacturer's studies.

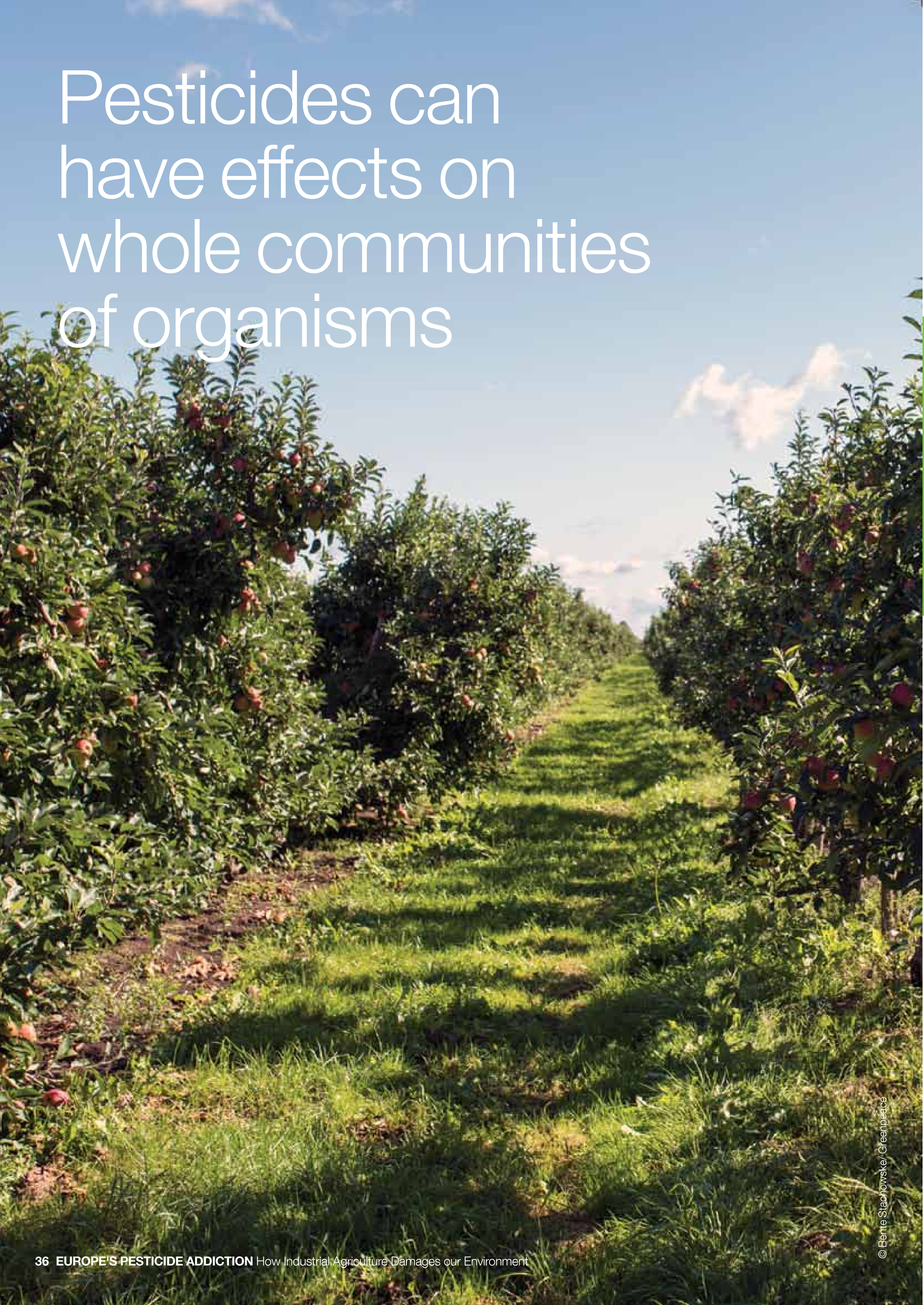
## **More pesticides, more risks**
## Combination effects

In the European Union, 477 pesticide active ingredients are authorised for use. Imagining the possible theoretical number of combinations of these substances is enormous, it will never be possible to evaluate these combinations and their effects. Nevertheless, since 2006 the EU Commission has been trying to find strategies and methods for evaluating the effects of combined exposure to pesticides.[28] In the meantime, new pesticides are being authorised and released into the environment, adding to the impacts of those already authorised and to those not being used any more but still abundant due to their persistency.

## Uncertainties in Risk Assessment

EFSA is about to assess the influences that scientific uncertainties have in the risk pesticides' assessment. In a draft guidance document, EFSA offers a tool-box made of both quantitative and qualitative methodologies. Through the application of these tools EFSA aims to give decision-makers a clearer picture of the scientific uncertainties affecting each assessment and, where possible, quantify their impact on the conclusions that decision-makers have to take in their role of risk managers. The public consultation carried out for EFSA guidance on uncertainty in scientific assessments guidelines ended in September 2015 and, after a test phase, new guidelines will be applied to all EFSA's scientific assessments.[29] It remains to be seen which measures will be specifically suggested when dealing with uncertainties. Additional safety factors (e.g. applied to maximum residue levels in water or the environment), which reflect scientific uncertainties, would respond to the need of applying the precautionary principle at EU level.

# Pesticides can have effects on whole communities of organisms



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# 03

# Pesticides in the environment

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## Paths of pesticides into and within the environment

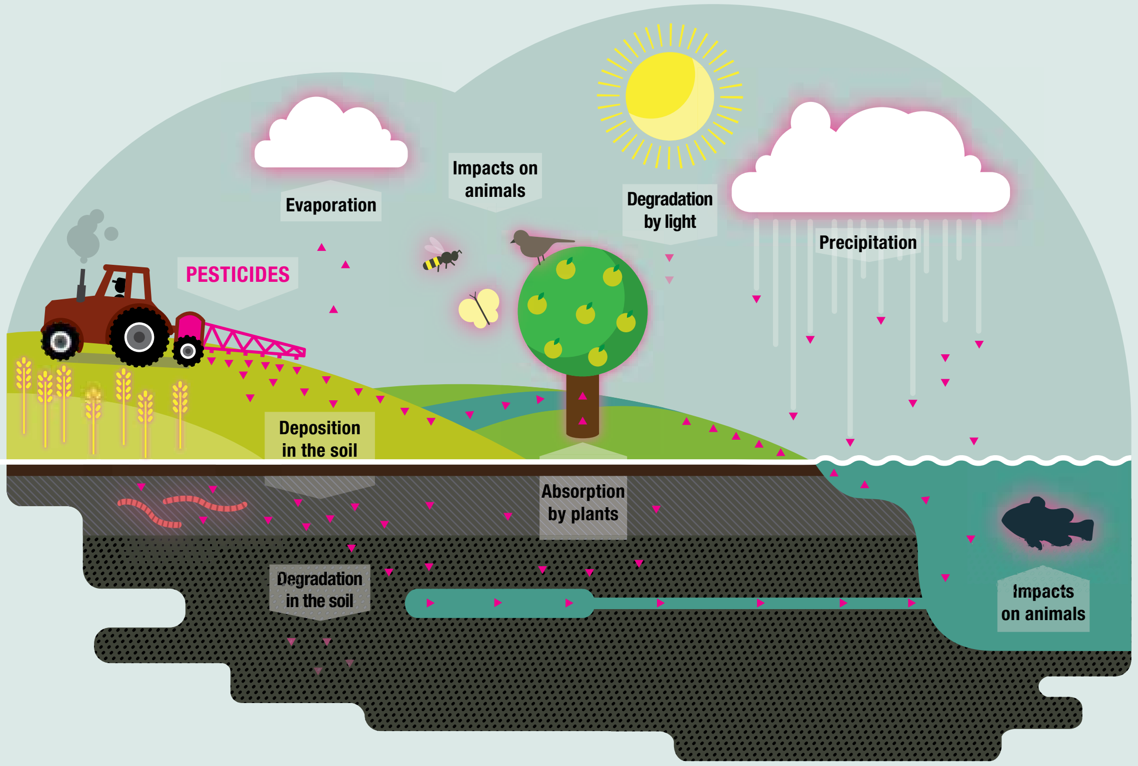
Pesticides are transferred into and distributed throughout the whole natural environment; persistent ones can even be found in organisms thousands of kilometres away from the locations where they were first applied, such as DDT being found in polar bears. (Dietz 2013).

When applied to soil or plants, pesticides can enter the environment via spray mist not reaching the plants and as dusts when pesticide solutions dry on the plant and are then distributed by the wind. Pesticides can also enter into air and rainwater when a dissolved sample is vaporised (volatilisation). Based on a literature review of 28 European studies from 10 EU countries, Dubus et al. (2000) reported that 50% of 99 chemically analysed pesticide-active ingredients (including isomers and metabolites) were found in rainwater.

After rainfall, pesticides can wash off plants onto and into the soil. Bach et al. (2005) estimated runoff rates of 59 pesticide active ingredients for field crop treatment to be 14.9 tonnes, 0.11% of the total amount (14,053 tonnes) of these 59 substances applied in Germany in 2000. Via leaching and drainage, an average of between 1% and 5%, in exceptional cases, can be lost through lateral and vertical infiltration into groundwater (Carter 2000).

During the sowing of coated seeds, pesticide dust can enter into the air and from the seeded grain into the soil. In the soil the pesticides can be mobilised by soil water, depending on the solubility and the adhesion potential of the substance. From the soil water or from contaminated puddles, the pesticides can get into ground and surface waters and from there into brooks, rivers and their sediments and, finally, into the oceans, depending on their individual water solubility and persistence.

Fig 8: **Overview of paths of pesticides into adn within the environment**






**Alarmingly, data about the amount of pesticides entering into the environment is very limited.** Up to 10% of the active pesticide ingredient concentrations measured in treated crops can be detected in adjacent untreated plants (Bavarian Environment Agency 2008). Municipal sewage treatment plants may contribute 65 - 95% of the pesticide load that reaches small bodies of running water (Schulte-Oehlmann et al. 2011).

Animals can ingest or absorb pesticides via all of the above paths: by eating the pesticide directly or parts of a treated plant or sucking plant sap; by drinking from pesticide contaminated puddles, runoffs or brooks; via the skin or the insect carapace e.g. during spraying or in the sediment or; directly via the respiratory tract. The food chain is another very important pathway for pesticides. Pesticides, depending on their physicochemical properties, can accumulate in animals with those on higher trophic levels - higher up the food chain - e.g. birds of prey, ingesting or absorbing a higher concentration of pesticide. As humans are at the top of the food chain, we also take up persistent and fat soluble pesticides via animal products like fish, milk, or meat. For example, human breast milk contains a cocktail of chemicals, including both the well-known persistent pesticides like DDT, as well as less well known, non-persistent ones like chlorpyrifos or permethrin (Weldon et al. 2011).

# Pesticides found in the environment

Analysis of ground and surface water samples in the German state of Baden-Wuerttemberg in 2006, identified 100 different substances (pesticide active ingredients and metabolites). Of these, 43% were approved substances (according to EU directive 91/414/EEC), 50% were prohibited, and 7% represented metabolites - the degradation products of active pesticide ingredients. The drinking water reference value of 0.1 µg/L was exceeded for 82% of all positive findings. (Sturm et al. 2007).

From 2009 to 2013, 2,280 German ground water sampling points were analysed for 23 pesticides. Pesticide active ingredients or their metabolites were found at more than 60% of the points and respective limits and thresholds for health orientation values were exceeded at 154 sampling points (GW-DB 2013).

An analysis of surface waters from 29 studies covering nine countries worldwide showed that neonicotinoid exposures were frequent, long-term and at levels (geometric means = 0.13 µg/L (averages) and 0.63 µg/L (maxima)) which commonly exceed several existing water quality guidelines. Ecological thresholds for neonicotinoid water concentrations need to be below 0.2 µg/L (short-term acute) or 0.035 µg/L (long-term chronic). 81% and 74% of the studies reporting maximum and average individual neonicotinoid concentrations respectively, exceeded these thresholds even without applying safety factors (Morissey et al. 2015)

An analysis of pesticides in European apple orchards representing a “snapshot” of the situation at the start of blossoming, revealed that across the entire set of 85 samples taken from soil, puddles and brooks, a total of 53 different pesticides were found; with boscalid and chlorantraniliprole the most frequently found (in > 20% of samples) (Greenpeace 2015b).

Between 2002-2007, German water suppliers recorded the following pesticides or their metabolites as being most frequently detected in drinking water: atrazine, desethylatrazine, diuron, simazine, isoproturon, and its dichlobenil metabolite 2,6-dichlorobenzamide. Surface water contamination resulted mainly from substances that are no longer approved by EU pesticide regulation. The most frequently detected pesticides in streaming waters (like brooks, streams and rivers) that are still authorised were bentazone, diuron, glyphosate, isoproturon, MCPA, mecoprop, metamitron, pendimethalin, and tebuconazole (Schulte-Oehlmann et al. 2011).

# Pesticides change within the environment

Pesticides can be degraded in the environment by the following mechanisms (Fenner et al. 2013):

- By sunlight, like carbofurans (direct splitting) or atrazine (via hydroxylation)
- By water like hydrolysis of parathion, trifluralin
- By organisms like microbial transformation of glyphosate or organophosphates.

From one pesticide, several breakdown products can occur. A complete degradation process down to the inorganic molecules like salts or CO2 can take some hours but also many years, e.g. DDT has a soil half-life period of 6200 days.[27]

The degradation products can have a lower effect in many cases, but there are also cases where the metabolites have an additive effect (Choung 2011). Furthermore, a metabolite can also have additive effects on the parent compound, enhanced by a second metabolite (Pesce et al. 2010).

Other toxic structures can also occur during degradation: Phenolic metabolites from pyrethroids or aryloxyphenoxypropionic herbicides can act as oestrogen receptors with a stronger effect than the parent compound (Jin 2010).

As the metabolites are usually smaller and more hydrophilic, they have a higher potential to be distributed within the environment up to ground and surface waters (Huntscha et al. (2008) for the metabolite ESA of the herbicide metolachlor).

Another aspect of degradation is the unexpected behaviour during water treatment: During drinking water ozonation, a carcinogenic microbial metabolite from tolylfluanide and dichlofluanide occurred (Schmidt and Brauch 2008).

Finally, it is important to note that it can sometimes take several decades to identify toxicologically relevant metabolites after their market introduction, and also may be dependent on analytical improvements (Buttiglieri et al. 2009).

# Pesticide hazards to animals and plants

Pesticides are produced with the aim of killing specific organisms that are presenting a problem for farmers. This goal is sometimes successful for a specific mode of action, for example some pheromones attracting specific threatening species. But the mode of action of others like organophosphate (OP) insecticides can impact many more non-target organisms as it is widely used in animal habitats.

Indirect effects include:

- Predator-prey relationships e.g. reduced insect and spider abundance impacts insectivorous birds.
- Pollination e.g. reduced pollination efficiency threatens the whole beehive.
- Parasite-host interactions e.g. immunotoxic pesticides can compromise the immune systems of some organisms so that the likelihood of parasitic infection is increased.

Direct effects are detailed for the other main groups of organisms in Chapters 4 - 7.

# Pesticides and ecosystem-level effects

A review by Goulson (2015a) suggests that the annually increasing use of neonicotinoids may be playing a role in driving species declines. The concentrations accumulating in soil (1 to >100 parts per billion (ppb)), waterways (often in excess of 1 ppb, sometimes up to 200 ppb), field margin plants (1–9 ppb) and nectar and pollen of flowering crops (1–50 ppb), exceed levels in crop tissues needed to control pest insects (5–10 ppb) and overlap with LC50 values for a range of non-target insects. They would appear to be sufficient to cause both direct mortality in the more sensitive non-target species and chronic sublethal effects in many more. The groups most at risk are likely to include soil-dwelling insects, benthic (bottom dwelling) aquatic insects, granivorous (feeding on seeds) vertebrates and pollinators. Herbivorous insects feeding on field margin and hedgerow plants may also be exposed.

Van der Sluijs et al (2015) conclude that present-day levels of pollution with neonicotinoids and fipronil caused by authorised pesticide uses frequently exceed the lowest observed adverse effect concentrations for a wide range of non-target species, and are thus likely to have a wide range of negative biological and ecological impacts. The combination of prophylactic use, persistence, mobility, systemic properties and chronic toxicity is predicted to result in substantial impacts on biodiversity and ecosystem functioning.

Pesticides are reported to be one of the causes of reduced species diversity in Great Britain (Firbank et al. 2008). Butterflies in farmland, urban, and particularly woodland areas showed the largest decline in species abundance (Van Dyck et al. 2009).

Beketov et al. (2013) investigated the effects of pesticides on stream invertebrate species richness in France and Germany. According to their analysis, pesticides caused statistically significant effects on species richness with losses of up to 42% depending on pesticide concentrations. The effects were detected at concentrations that 'current legislation considers environmentally protective'. The authors close with: ***'Thus, the current ecological risk assessment of pesticides falls short of protecting biodiversity, and new approaches linking ecology and ecotoxicology are needed."***

# Pesticides and community effects

Pesticides can have effects on whole communities of organisms. Effects can for example be measured by ecosystem services like e.g. the leaf litter breakdown which is performed by a community of different organisms like bacteria, earthworms, or beetles. By literature review, Peters et al. (2013) found, that in more than one third of observations where pesticides reduced ecosystem services, these reductions were shown at concentrations that are assumed being protective in regulation: Adverse effects were found at concentrations up to 1000-fold below the Toxic Units of 0.01 and 0.1[31] for a water flea and a freshwater alga species, respectively. These Toxic Unit values represent the usually used safety factors in the risk assessment of chemicals. So effects were observed in concentrations up to 1000-fold lower compared to the assumed 'safe' concentrations.

Lo et al. (2010) reported changes in microorganism communities in soil by some pesticides stimulating the growth of microorganisms and others having depressive effects.

Systemic pesticides are taken up by the plant and transported to all the tissues (leaves, flowers, roots and stems, as well as pollen and nectar). They have a broad and high impact on ecosystem services. Chagnon et al. (2015) gave several examples demonstrating evidence of the negative impacts of systemic insecticides on decomposition, nutrient cycling, soil respiration, and invertebrate population. Invertebrates, particularly earthworms that are important for soil processes, wild and domestic insect pollinators which are important for plant and crop production, and several freshwater taxa which are involved in aquatic nutrient cycling, were all found to be highly susceptible to lethal and sublethal effects of neonicotinoids and/or fipronil at environmentally relevant concentrations.

n laboratory microcosms,[32] the residues of imidacloprid in fallen leaves of treated maple trees were not directly toxic to earthworms, but did cause feeding inhibition that resulted in a significant reduction in leaf litter breakdown (Kreutzweiser et al. 2008, 2009). Further observations were changes in soil community structure and reduced soil metabolic activity at or near realistic field rates of imidacloprid (Cycon et al. 2013). Reduced soil respiration was also reported for acetamiprid by Yao et al. (2006).

Data from long-term and large-scale field monitoring by Van Dijk et al. (2013) has also demonstrated the negative effects of imidacloprid on invertebrate life; the authors compared the found adverse concentrations with three water quality norms for imidacloprid in the Netherlands and found two of them not to be protective.

Since neonicotinoids can persist in soil for several years, the risk from these compounds to soil ecosystem services can be long term (Bonmatin et al. 2014, Chagnon et al. 2015).

In aquatic systems, effects for the food chain were shown for imidacloprid and fipronil: two annual applications of both reduced arthropod prey, which led to reductions in growth of medaka fish (Oryzias latipes; Hayasaka et al. 2012). Insectivorous birds can also be affected by low neonicotinoid concentrations in water (Hallmann et al. 2014); The authors concluded: 'Future legislation should take into account the potential cascading effects of neonicotinoids on ecosystems.' The biological control of invertebrate 'pests' by predators may be one of the most important ecosystem services; but although only pest species are targeted by the insecticide, both the pest and natural predators can be affected (Chagnon et al. 2015). Further examples are given in the review of Desneux et al. (2007). Hopwood et al. (2013) concluded on the basis of more than 40 toxicity studies across a range of biological pest control species, that the widespread use of neonicotinoids negatively impacts predatory and parasitoid species that provide much needed biological control of crop pests.

Another of the most essential ecosystem service is pollination, as it is a critical service for the production of agricultural crops such as fruit, vegetables, nuts, cotton, and seed crops, among many others (Kremen et al. 2007; Vanbergen 2013). Aside from honey bees and wild bee species, flies, butterflies, wasps, moths, beetles, other invertebrates and, in some cases, vertebrates (such as bats, squirrels, birds and some primates), are also known to pollinate natural plants and crops. In Europe alone, more than 2,500 species of bees are known pollinators (Vaissiere et al. 2005). Besides pollinated crops, which represent <0.1 % of all flowering plants worldwide, between 60 and 85% of wild flowering plants require animal pollinators (Ashman et al. 2004).

The loss of pollinating species can also affect other networks, thus leading to impairment in ecosystem functioning as a whole (Chagnon et al. (2015).

Of the 124 major commodity crops directly used for human consumption, 87 (70%) are dependent on pollination for enhanced seed, fruit, or vegetable production (Klein et al. 2007).

The annual economic value of ecosystem services provided US$57 billion (Losey and Vaughan 2006). The estimated global value of the two ecosystem services of pollination and biological control is about US$215 billion in 2005 (Vanbergen 2013).

# Pesticides and population/colony effects

After the first unexpectedly high honey bee colony losses in 2006, one of the most discussed causes is the use of neonicotinoid insecticides. Colony collapse disorder (CCD) describes the phenomenon of adult worker bees suddenly abandoning their hives, leaving behind food, brood, and queen. Honey bees are social insects, so behavioural effects have an important function for colony survival. A wide variety of behavioural effects in bees following exposure to pesticides, primarily insecticides, were reported by Fairbrother (2014) and Thompson (2003).

Many laboratory studies described lethal and sublethal effects of neonicotinoids on the foraging behavior, and learning and memory abilities of bees, while no effects were observed in field studies at field-realistic dosages (Blacquière 2012).

Chronic exposure of neonicotinoids and formamidines to honey bee foragers in hives and agricultural fields can disrupt neuronal signalling which impairs their olfactory learning and memory, therefore foragers do not return to their hive (Farooqui 2013).

Winter losses of honey bee populations in Germany could not be linked to pesticides but according to the authors, further investigations and controlled experiments with improved methodology are undoubtedly necessary because several studies did prove negative effects of pesticides on honey bees (Genersch e al. 2010).

Three levels of clothianidin concentration were tested for CCD with 10 (high-conc.), 50 (middle-conc.), and 100 (low-conc.) times lower than that in practical use. Each colony with the pesticide administered collapsed to nothing within 84 days after passing through a state of CCD; the high-concentration pesticides seemed to work as an acute toxicity and the low- and middle-concentration ones did as a chronic toxicity (Yamada et al. 2012).

Wild bumble bee colonies located in hedgerows and woodland adjacent to or near arable farmland are likely to be experiencing significant negative impacts on growth and queen production. Those colonies which, by chance, choose to feed upon flowers contaminated with higher levels of neonicotinoids are unlikely to produce many queens (Goulson 2015a). This is very likely to have knock-on effects on population size the following year.

There is evidence that neonicotinoid pesticides disrupt biogenic amine signalling and cause subsequent olfactory dysfunction, as well as affecting foraging behaviour, learning, and memory abilities, but it is still unclear whether bee societies can buffer individual effects at field-realistic dosages (Koehler und Triebskorn 2013). Two recent studies found that bumble bees exposed to field-realistic concentrations of imidacloprid suffer from impaired foraging, brood development, and colony success in terms of growth rate and new queen production, particularly in combinatorial exposure to the pyrethroid l-cyhalothrin (Gill et al. 2012; Whitehorn et al. 2012). In honey bees, thiamethoxam caused high worker mortality due to homing failure, but possible risks for colony collapse remain controversial (Henry et al. 2012).

Latest findings of Menzel (2014) showed that sublethal doses of neonicotinoids caused behavioural changes by interfering selectively with the homing flight memory and so reducing the probability of successful returns to the hive. Chronic exposure to the neonicotinoid thiacloprid reduces the attractiveness of a feeding site and the rate of recruitment and massive changes in dance communication, collecting activity and navigation were found in a fiftieth of the LD50 value.[30]

Only a few reports are available for other invertebrates. In a recent review, Pisa et al (2015), reviewed the literature on other terrestrial and aquatic invertebrates including butterflies, flies, hymenopterans, spiders, earthworms, crustaceans and concluded. Neonicotinoid insecticides exhibit very high toxicity to a wide range of invertebrates, particularly insects, and field-realistic exposure is likely to result in both lethal and a broad range of important sublethal impacts. Despite large knowledge gaps and uncertainties, enough knowledge exists to show that existing levels of pollution with neonicotinoids and fipronil resulting from presently authorised uses, frequently exceed the lowest observed adverse effect concentrations and are thus likely to have large-scale and wide ranging negative biological and ecological impacts on a wide range of non-target invertebrates in terrestrial, aquatic, marine and benthic habitats.

Hallman et al. (2014) showed that, in the Netherlands, local bird population trends were significantly more negative in areas with higher surface-water concentrations of imidacloprid. At imidacloprid concentrations of more than 20 nanograms per litre, bird populations tended to decline by 3.5 per cent on average annually. Additional analyses revealed that this spatial pattern of decline appeared only after the introduction of imidacloprid to the Netherlands in the mid-1990s.

## Pesticides and individual effects

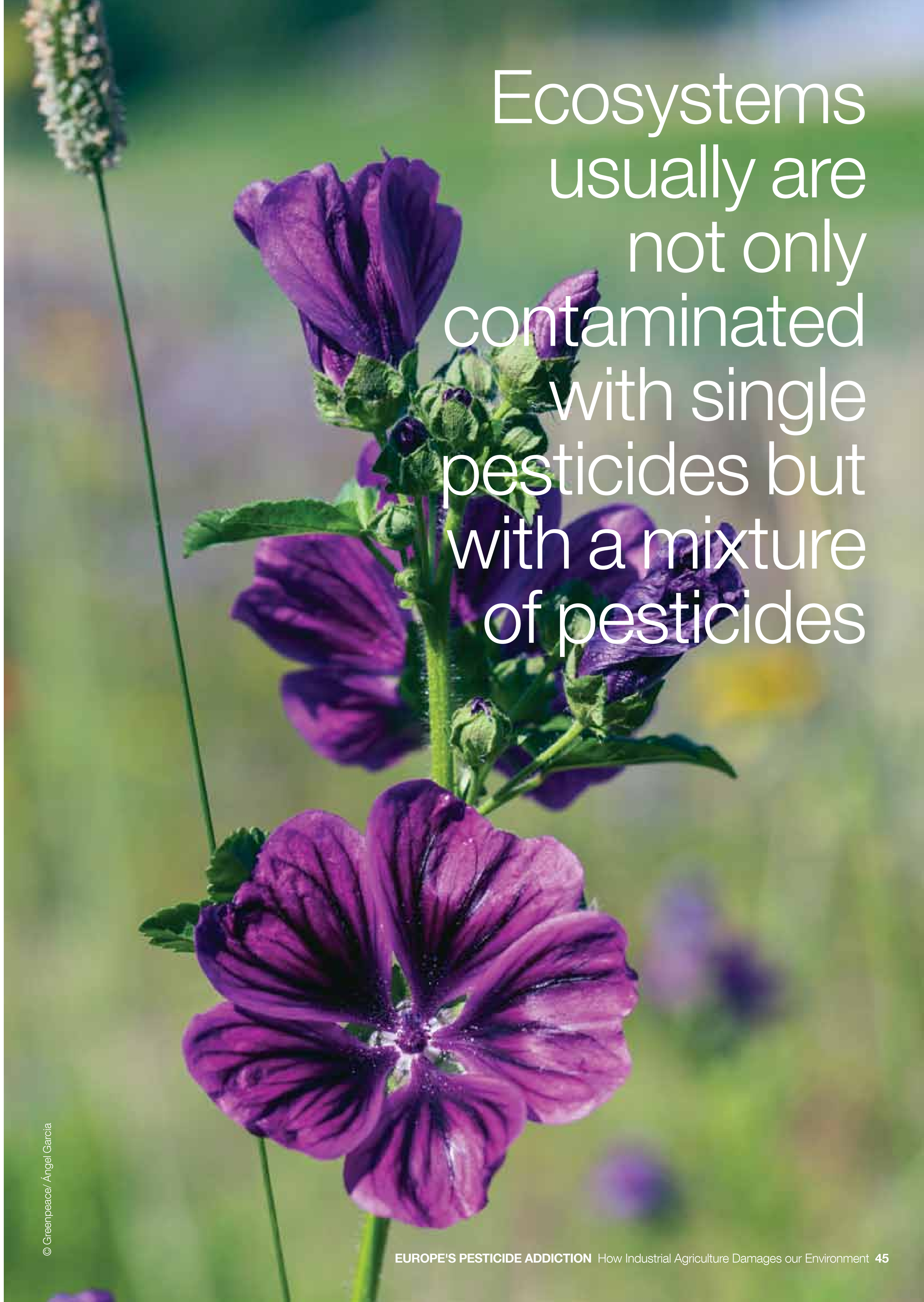
Generally, the effects of pesticides on wildlife are similar to the human effects: acute poisonings, long term effects, teratogenicity, endocrine effects, carcinogenicity, or neurotoxicity. Reports about these direct effects of pesticides on individual animals and plants are numerous. In this study, we evaluate primary and secondary scientific reports from the last decade for several groups of organisms; please refer to Chapters 4-7.

One general and little known but important aspect of how pesticides affect wildlife is via immunotoxicity - A number of pesticides have been proven to affect immune parameters, and some cases of immunosuppression (exerted by organochlorine pesticides, organophosphates, carbamates, atrazine, and 2,4-D) were correlated to higher susceptibility of organisms against infection and parasite caused diseases (Koehler and Triebskorn 2013).

**Examples for reported threats of wildlife via immunotoxicity are:**

- Paraoxon and Tularemia in hares (Bandouchova et al. 2011)
- Organochlorines and phocine distemper virus in seals (Kendall et al. 1992)
- Atrazine, malathion, and esfenvalerate in environmental realistic concentrations and trematodes resulting in limb deformities in tadpoles (Kiesecker 2011) , or glyhosate (Koprivnikar et al. 2012)
- A pesticide mixture[31] and increased development of lungworms in leopard frog (Gendron et al. 2003)
- Atrazine and iridovirus infection on survival of the long-toed salamander (Forson and Storfer 2006)
- Atrazine and inorganic phosphate and trematodes in the leopard frog (Rohr et al 2008).





Atrazine is a notable example of a pesticide disturbing the ecosystem balance: Atrazine kills the phytoplankton -> light penetrates the water column and nutrients get released -> natural cover layer (periphyton) growth -> more food to grazers -> more snails being intermediates for trematodes -> higher abundance of trematodes in the aquatic ecosystem -> higher infection rates of leopard frogs (Rohr et al. 2008).

Parasites are generally not abundant in laboratories and so the secondary effects of parasites on organisms with pesticide-weakened immune system are not detected in laboratory testing.

Several immunotoxic effects are exemplified in a review by James and Xu (2012): Organophosphates and some botanicals have been found to impact hemocyte number, differentiation, and thus affect phagocytosis. The phenoloxidase cascade and malanization have also been shown to be affected by several insecticides. Many synthetic insecticides increase oxidative stress, and this could have severe impacts on the production of some antimicrobial peptides in insects, but research is needed to determine the actual effects. Pesticides can also affect grooming behaviors, rendering insects more susceptible to disease. Despite laboratory data documenting pesticide/pathogen interactions, little field data is available at the population level.

An effect of low biodiversity closely connected to human infectious diseases was shown by LoGuidice et al. (2003) for the pathogen of Lyme disease: Some animals, in this case the white-footed mouse in North America, are more efficient in transferring the pathogen into the ticks feeding on this mouse. The mouse is one of the most abundant and widespread of all possible hosts for ticks, present also in species-poor vertebrate communities so the tick infection rate in such areas is higher resulting in higher human infection risk. Similar cases were described for protozoans in opossums (Travi et al. 1994) and bacteria in ticks in sheep (Ogden et al. 1998).

The ecological impacts of the neonicotinoid[35] group of systemic pesticides have been particularly damaging for insects. In early 2015 the 'Task Force on Systemic Pesticides' (TFSP),[36] in its investigation of the catastrophic decline of insects all over Europe, concluded 'that the new generation of pesticides, the persistent, systemic and neurotoxic neonicotinoids and fipronil, introduced in the early 1990s, are likely to be responsible at least in part for these declines'. The steep decline in European insect populations between 1990 - 2000, followed by the decline of insectivorous and other bird species, coincided with the introduction and increasing use of the persistent, systemic and neurotoxic insecticide group of the neonicotinoids and fipronil. The TFSP 'Appeal of Notre Dame de Londres' raised the alarm and demanded a 'much stricter adherence to the Precautionary Principle as enshrined in the EU Commission's Directive 91/414, and defined by UNESCO in 2005' (TFSP 2015).

## The cocktail effects of pesticides

Ecosystems usually are not only contaminated with single pesticides but with a mixture of pesticides and other xenobiotics (chemicals that are not produced in nature).

The analysis of pesticides in European apple orchards cited above (Greenpeace 2015b) showed that more than half of the soil and water samples combined (56%) contained traces of at least two pesticides and in five samples, 10 or more pesticides were found. From the 38 pesticides found in the water samples, eight had a very high toxicity against water organisms.[37] One pesticide found in the soil samples had very high earthworm toxicity and eight of the pesticides found in all samples had very high bee toxicity. Twenty of the pesticides found were very persistent, while five found in the soil samples had a high leaching potential. These environmentally critical properties enhance the threat from toxic pesticides (Greenpeace 2015b).

Bumble bees in farmland are found to be exposed to a cocktail of clothianidin and thiamethoxam in both nectar and pollen (Goulson 2015a).

From investigations of the effects of mixtures of organophosphate and carbamate on Pacific salmon, Laetz et al (2007) observed addition and synergism, with a greater degree of synergism at higher exposure concentrations. Several combinations of organophosphates were lethal at concentrations that were sublethal in single-chemical trials.

Significant synergistic effects (i.e. more than additive effects of mixtures) were found in nine of 21 investigated antifoulant mixtures including herbicides when tested on plants or algae (Cedergreen 2014). Of the 23 ternary mixtures of antifoulants and the ten quaternary mixtures, four mixtures were antagonistic (i.e. less than additive effects), nine additive and the remaining 20 mixtures were synergistic. The review also revealed synergistic chemical combinations where the mechanisms are unknown. These were mainly the interactions between herbicides with other herbicides, metals or non-azole fungicides in the antifouling mixtures, together with the mixtures of metals and organo-metals or simply metals and organic pesticides.

# Exceedances of critical environmental thresholds

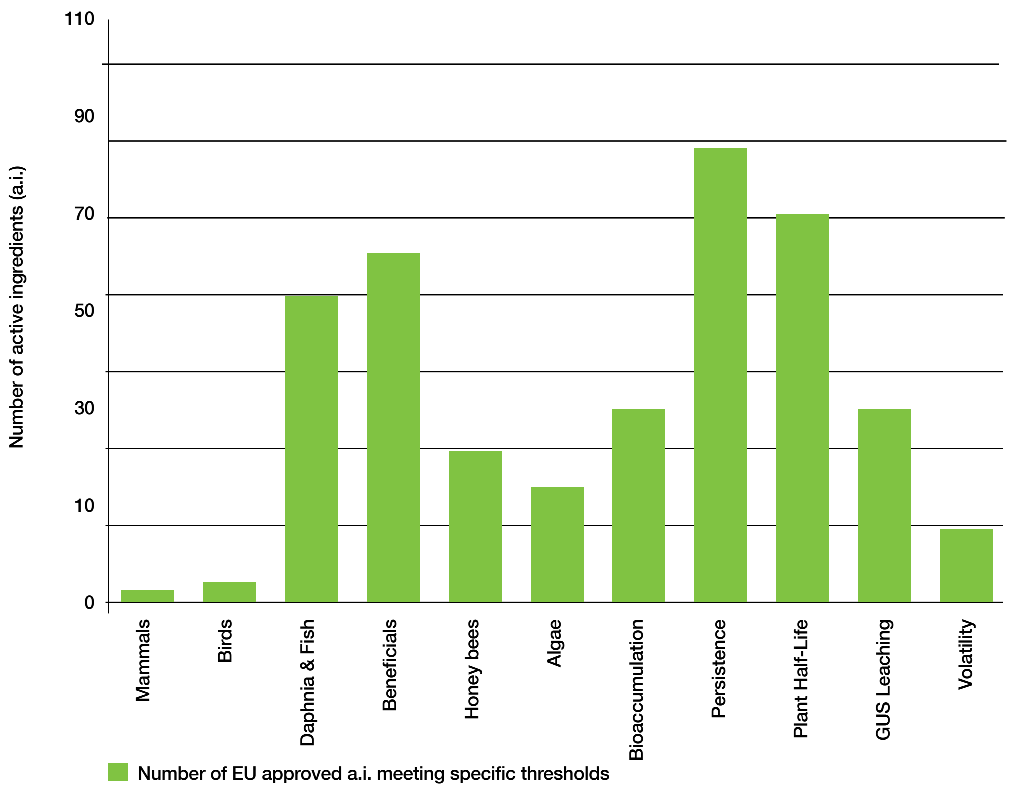
## PEC/PNEC exceedances

If the predicted environmental concentration (PEC) exceeds the predicted no effect concentration (PNEC), a risk for the environment cannot be excluded.

Testing of groundwater ecosystems in the European Union, found that nearly all (99.7%) of the measured field concentrations of pesticides exceeded the calculated concentrations,[38] 36.7% of the concentrations by more than 100 (Pereira et al. 2014).

The risk of 500 organic substances based on observations in four European river basins, Elbe, Scheldt, Danube and Llobregat, was assessed by Ohe et al. (2011) to find a prioritisation strategy for risk assessment. Thirty-one of the 44 substances with a risk factor[39] of more than 10 were pesticides - in other words: Three quarters of the substances whose environmental concentrations exceeded the No-Effect-Concentrations were pesticides.

Fig 9: **Number of EC approved pesticides exceeding critical environmental thresholds**

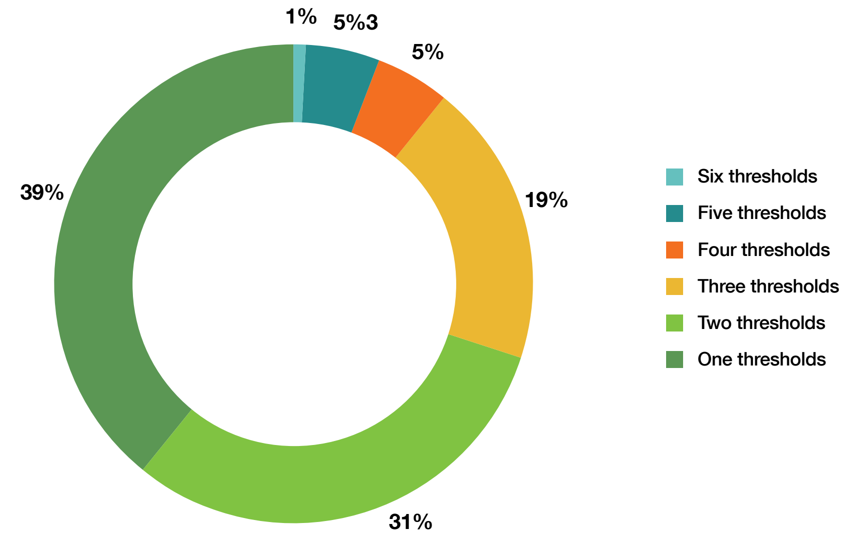



## Other environmental thresholds

A comparison of general indicators and thresholds for environmental toxicity, transport (volatility, leaching potential) and fate (soil half-life, plant half-life)[40] with the individual properties of active pesticide ingredients show that a large number of these pesticides reach or exceed these thresholds. From 471 active ingredients approved in the EU,[41] a quarter (118) exceeds the critical thresholds for persistence in soil or water. Ninety of these pesticides exceed the critical toxic values for beneficial organisms and 79 for water organisms (Fig. 9).

Sixty-one percent of pesticides authorised in the EU exceed more than one threshold, one percent exceed six thresholds, five percent exceed five thresholds, and a further five percent exceed four thresholds (Fig. 10).

Fig 10: **Percentage of EC approved pesticides exceeding more than one critical environmental threshold**



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The reduction of food resources seems to be significantly impacting bird populations



# 04

# Pesticides and birds

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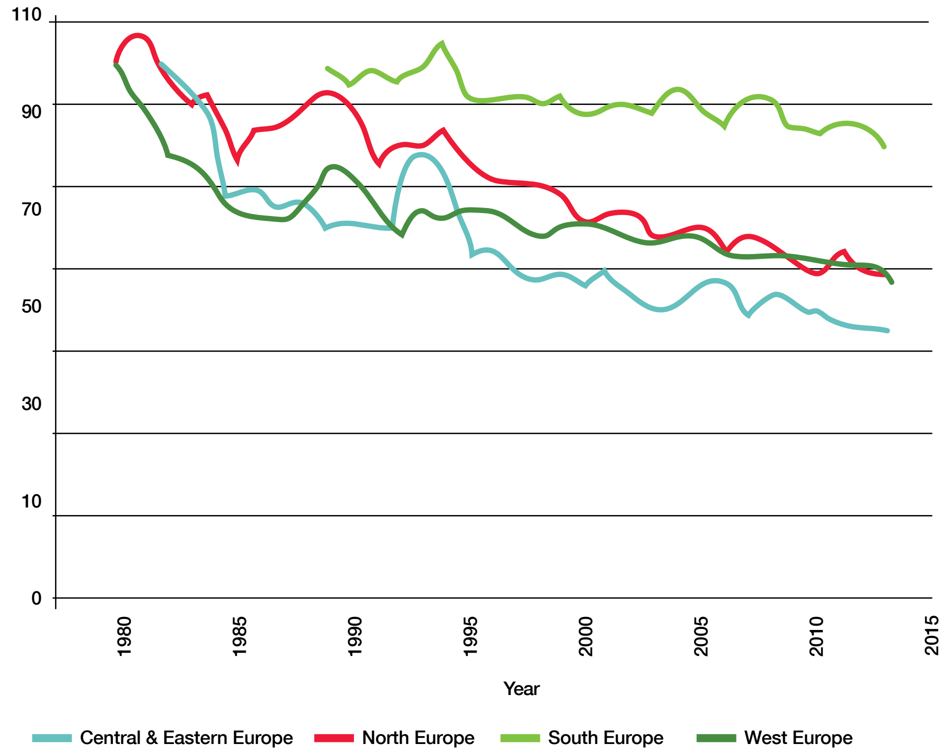
Birds play an integral role in natural ecosystems and agro-ecosystems. Birds can significantly reduce pests and disperse wild plant seeds to remote places, ensuring higher genetic variability and the creation of diverse habitats. In some cases, seeds (e.g. wild cherry tree [Prunus avium]), have to pass through the digestion system of birds before they can germinate.

Over the last few decades many bird species have suffered serious population declines. While some populations have since recovered others have declined further. Populations of common farmland bird species have experienced a steep decline in the last three decades all over Europe (Fig.11). Contributing factors are re-cultivation of set-aside land, conversion of meadows to arable land or intense use grassland, abandonment of traditional land uses, destruction of natural or semi-natural landscape elements, changes in harvest machinery and harvesting periods, and use of pesticides and fertilisers.

In the past, it was difficult to disentangle, among other factors, the contribution of pesticide use to species decline, but recent research in Europe (Geiger et al. 2010), the USA (by Mineau & Whiteside 2013) and Canada (Gibbs et al. 2009) has further illuminated the role of pesticides. Geiger et al. (2010) investigated across Europe (Sweden, Estonia, Poland, the Netherlands, Germany, France, Spain and Ireland) the effects of pesticides on birds and other species groups. Among 13 different components of agricultural intensification, use of pesticides, especially insecticides and fungicides, had the most consistent negative effects on the species diversity of ground-nesting farmland birds. Gibb et al. (2009) discovered a linear relationship between species loss (birds and other species) and herbicide use in Canada. In France, herbicide use was related to a decrease in habitats of specialists (species specialised on specific habitats or diets), particularly of herbivorous species (Chiron et al. 2014).

Fig 11: **Farmland Bird Index by Region**
(Data provided by Pan-European Common Bird Monitoring Scheme (PECBMS) 2015)



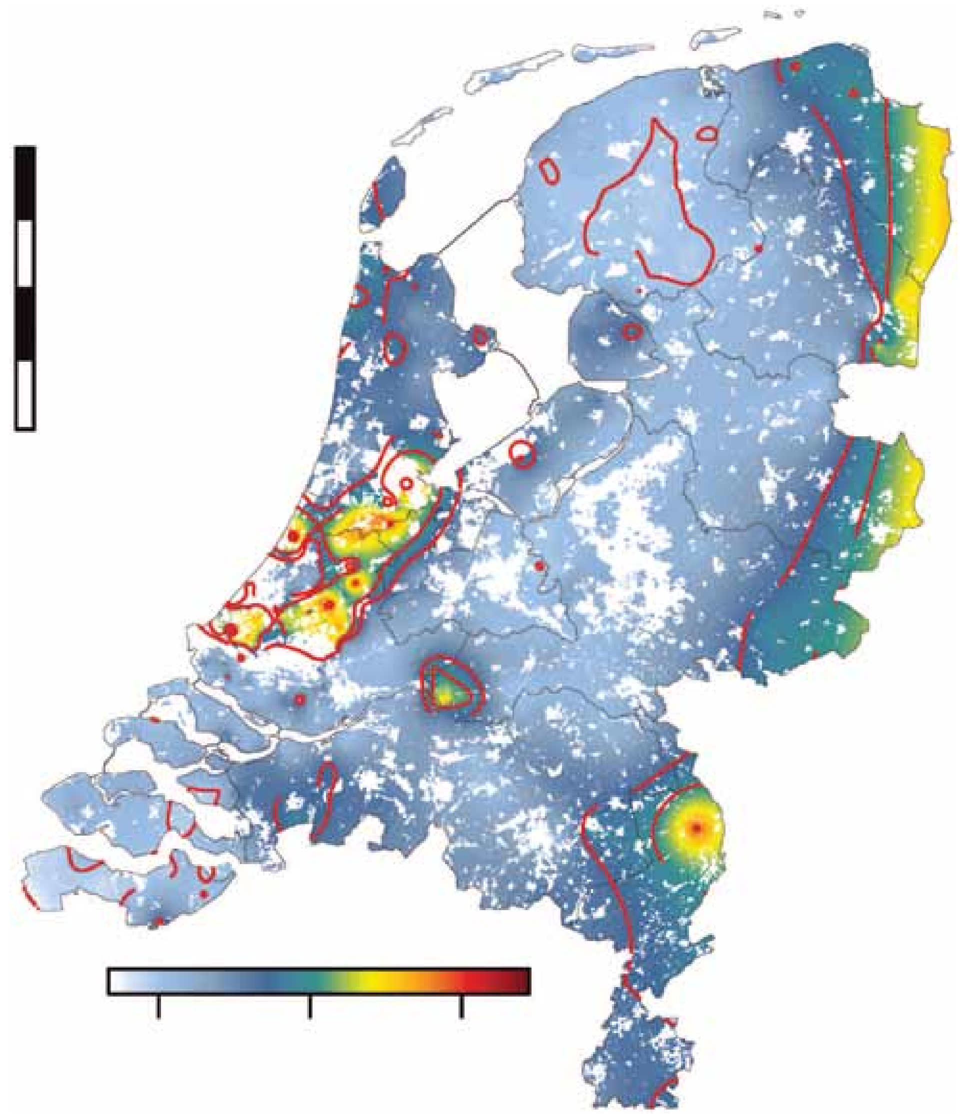

Individual birds and bird populations can be affected by pesticide use in different ways. They can be directly (incidentally or deliberately) poisoned, food resources can be reduced (insects [Boatman et al. 2004; Hart et al. 2006; Tennekes 2010; Goulson 2014], seed delivering weeds [Gibbons et al. 2006; Marshall et al. 2003; Newton 2004]) and habitats destroyed by herbicides. In intensively managed farm areas birds nesting on arable fields are directly exposed to pesticides multiple times. A recent, extensive study (covering 6,500 ha) in France showed that 71.4% of gray partridge (Perdix perdix) clutches were exposed to at least one pesticide (active ingredient). Exposure occurs mostly during egg formation and the authors identified a potential risk to reproduction (Bro et al. 2015). A further analysis assessed the mortality rates of gray partridge within 10 days following a potential exposure. The results show that five pesticide active ingredients were associated with a "10-day mortality rate" higher than 10%. One (thiacloprid) is reported to be highly toxic to these (rather large) birds. Cumulative toxicity was not evaluated. In about 40% of analysed gray partridge carcasses one or more pesticides were determined (Millot et al. 2015).

The reduction of food resources seems to be significantly impacting bird populations. Right now, a massive collapse of arthropod populations is being observed all over Europe, which coincides with the severe decline of populations of different insectivorous bird species such as swallows and starlings. An international group of entomologists and ornithologists conclude that neonicotinoids are likely to be responsible at least in part for these declines (van Lexmond et al. 2015).

However, the first comprehensive study warning that the recent decline of many bird species correlated with the increasing depletion of food resources caused by the use of imidacloprid and other neonicotinoids was carried out by Tennekes (2010).

Hallman et al. (2014) basically confirmed the results by Tennekes (2010) and correlated concentrations of a specific neonicotinoid insecticide (imidacloprid) in aquatic ecosystems to bird decline (Fig. 12). The spatial analysis showed that concentrations of 20 nanograms/litre [ng/g] and above of imidacloprid resulted in an annual decline of bird populations of 3.5%. Additional analyses showed that this kind of decline appeared only after the introduction of imidacloprid to the Netherlands.

Fig 12: **Interpolated (universal kriging) mean logarithmic concentrations of imidacloprid in the Netherlands (2003–2009)**
Reprinted by permission from Macmillan Publishers Ltd: Nature (Hallmann et al. 2014), Copyright ©2014



Over the last 15-20 years the use of glyphosate-based, non-selective herbicides has increased tremendously, and it is now the world's best-selling pesticide. Due to overuse, more and more plants have become resistant to glyphosate and farmers now use more products containing glufosinate-ammonium. Glyphosate and glufosinate-ammonium are both non-selective and systemic herbicides and can kill almost all (non-resistant) plants. The adverse impact that such effective herbicides can have on food resources for birds was shown by Gibbons et al. 2006. The researchers looked at the diet of 17 primarily herbivorous birds and the consequences of herbicide spraying on seed availability. They compared different weed management strategies, one involving genetically modified (GM) crops made resistant against non-selective herbicides. In beet and spring oilseed rape significantly lower amounts of weed seeds, which are important in the diets of all 17 granivorous bird species studied, were found. The authors also predicted an annual seed bank decline of seven percent, if those GM crops would be integrated in the commonly applied rotation.

However, any very efficient weed control method, which prevents weed reproduction, has an effect on birds depending on seeds. Newton (2004) saw herbicide use, leading to seed-bank depletion (see also Chapter 7) as one major reason for declines of granivorous farm bird species.

The effects of highly effective chemical pest and weed control on food sources of terrestrial populations are not covered by the current conventional pesticide risk assessment. For aquatic ecosystems the potential exposure and effects on aquatic invertebrates and fish are modelled. Even if that modelling has serious limits and weaknesses (see Chapter 5), effects of pesticides on the terrestrial ecosystems have to be evaluated by risk assessment and then managed by decision makers. Risk assessment must adopt an ecosystem approach that looks at cumulative effects on all trophic levels.

Birds higher up in the trophic level, (raptors, owls), are seriously affected by pesticides all over Europe. Thousands of buzzards, owls, eagles, vultures and other predators are killed each year - the real number is unknown. The main cause being considered is the widespread legal and illegal use of anti-coagulant rodenticides in urban and agricultural settings. In France, one single control of voles in winter 2011 caused the death of 28 red kites and 16 common buzzards (Coeurdassier et al. 2014).

The "by-kill" of predators preying on intoxicated rodents is called *secondary poisoning* and affects not only birds, but also mammalian predators (see Guitart et al. 2010). The main reason for secondary poisoning of birds is the slow action and the persistence of anti-coagulant rodenticides currently used. Previous overuse of fast acting, non persistent anti-coagulant rodenticides has led to resistance and adaptation of the rodents to the poisons, and the substitutes now pose a threat to all predators. Intoxicated rodents die rather slowly, and the rodenticide remains in their livers for a long time (half-life up to a year [DPR 2013]), which means that any predator feeding on them will also get intoxicated. While high pesticide exposure levels certainly kill birds, lower, sub-lethal exposure levels may also result in decreased fitness due to greater susceptibility to infection, increased parasite burdens, and decreased breeding success and population recruitment as young animals may be more susceptible. (Christensen et al. 2012).

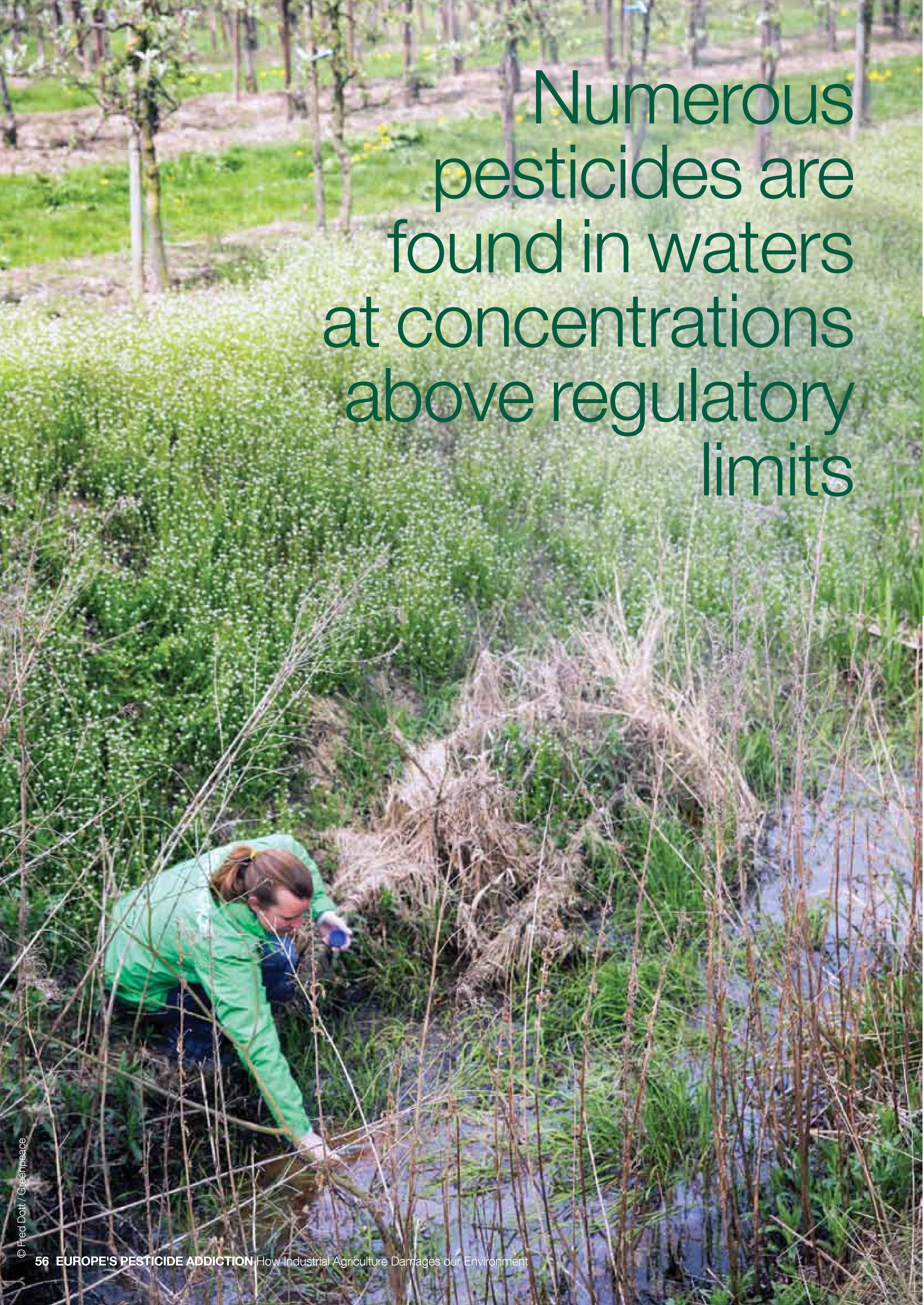
The full impacts of pesticide poisoning on birds and other animals in Europe is unknown. Reporting schemes for wildlife poisonings exist only in few countries, and not every case is discovered and reported. However, the following examples illustrate the scale of contamination across Europe.

In **Denmark**; 430 dead birds were analysed for anti-coagulant rodenticides, and these were detected in 84-100% of individual birds, with multiple residues detected in 73% of all birds. High residue concentrations (>100 nanograms per gram [ng/g] wet weight) in liver, which have been associated with symptoms of rodenticide poisoning and increased mortality, recorded high frequencies (12.9-37.4 %) in five of the six core species. The high prevalence and concentrations in highly endangered little owls (*Athene noctua*) are especially concerning (Christensen et al. 2012).

In **Norway**, four anti-coagulant rodenticides were detected in golden eagles (*Aquila chrysaetos*) and eagle owls (*Bubo bubo*) livers. Approximately 70% of the golden eagles and 50% of the eagle owls contained poisons. Thirty percent of the golden eagle and eagle owl livers contained concentrations of 100 ng/g wet weight or more (Langford et al. 2013).

In **Spain**, concentrations of seven widely used anti-coagulant rodenticides were determined in 104 liver samples of six species of birds of prey (*Buteo buteo, Accipiter nisus, Falco pelegrinoides, Falco tinnunculus, Asio otus,* and *Tyto alba*). Residues of at least one anti-coagulant rodenticide were detected In 61% of the livers of these bird species. The most frequently detected anti-coagulant rodenticide was bromadiolone, which was detected in 60.3% of the positive cases. More than 75% of the *A. nisus*, *T. alba*, and *A. otus* individuals had detectable rodenticide residues in the liver. Approximately, 35% of the concentration exceeded the threshold levels of toxicity (Ruiz-Suárez et al. 2014).

In **Scotland**, 70% of red kites (*Milvus milvus*) tested contained anti-coagulant rodenticides, and 10% died as a result of rodenticide ingestion. Sparrow hawks (Accipiter nisus), which prey almost exclusively on other birds, had similar exposure rates to species that prey on rodents (Hughes et al. 2013).



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# Numerous pesticides are found in waters at concentrations above regulatory limits



# 05

## Pesticides and aquatic organisms

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Pesticides can enter surface waters in many ways. They can run-off from fields, drift or evaporate off-site or erode with soil particles into drainage, rivers and ditches. Pesticides are also released into the environment if pesticide users wash their spraying equipment in rivers or do not respect the required buffer zones.

Many pesticide active ingredients are highly toxic to aquatic organisms and are quite mobile (leaching thresholds), (Fig.13). However, the mobility of a pesticide depends on many variables. For example, numerous pesticides are found in waters at concentrations above regulatory limits (Stehle & Schulz 2015; Pesticide Atlas Netherlands),[42] although some of these substances are supposed to be "immobile". Whether or not those occurrences come from bad agricultural practices or from an underestimation of mobility has yet to be determined. Another possible explanation might be the effect of so called inert ingredients (see Chapter 2.2). According to Bonmatin et al. (2015), commercial formulations may contain additional substances (inerts) that increase the solubility of the active substance. One research group consistently found commercial pesticide products to have a higher leaching potential than the actual active ingredient (ibid. see also Krogh et al. 2003).

The true scale of surface water pollution caused by pesticides in Europe is largely unknown. Even though the European Environment Agency (EEA) collected monitoring data for the period 1965-2012 from member states, the evaluation reveals major imbalances in the level of national data, and highlights some serious gaps - the database is publicly available for download.[43] In 2012, only 3434 river stations were measured for agricultural pesticides, with most of the measurements (68%) coming from just three countries - France, Great Britain and Italy.

The spectrum of tested pesticides also reveals major deficiencies, for example the EFSA's conclusion for imidacloprid in 2008.

***"Overall it is concluded that a high risk for aquatic organisms is indicated for the representative uses in orchards and tomatoes requiring substantial risk mitigation measures to reduce spray drift and runoff."*** - The European Food Safety Authority (2008).

Despite this warning, imidacloprid[41] was only measured in three countries at 179 stations, with most (167 - 93%) in Italy. Bifenthrin, another highly problematic insecticide (see Stehle & Schulz 2015), was only measured in Italy at 19 stations. There could have been more measurements at national and regional levels, but if they did exist these results were not submitted to the EEA. In general, it appears that by focusing monitoring measures on the priority substances presented in the EU Water Framework Directive (WFD) in recent years, monitoring of "new" potential hazards has been neglected.

A recent report by the Italian National Institute for Protection and Environmental Research (ISPRA) shows that the two global bestsellers (glyphosate and imidacloprid) are also those detected most frequently in surface waters. AMPA, the metabolite of glyphosate, was detected in 46% of the analyses and imidacloprid in 21% (see fig.16). In addition, AMPA exceeded the quality threshold at 56.6% of the monitoring stations (ISPRA 2014).

An investigation by the German state of Rhineland-Palatinate provides a more realistic indication of what a pollution scenario might look like in a winegrowing area. Throughout 2010, samples were collected from nine stations and tested for 184 pesticides. In the analysis, 116 pesticides (63%) were above the limit of detection (55 herbicides, 40 fungicides and 16 insecticides) (LUWG 2012).

The Netherlands has the EU's most comprehensive, nationwide online database on pesticides in waters,pesticidesatlas.nl, but this data is not included in the EEA pesticide database.

Fig 13: **Frequency of detection in surface waters in Italy 2012 (ISPRA 2014)**
(Robinson & Sutherland 2012, Copyright © 2002, John Wiley and Sons)

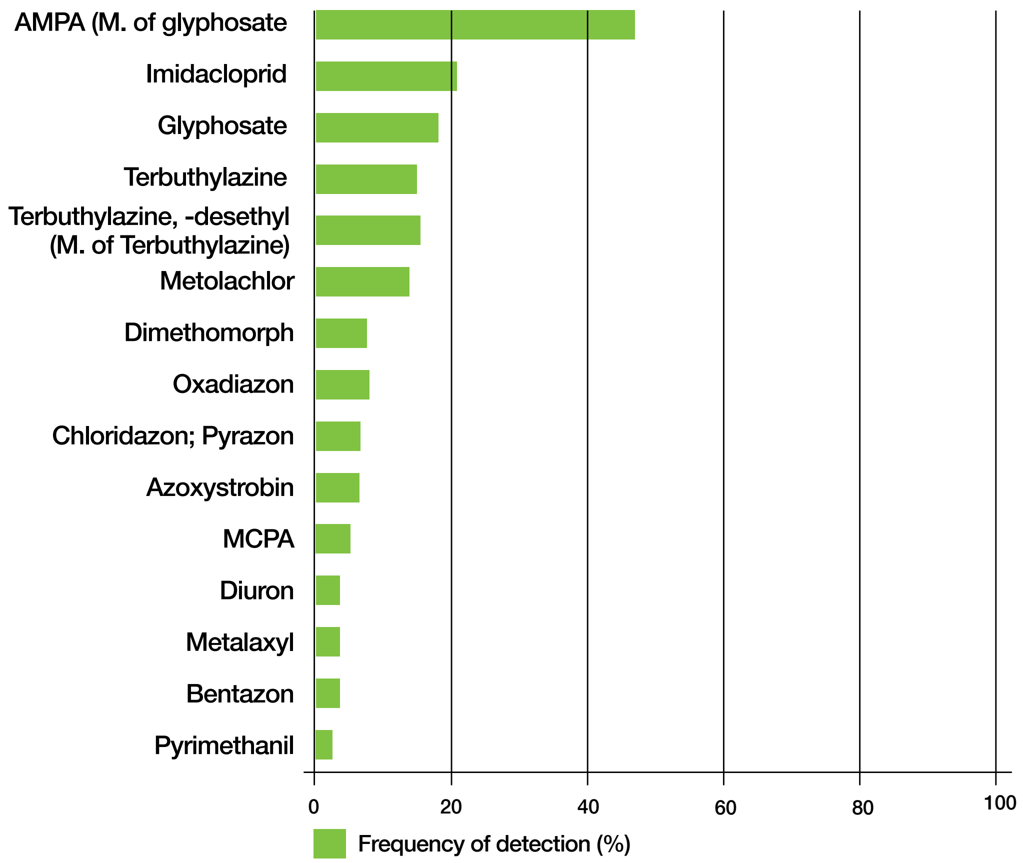


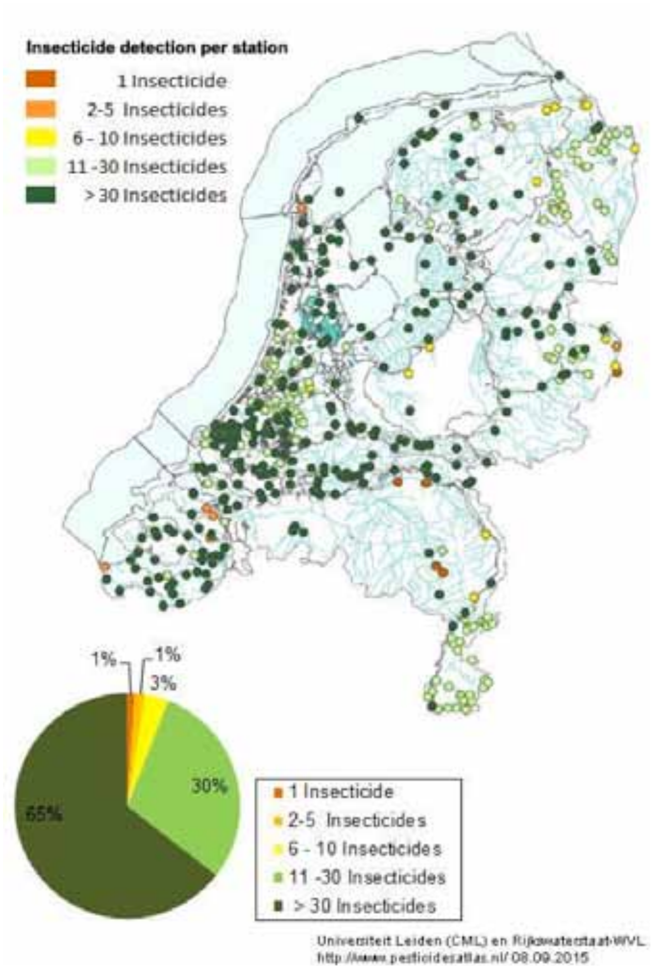

**Fig 14: Pesticides that caused the highest number of water quality standard violations in the Netherlands in 2013.**

| | Priority pesticide acc. Regulation 2013/39/EU | Chemical group (neuro toxic mode of action |
|---|---|---|
| ETU (metabolite of Ethylenebisdithiocarbamate [EBDC] fungicides: Mancozeb, Maneb, Metiram etc.] | No | |
| Azoxystrobin | No | |
| Bifenox | No | |
| Carbendazim | No | |
| Cyhalothrin, lambda- | No | Pyrethroid |
| Cypermethrin-alpha | **Yes (Cypermethrin)** | Pyrethroid |
| DDT, 24 | No | Organochlorine |
| Deltamethrin | No | Pyrethroid |
| Dichlorvos; DDVP | No | Organophosphate |
| Dinoterb | No | |
| Esfenvalerate | No | Pyrethroid |
| Imidacloprid | No | Neonicotinoid |
| Methiocarb | No | n-methyl carbamate |
| Permethrin, trans- | No | Pyrethroid |
| Pirimicarb | No | n-methyl carbamate |
| Pirimifos-methyl | No | Organophosphate |
| Spinosad | No | Spinosoid |
| Teflubenzuron | No | |
| Terbuthylazine, desethyl- (metabolite of Terbuthylazine) | No | |
| Thiacloprid | No | Neonicotinoid |
| Thifensulfuron-methyl | No | |

Sources: Top Ten Problem Substances Universiteit Leiden (CML) en Rijkswaterstaat-WVL http://www.pesticidesatlas.nl/ 08.09.2015 matched with Priority pesticides acc. Regulation 2013/39/EU). Chemical groups assigned per database of the author.

Figure 14 lists the 21 pesticides or metabolites that caused the highest number of water quality standard violations in the Netherlands in 2013. Many of these pesticides are highly toxic to aquatic organisms and act at least as an additive, meaning that the combined effect caused by the action of two or more agents is the same as the sum of the individual effects. These 'additive' effects can be - at least - assumed within the groups: pyrethroids; neonicotinoids; organophosphate + n-methyl carbamate). Pavlaki et al. (2011) discovered a more than additive (synergy) effect, when water fleas were exposed to a sub-lethal mixture of imidacloprid and thiacloprid. Ethylene thiourea (ETU) is an endocrine disruptor (Maranghi et al. 2013). Only three of the pesticides in Fig. 14 are listed as priority pesticide under Directive 2013/39/EU.

Fig 15: **Number of insecticides detected by station in the Netherlands 2013.**




Pesticides are usually found with other contaminants in the environment. The general contamination involves pesticides, biocides, pharmaceuticals, illicit drugs, sweeteners, household cleaners and industrial contaminants (see for Italy Meffe & de Bustamente 2014). For example, more than 30 insecticides were detected at 65% of sample points in the Netherlands (Fig. 15).

Pesticide contamination levels in the Netherlands are now so severe, especially with imidacloprid, that scientists assume a decrease of bird populations as a consequence (see Chapter 4). The Netherlands might be an extreme case, due to a combination of the large number of aquatic habitats and very intense agricultural production.

However, Italy and the Netherlands are not the only countries where pesticides are frequently detected in surface water above quality standards. Monitoring data from France shows that 37% of pesticide concentrations in watercourses did not comply with the quality standards established by the European Water Framework Directive for drinking water (0.5 µg l–1 for total pesticides) in 2011(Hossard et al. 2014).

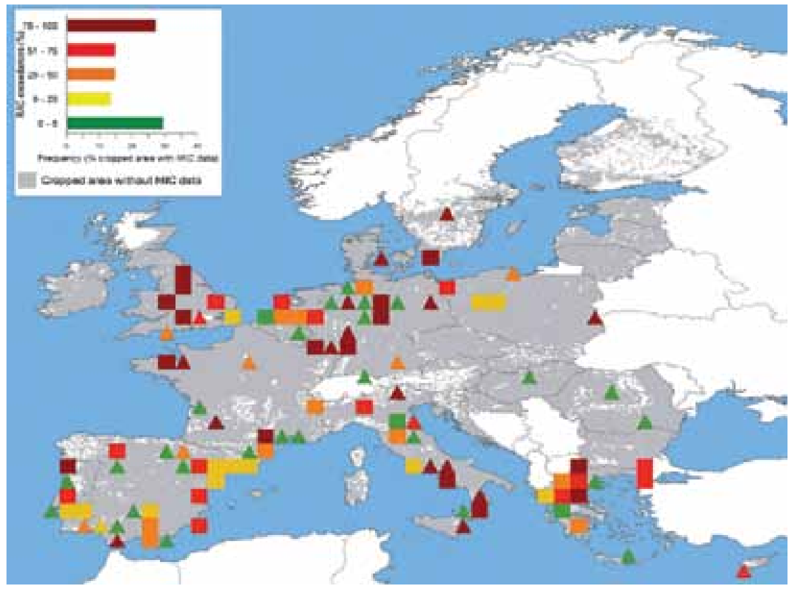
A meta-analysis by Stehle & Schulz (2015) of 165 peer-reviewed studies on agricultural insecticide concentrations in surface waters evaluated 1566 cases of measured insecticide concentrations (MICs) across Europe. The evaluation showed that in 44.7% of cases the measured concentration exceeded the regulatory acceptable concentration (RAC). The authors conclude that:

**"Current EU pesticide regulations do not protect the aquatic environment and that insecticides threaten aquatic biodiversity"**. Furthermore, the results show that the level of protection after the pesticide re-authorisation process and cancellation of many pesticides according to 91/414/EC (see Chapter 8), did not reduce the acute risks for surface waters caused by insecticides (ibid.).

The current exposure assessment, in particular the model which calculates the "*predicted environmental concentration (PEC)*", is not accurate enough and underestimates exposure of aquatic ecosystems (Stehle & Schulz - 2015).

Last year saw the publication of a similar critique, where real life measurements of insecticides (Knäbel et al. - 2012) and fungicides (Knäbel et al. - 2014) were compared with scenarios predicted by the FOrum for the Co-ordination of pesticide fate models and their Use (FOCUS) exposure models. The authors conclude that the models commonly used in risk assessment underestimate exposure and need an urgent re-think (ibid).

Fig 16: **Insecticide concentrations in Europe.**



Cropping area (grey) and the distribution of regulatory acceptable concentration (RAC) exceedance rates for the reported measured insecticide concentrations (MICs, n = 1,471), aggregated in 1° grid cells. Rectangles represent sub-classified cropped areas with five or more MICs, and triangles display grid cells with fewer than 5 MICs. Please note that 95 MICs could not be allocated to a specific grid cell due to the provision of imprecise location information in the studies. The horizontal bars in the legend illustrate the relative distributions of the respective insecticide RAC exceedance classes among the European cropped area with information on insecticide exposure. (With kind permission from Springer Science+Business Media: reprinted from Stehle & Schulz (2015), Figure S1, Page 8 of Suppl. Mat. © Springer-Verlag Berlin Heidelberg 2015)

The potential impact that pesticide concentrations can have is illustrated by Hallmann et al. (see Chapter 4) and by Beketov et al. (2014). Beketov et al. (2014) measured pesticide concentrations in small streams in Germany, France and Australia, at times, when exposure was expected, and also collected samples of aquatic organisms (macroinvertebrates) to assess species diversity. Results demonstrate that pesticides produce measurable adverse effects on the biodiversity of stream invertebrates in small streams. Furthermore, they concluded that the reference species for the current risk assessment (the water flea Daphnia magna) is not sensitive enough to represent other species. These findings were supported by Morrissey et al. (2015), who calculated that water flea were 2-3 orders of magnitude less sensitive than all other invertebrate species tested.

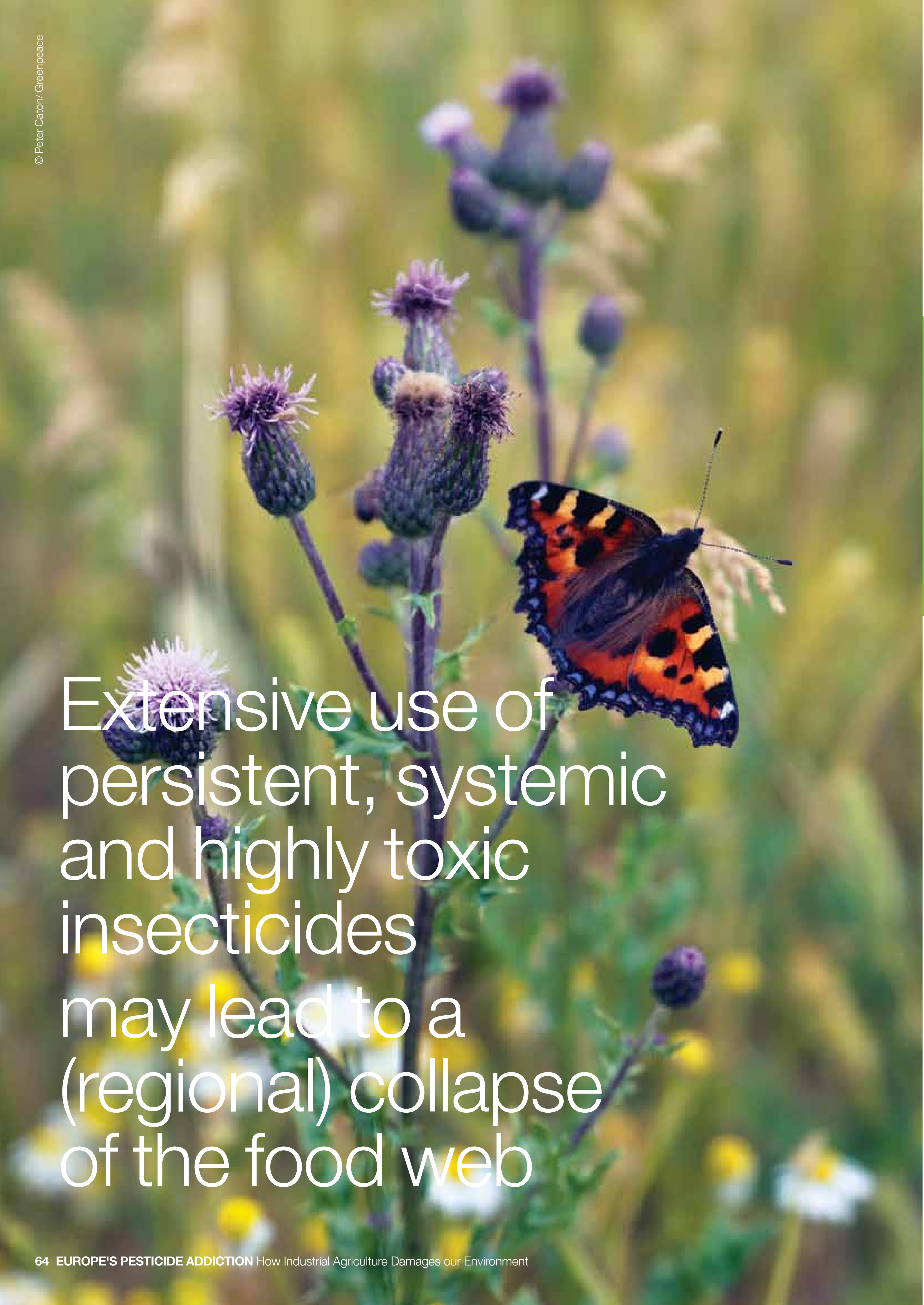
The effects observed by Beketov et al. (2014) cannot be associated with a single pesticide – is can be assumed that the mixture of pesticides caused the reduction in species diversity.

It has been well known for a long time that pesticides can act in an additive (1+1=2) or even synergistic (1+1=3 or more) manner. Pesticides with the same mode of action on a specific species (Fig.14) show (at least) additive effects. Synergies as well as antagonisms (1+1=0) are more rare (see review on synergism: Cedergreen 2014), but can also occur in mixtures. Leatz et al. (2009) investigated mixtures of three organophosphates and two n-methyl-carbamates on young salmon. All tested pesticides are neurotoxic and block the same enzyme (Cholinesterase). Both addition and synergism was observed with a greater degree of synergism at higher exposure concentrations. Synergism can also occur in mixtures with chemicals that are not related. Kretschmann et al. (2015) showed, for example, that a short-term exposure of water fleas to a pyrethroid insecticide followed by exposure to fungicides causes synergising effects reaching maxima several days after first exposure. Synergistic effects on a fish and a crustacean species (fathead minnow (*Pimephales promelas*) and the amphipod *Hyalella azteca*) were also observed by Lanteigne et al. (2015) after exposing the species to a mixture of cyfluthrin and imidacloprid. This could be of particular concern if that particular synergy can be extrapolated to pyrethroids (such as cyfluthrin) and neonicotinoids (such as imidacloprid) in general, because they commonly occur together in aquatic environments.

However, addressing the cumulative effect, rather than the much rarer synergistic effect of co-occurring chemicals by assuming a general concentration addition across all contaminants, should be regarded as the most important and appropriate step in the risk assessment of chemical mixtures (Cedergreen 2014).

A large variety of herbicides are commonly found in aquatic environments in relatively high concentrations, and there are probably many more that are undetected. EU monitoring focuses on a narrow spectrum, usually based on the requirements of the inadequate regulations. Since herbicides are designed to kill plants, their primary effect on aquatic communities should be on aquatic plants. Herbicides can affect algal growth and physiology, as well as community structure, but the responses to pesticide contamination vary greatly among compounds and their combinations and concentrations and the species/strains involved (Morin et al. 2009).

Different species of algae are known to have different sensitivities to pesticides. Eutrophic and small species are recognised for their tolerance to pesticide exposure and therefore pesticide use can alter species composition (Debenest et al. 2010, Morin et al. 2009), affecting the balanced interactions in ecosystems, which can lead to their disruption Although assessing the effect on algae in the field is extremely difficult, measurements of pesticide concentrations and observations on algal communities have shown that pesticides can change the structure of the local algal communities (Morin et al. 2009). Dorigo et al. (2004) observed a 'memory effect' both in herbicide sensitivity and in the structure of algal communities that persisted even when peak contaminations had disappeared.

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# 06 Pesticides and beneficial organisms

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Beneficial species in an agricultural context are species that serve as controls for agricultural pests like, for example, the larvae of ladybeetles feeding on aphids. Beneficial organisms like microorganisms, beetles or spiders play a key role in establishing ecosystems and their services.

Beneficial organisms comprise a broad spectrum of mammals, birds, amphibians, beetles, bees, wasps, spiders, earthworms, and soil microorganisms. Insects act as the main pollinators; soil organism and earthworms increase soil fertility by breaking down organic matter and creating more permeable soil. Foxes and predatory birds hunt mice and voles; bats, shrews and spiders prey on insects, and insects hunt or parasitise other insects. In the soil, predatory nematodes eat snail eggs or hunt other nematodes. The diversity of beneficial organisms is immensely large, and integral to a functional agro-ecosystem.

Because assessing the impact that pesticides have on beneficial organisms is such a large topic, this Chapter will focus on some more general aspects and provide some examples. In Chapter 4 we deal specifically with the impact of pesticides on birds, and Greenpeace has also recently published a review on the impact of pesticides on pollinators, specifically honey bees.[45]

Pesticides can interfere with beneficial organism in many different ways. They can directly poison organisms causing mortality or sub-lethal effects, or they can indirectly affect them.

The most commonly measured **direct effect (lethal)** is acute short-term mortality. Under laboratory conditions natural enemies are exposed to a pesticide and the survivors are counted after 1-3 days. The results of these tests are used to assess how toxic a particular pesticide is to natural enemies, but this method has serious deficiencies. Important aspects such as delayed toxicity, sub-lethal or indirect effects (see below) are not considered. In addition, results from one species are not representative for another - not even life-stages or sexes of the same species react in the same way. In addition, laboratory conditions do not always translate into field conditions, where organisms are exposed to multiple stressors.

Figure 17 compares the acute toxicity of nine insecticides to four parasitoid wasp species (adults). The organophosphate (OP) chlorpyrifos has the highest toxicity to all four species, followed by the pyrethroid bifenthrin. The selective insect growth regulators (IGR) are of lower toxicity to adult wasps. Fenpropathin shows the lowest acute toxicity among the pyrethroids (Pyr.) for the selected species.

*Aphytis melinus* is the most sensitive species to pesticides (except for *cyfluthrin)*. For two species, acetamiprid is of lower toxicity than the related thiamethoxam, but for *Gonatocerus ashmeadi* it is ten times more toxic than thiamethoxam.

Newer insecticides (spinosad, emamectin benzoate, dinotefuran, nitenpyram, tolfenpryrad) are not necessarily of lower acute toxicity. Ohta and Takeda (2015) showed mortality rates of over 95% for adults of the parasitic wasp Aphidius gifuensis on contact with residues of these pesticides.

Pekár (2012) conducted a meta-analysis on the toxicity of pesticides to spiders. He analysed results of experiments of almost 50 spider species and 130 pesticides (12 acaricides, 34 fungicides, 19 herbicides, 61 insecticides). Around half of the studies focused on direct lethality. The analysis showed that acaricides and insecticides, in particular organophosphate and pyrethroids,[46] caused significantly higher mortality than herbicides and fungicides. The effect is highly species specific and higher mortality was recorded in males compared to females and juveniles.

Pekár and Beneš (2008) showed that mortality in different spider species varied between 0 and 90% when exposed to pesticide spray residues. For one species the mortality gradually declined with the age of residues, while in another species the mortality increased. In two species the mortality declined up to 10-day-old residues and then increased so that 20-day-old residues caused almost as high mortality as the new residues.

Due to the high diversity of beneficial organism, their different life-stages and the high number of different pesticides, it is very difficult to make a general assessment on the acute toxicity of pesticides. However, more selective pesticides (e.g. entomopathogens, insect growth regulators, pheromones) are commonly less acutely toxic to non-target organisms, including natural enemies, than broad-spectrum pesticides.

The strongest **indirect effect** for parasitoids and predators might be the reduction of food sources - as a "pest" may be the staple food of another animal. Therefore, very effective pest management practices, which wipe out essential parts of a food-web will indirectly affect all dependent species. **Extensive use of persistent, systemic and highly toxic insecticides may lead to a (regional) collapse of the food web, if no countermeasures are taken.**

Fig 17: **Acute toxicity (LC50) of four parasitoid wasp species to nine insecticides.**

| | LC50 (microgram a.i. /ml) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Systemic (neonicotinoids) | | | non-systemic (OP, Pyr.) | | | | IGR | |
| | acetamiprid | Imidacloprid | Imidacloprid | Chlorpyrifos | Bifenthrin | Cyfluthrin | Fenpropathrin | Buprofezin | Pyriproxifen |
| Parasitoid Species | 48 h | 48 h | 24 h | 24 h | 48 h | 48 h | 48 h | 96 h | 96 h |
| Eretmocerus eremicus | 108,27 | 1,01 | 1,93 | 0,012 | 0,011 | 0,096 | 111,42 | 120,41 | 95,56 |
| Encarsia formosa | 12,02 | 0,397 | 0,98 | 0,017 | 0,015 | 0,063 | 120,48 | 98,15 | 60,51 |
| Gonatocerus ashmeadi | 0,134 | 1,44 | 2,63 | 0,006 | 0,01 | 0,067 | 166,88 | 315,52 | 132,53 |
| Aphytis melinus | 0,005 | 0,105 (24 h) | 0,246 | 0,0008 | 0,001 | 0,007 | 0,01 | 0,764 | 0,421 |

Source: Prabhaker et al 2007; Prabhaker et al. 2011
(Note: there is a unit error in the original publication by Prabhaker et al. 2011 as it uses LC50 (mg [AI] /ml) as a toxicity unit, but the text always refers to microgram (µg): "The LC50 values expressed as micrograms").

This kind of population effect (see review by Stark & Bank 2003) is not considered by current risk assessment. Stark et al. (2007) therefore suggested that the growth of populations of natural enemies should be used as a more precise risk indicator for the authorisation of pesticides.

Another indirect effect is caused by the use of herbicides. Weeds provide shelter and habitat for natural enemies. They create a microclimate that benefits predators, and for web-building spiders weeds provide the architecture for webs. Haughton et al. (1999) found that, following the application of the herbicide glyphosate, the abundance of a particular web-building spider decreased by 50% due to a change in vegetation density.

**Sub-lethal effects** of pesticides encompass a large range of symptoms. Pesticide exposure below fatal concentrations can affect locomotion, development, orientation, mating behaviour/sex ratio, foraging behaviour and the immune system (for a review on arthropods see Desneux et al. 2007, for spiders see Pekár 2012). Pekár and Beneš (2008) showed, for example, that spiders seem to avoid surfaces treated with some common insecticides, which may result in a delay of the re-population of sprayed areas.

Kunkel et al. (2001) showed that exposure of ground beetles to imidacloprid caused a high incidence of sub-lethal, neurotoxic effects, including paralysis, impaired walking, and excessive grooming. Intoxicated beetles usually recovered within a few days in the laboratory, but in the field, they were shown to be highly vulnerable to predation by ants.

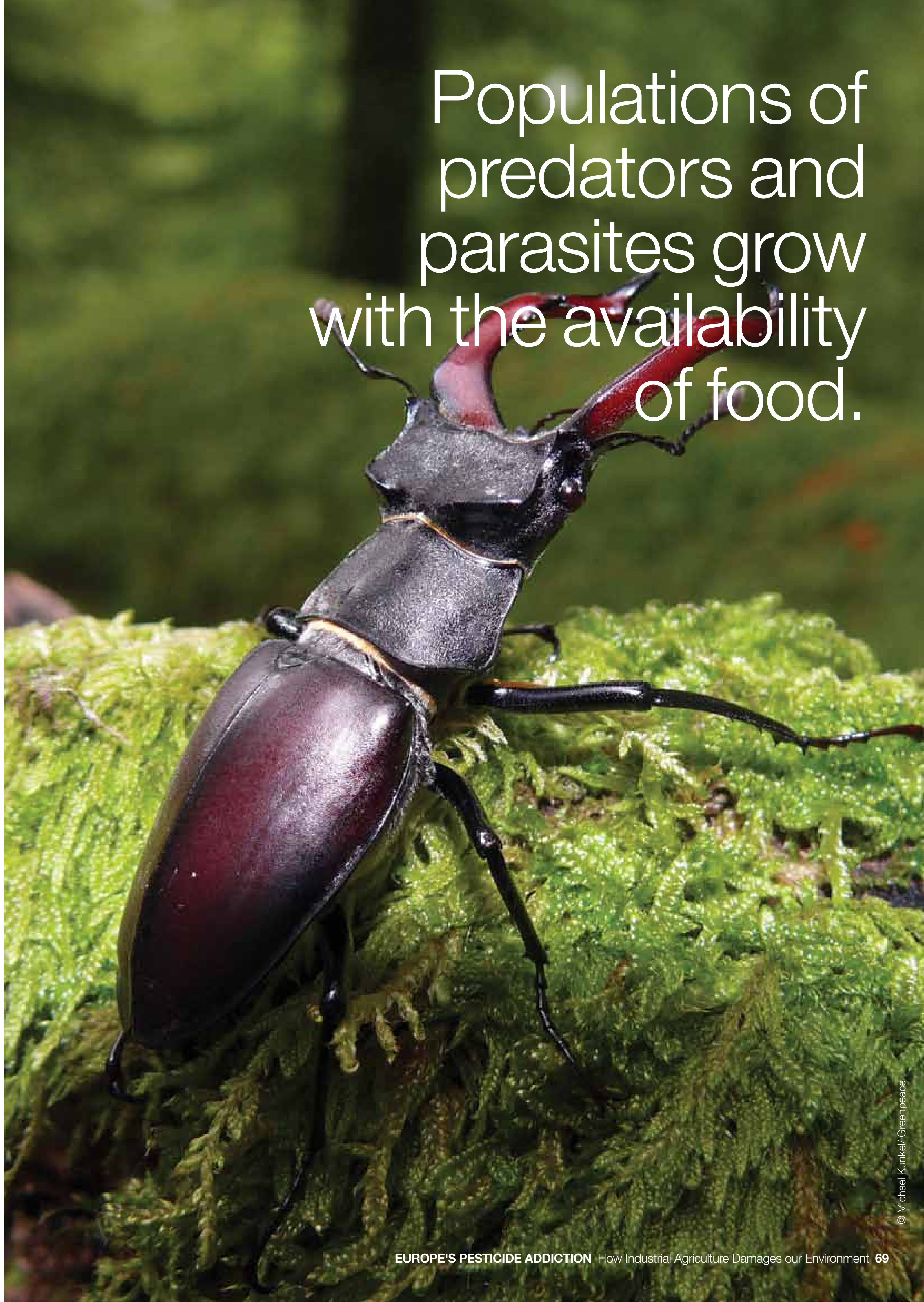
## When pesticides use benefits pests

When a pest population builds up, the size of the natural enemy population commonly lags behind. Populations of predators and parasites grow with the availability of food. Ecologists refer to this as a prey-predator oscillation, which are in synchrony.

When a pesticide is applied to control the pest it can seriously disrupt the synchrony. In a worst case, pesticide applications create a uniform pest age-structure, because susceptible life-stages are frequently eliminated. Parasitoids, which play a major role in natural pest control, often need specific life-stages and if these are not available the pest reproduces undisturbed. Examples of catastrophic pest resurgence due to a disrupted pest-natural enemy synchrony are frequently observed (see e.g. Dutcher 2007).

Some pests, weeds, or diseases survive pesticide applications because they are resistant. Resistance is an evolutionary process and can neither be anticipated nor prevented as long as chemical control dominates. The likelihood of resistance increases with higher frequency use of similar pesticides. Pesticide resistant pests and weeds are extremely common and pose a serious challenge. An investigation in Greece showed that within one year entire populations of the cotton bollworm became resistant against three pesticides groups (organophosphate, carbamates and pyrethroids), (Mironidis et al. 2013). Since decades (Hoy, 1998) scientists demand that pesticide use should be reserved for situations where it is truly needed – as tool to subdue an unexpected pest population outbreak.

In some cases, it seems sub-lethal pesticide exposure benefit specific pest species. Cutler et al. (2009) showed that green aphids (Myzus persicae) exposed to sub-lethal concentrations of imidacloprid and azadirachtin stimulates reproduction in the green peach aphid or the peach-potato aphid, M. persicae, and Barati and Hejazi (2015) confirm the findings of other researchers (e.g. James & Price 2002; Castagnoli et al. 2005; Zeng & Wang 2010; Smith et al. 2013), which showed that neonicotinoid insecticides enhance reproductive rates of spider mites (Tetranychus spp.), a serious pest.

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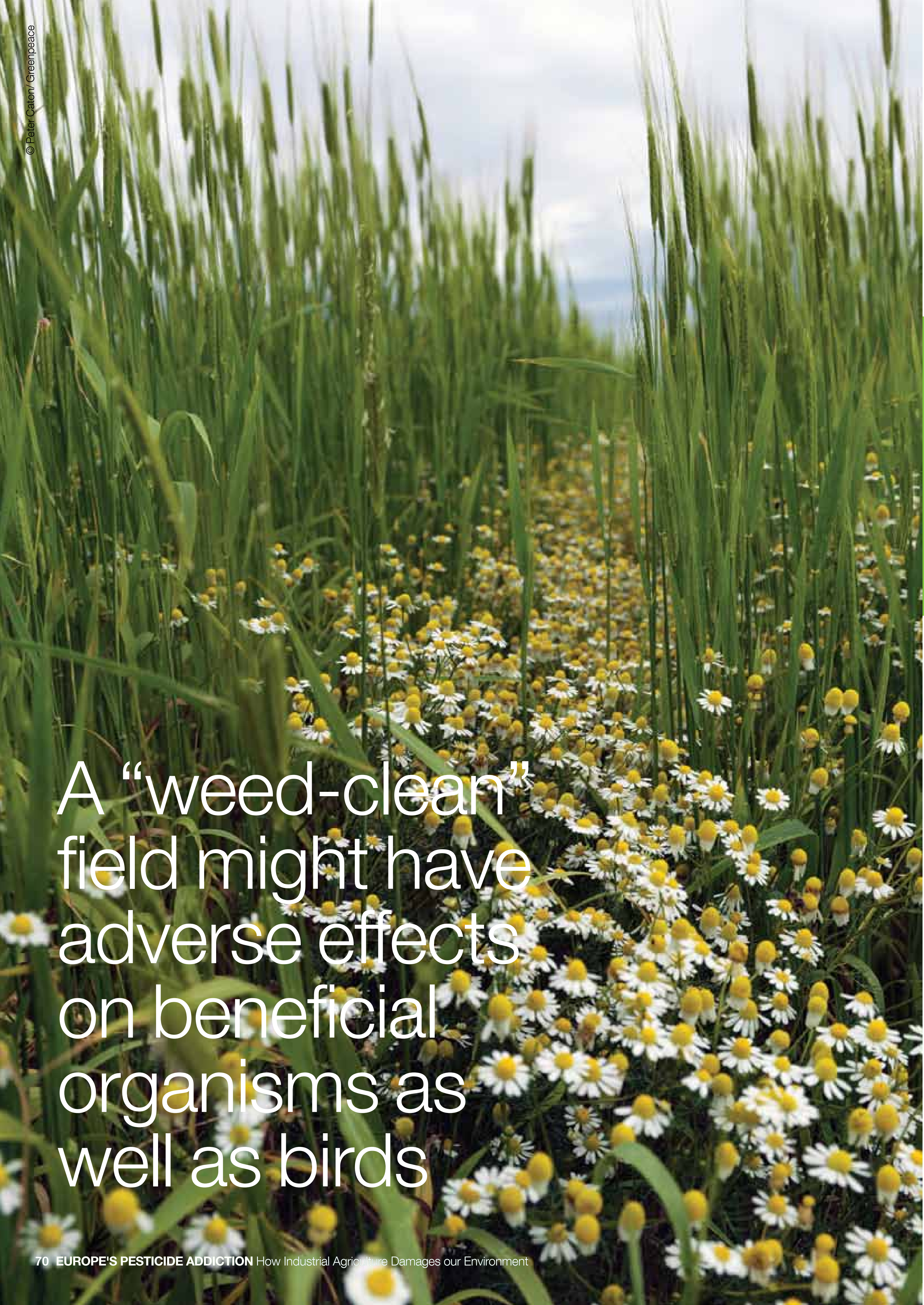





# 07

# Pesticides and plants


Plants build the foundation for most life forms on earth. Via photosynthesis they produce oxygen and provide nutrition, on which almost all other trophic levels depend. Pesticides were initially created to protect certain plants from damaging pests and diseases. Herbicides, designed to kill plants and to reduce competition from weeds, are a rather new development (1940's). Despite often being referred to as *plant protection products*, pesticides can adversely affect plants both directly and indirectly.

When insecticides affect pollinators, which are essential for the reproduction of plants, they can indirectly affect the abundance of seeds, nuts and fruits. Herbicides running off or drifting away from fields may also harm non-target plants.

The highest impact on plants is probably directly on the fields. Herbicides are designed to kill unwanted herbs and continued use changes species composition on arable land. Non-selective and systemic herbicides, like glyphosate and glufosinate, basically kill all (non-resistant) plants entirely, while other herbicides "burn down" all green parts they touch. Over the last years it has become standard practice in arable crop production to apply non-selective, systemic herbicides like glyphosate and glufosinate between rotation. After crop emergence numerous selective herbicides are available. About a quarter of all pesticide active ingredients approved in the EU are herbicides (EU Pesticide Database 2015).

A "weed-clean" field might have adverse effects on beneficial organisms as well as birds (see Chapter 4). An investigation in France showed for example that the diet of honey bees largely depends on flowering weeds in periods where flowering of crops (sunflower and rape in that case) already ceased (Requier et al. 2015). Flowering weeds may diversify a potentially unhealthy monotonous pollinator diet (Goulson et al. 2014) from crops. Herbicide use can potentially disrupt that interdependence between plants and pollinators.

Fig 18: **Comparison of historic and recent plant diversity on fields**

| | | | | Average Number of Species | |
|---|---|---|---|---|---|
| Start of Study | End of Study | Country | Crops | Historical | Recent |
| 1968 | 2006 | France | All | 16.5 | 9.3 |
| 1960 | 2011 | Germany | All | 24 | 13 |
| 1949 | 2006 | Slovak Rep. | All | 14.7 | 17.7 |
| 1976 | 2005 | Czech Rep. | All | 32.86 | 17.71 |

Source: Richner et al. (2015)

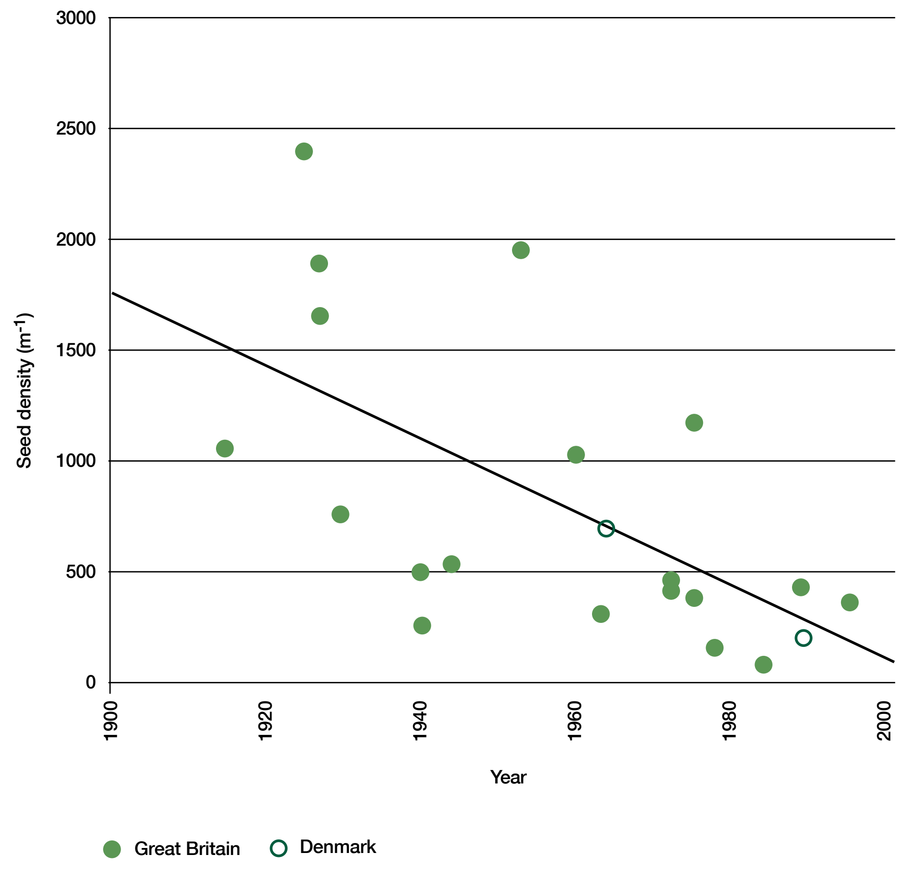
There are many factors influencing weed flora: choice of crop, type of crop rotations, tillage, fertilisation, introduction of invasive species and machinery. That the weed species composition has changed over the last decades is evident, but there are few European wide statistics on species composition and abundance on the change of arable, non-crop plants.

A recently conducted meta-analysis showed a decline of arable plant species numbers across Europe, and a shift towards species preferring nutrient-rich sites, neophytes and monocotyledons (grasses), (Richner et al. 2015). The meta-analysis shows some gaps: there is limited data for southern Europe and more recent data is missing, which makes it difficult to interpret the entire meta-analysis. Figure. 18 compares the average number of plant species found in fields at the beginning of a study and 40-50 years later. In three out of the four cases the number of species declined. In Slovakia, the number of species increased, but while rare species declined, the proportion of nitrophile and/or invasive species rose (Májeková et al. 2010).

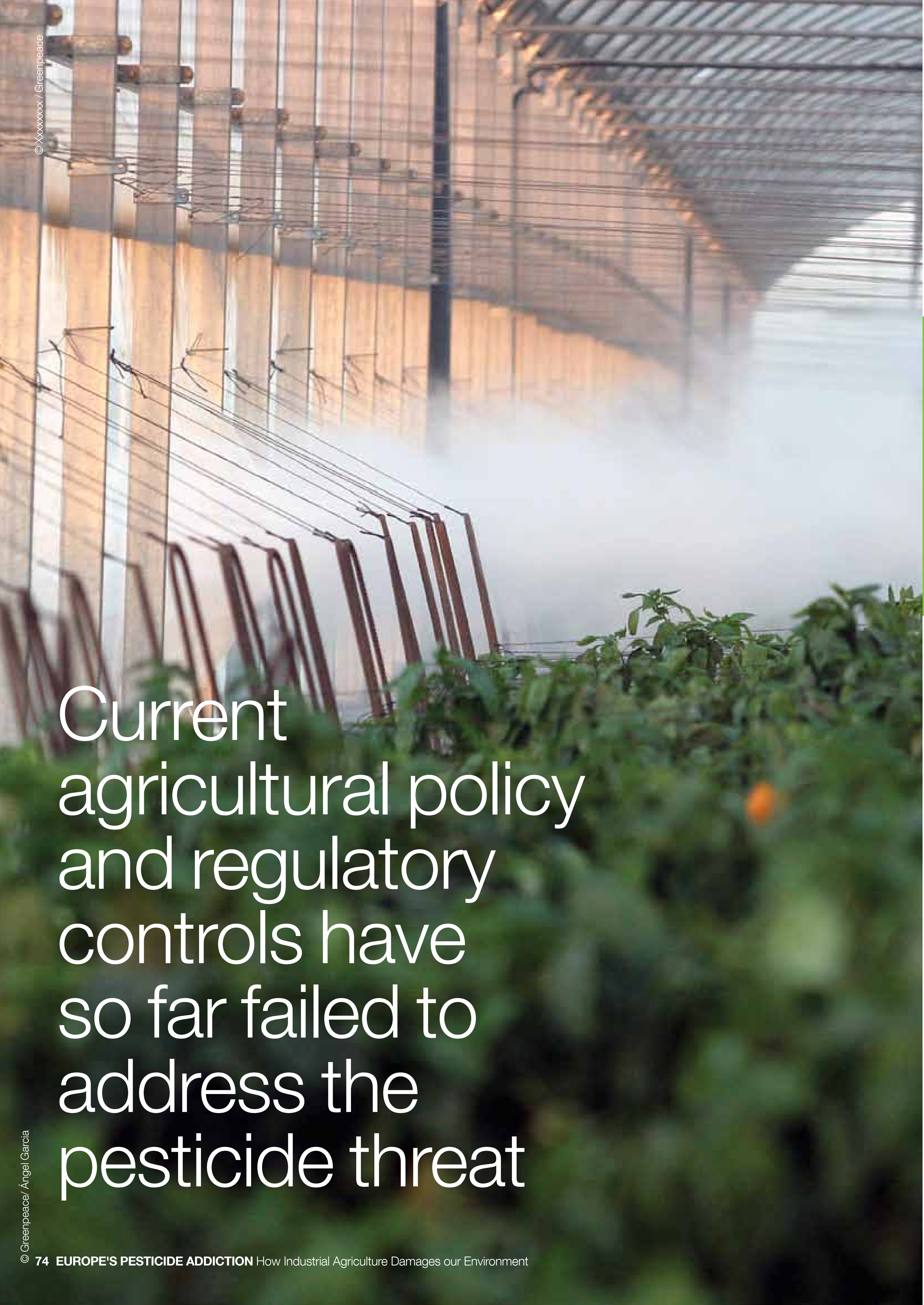
Plant species preferring nutrient-rich sites, neophytes and monocotyledons (grasses), generally increased since 1980, while characteristic or threatened species of arable weed communities further declined.

The contribution of herbicide use to species decline is not discussed by Richner et al. 2015 or Májeková et al. 2010, although the latter mentions an increase of herbicide resistant weed species. Weed abundance is also not discussed. Robinson & Sutherland (2002) showed that the seed density in soils in England and Denmark strongly declined (Fig. 19), but this data is older and recent changes in agriculture, such as more conservation tillage, more use of non-selective, systemic herbicides, increased herbicide resistance, invasive species, make a trend evaluation difficult.

Fig 19: **Seed bank density in Great Britain (full circles) and Denmark (hollow circles) over time**
(Robinson & Sutherland 2002, Reprinted by permission John Wiley and Sons, Copyright ©2002 )




Basically, there are opposing forces: conventional farmers apply herbicides one to three times a year, but some plants adjust genetically and become resistant. In 2004, Moss (2004) already counted 55 weed species in 21 European countries resistant to herbicides. On a global scale, about 220 weeds became (locally) resistant (Heap 2014). The typical solution of the current chemical-intensive agriculture system is to increase the intensity and frequency of product applications, including adding three or four active ingredients to tank mixes. Non-chemical methods are tillage (ploughing) and a diverse crop rotation.



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## Current agricultural policy and regulatory controls have so far failed to address the pesticide threat

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# 08 Pesticide use and risk reduction

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This report clearly demonstrates that the environment is still under severe threat from chemical pesticides, as these synthetic compounds are degrading many of the ecosystem services that are crucial for maintaining environmental health. Current agricultural policy and regulatory controls have so far failed to address the pesticide threat.

In order to put the brakes on the accelerating loss of biodiversity caused by industrial agriculture, urgent changes are needed, which promote the uptake of ecological agriculture to replace the current destructive chemical-intensive food production system. A lack of action now could not only further damage the biodiversity of our planet, but also agricultural production, by diminishing ecosystem services such as pollination and natural biological control.

## Key measures to be taken as a priority:

**01** Put in place effective policy mechanisms at EU and national levels encouraging farmers to substantially reduce pesticides use.

**02** Ensure a rigorous implementation of the Sustainable Use of Pesticides Directive.

**03** Improve the EU authorisation process for pesticides by strengthening risk assessment systems and refocusing regulatory measures on risk reduction (e.g. rejecting approvals of particularly hazardous chemicals, limiting the number of approved uses and/or setting stricter conditions for use such as sufficiently broad buffer zones).

**04** Switch public money currently fuelling environmentally harmful farm subsidies towards promoting ecological farming.

# Pesticide use reduction at farm level

There are many ways to prevent damage by pests, diseases and weeds at a farm level. Most of them are well known, efficient and were once common practice (e.g. crop rotation). In most cases they are not competitive - in conventional agriculture - under the current economic settings.

There is exhaustive literature on environmentally friendly pest control (see e.g. Hajek 2004, Jervis 2004, van Driesche and Bellows 1996, Howse et al. 1998, Wood et al. 1970), therefore only some key measures, which prevent pest problems are outlined here. Specific techniques like release of biocontrol organisms, lower-risk pesticides, biofumigation, solarisation, crafting (applied in vegetable production) etc. are not discussed.

# Convert to ecological agriculture

Synthetic chemical pesticide use is zero in arable organic crops in Europe (Lechenet et al. 2014). However, some organic crops may be treated with pesticides registered for organic production like Spinosad or Pyrethrum-based solutions, e.g. potatoes and rape seed. Copper salts and sulfur remain important fungicides mainly in grapes, some fruits and potatoes, but the solutions of microbial antagonists or more important, fungi tolerant/resistant varieties need time for development and acceptance on the consumer side. Direct marketing and food processing are one way to establish a market for non-standard varieties.

While organic agriculture in a market economy relies on the same market mechanisms, the negative side effects are less severe (Lechenet et al. 2014; Gomiero et al. 2001; Reganold 2001), and as a recently published meta-analysis (Crowder & Reganold 2015) shows, it is more profitable compared to conventional agriculture. While yields per area are equal or not significantly lower, depending on the crop (see also Seufert et al. 2012; Reganold 2001), the lower costs for inputs and the premium prices outweigh the smaller production volume.

In times of higher climatic variability, organic agriculture is the safer way. Soils in the organic systems capture and retain more water (Gomiero et al. 2001).

# Soil management - build a sustainable foundation

Sustainable farming is based on the efficient management of soil and continuous improvement of soil quality. Soils high in organic matter, an active soil biology and little disturbance, develop a rich diversity of disease and weed-suppressive bacteria (Kremer & Li, 2003; Peter et al. 2003). Such soils provide good soil fertility and plants exhibit a lower abundance of insect herbivores (Altieri & Nicholls 2003). Several key techniques are used to establish and maintain healthy soils: crop rotation, di-or poly culture including green manure and adding organic matter (compost), and reduced tillage/ploughing. Although, it might be sometimes necessary to reduce, prevent disease or weed pressure.

# Crop rotation

Crop rotation increases biodiversity both within and above the soil. Noxious diseases, pests, and weeds become established more slowly, because specific relationships between crops, weeds and pests are interrupted. Furthermore, crop residues are often host to pathogens or overwintering pest stages and alternating crops will prevent the accumulation and infection from residues to the host crop. In some crops, like potato and oilseed rape a 3-4 year pause of production on the same site is good practice to prevent the build-up of diseases and to restore soils (Carter et al. 2009, Walters [ed.] 2009). Certain crops can actively suppress diseases and weeds. Others such as legumes increase soil nitrogen and bacterial activity and thus increase yield (Zou et al. 2015). In general, the benefits of crop rotation are higher for controlling diseases and pests when crops are botanically not related to each other. Certain diseases can persist in soils for a long time and have a wide host range, therefore each rotation management has to be adjusted to the local situation (Walters [ed.] 2009). The biggest constraint to crop rotation are market demands and subsidies - agricultural corporations often reduce the number of crops only to those that are most profitable.

# Poly- or dicultures instead of monocultures

The low genetic variability and biodiversity in modern monocultures grown with hybrid seeds and treated with herbicides, makes that cropping system more susceptible to pests and diseases. A meta-analysis by Letourneau et al. (2011) showed overwhelming support for pest suppression, natural enemy enhancement, and decreased crop damage in diversified cropping systems (see “Tolerate and increase biodiversity“).

Mixing different cultivars of the same crop is the simplest form of disrupting a monoculture and can have a positive effect on disease pressure, as well as being easily implemented. One of the most common forms of di-culture is probably the use of cover-crops like clover under the main crop. More advanced forms mix different crops (Fernández-Aparicio et al. 2010).

Although intercropping has many benefits it is not easily adopted by arable farmers beyond traditional cover crops, there are technical issues (harvesting methods) and a lack of knowledge transfer.

## The benefits of moving away from monocultures

In general, growing more than one variety or crop on one plot/field has several effects on pest, weed and disease pressures:

**01** Dilution effect - an increasing distance between susceptible plants slows down the speed of infection (Castro 2007; Sapoukhina et al. 2010),

**02** Barrier effect - the presence of more disease resistant plants provides a physical barrier against fungal spore movement,

**03** Induced resistance - when plants are “attacked” by pest or diseases they emit biochemical compounds and neighbour plants raise their defense mechanisms. The presence of susceptible and less susceptible plants in one field supports that process,

**04** Modification of the microclimate - the presence of cultivars or species with different habitus (e.g. heights, leaf position) can modify the microclimate towards less favourable conditions for diseases (Castro 2007; Fernández-Aparicio et al. 2010),

**05** Shadow and/or competition effect - weeds can be suppressed when different crops or other beneficial plants (e.g. clover) outcompete weeds by occupying space or closing the canopy,

**06** Repellent effect - certain plants repel arthropod pests of the neighbour plants,

**07** Habitat delivery - intercropping with specific mixtures can provide food and shelter for natural enemies of arthropod pests of the main crop (Smith & Liburd 2015; Parolin et al. 2012; Iverson et al. 2015; Sunderland & Samu 2000).

# Tillage

No-tillage or minimum tillage often leads to an accumulation of pathogens in crop residues and of weed seed. In combination with monocultures (no crop rotation), conservation tillage leads to the necessity of chemical pest and weed control. Tillage, specifically ploughing, can bury weed seeds, pathogens and pests living in crop residues, and “immobilise” them. In arable organic agriculture ploughing is one of the key phytosanitary measures. However, ploughing also has many disadvantages and research is ongoing on how to reduce ploughing in organic agriculture without compromising yields (FIBL 2014). In conventional farming, the cautious use of (shallow) ploughing should be considered for integrated pest control and weighed against the agro-ecological disadvantages of pesticide use.



# Tolerate and increase biodiversity

Natural pest control is a free ecosystem service of great value (Cardinale et al. 2003). For the USA, these “services” have been valued at $13.6 billion per year (€ 12.3 billion) , (Losey & Vaughan 2006). Pesticide use is increasingly disrupting that service and measures at farm level are needed. Pesticides should only be used if unacceptable economic damage is anticipated and then the pesticide least harmful to other organisms should be applied (e.g. selective biological products or pheromone traps/dispensers).

Non-spray strips with reduced fertilisation benefit general biodiversity, and they are also a valuable refuge for natural enemies (Nash et al. 2008; Sunderland & Samu 2000). They are particularly important on large fields.

On large, less complex farms (large continuous fields) new landscape elements should be established and habitats (e.g. hedgerows, wildflower areas, flower strips) created (Fiedler et al. 2008; Schmidt-Entling & Döbeli 2009; Langelotte & Denno 2004). That enhancement of on-farm biological diversity for the purpose of enhancing biological control is called “farmscaping or conservation biological control”, and numerous practical reference guides as well as commercial solutions (seed mixtures attracting beneficial insects) are available (Philips et al. 2014, Landis et al. 2000). Research in Switzerland demonstrates the high effectiveness of annual flower strips in promoting pest control, reducing cereal leaf beetle pest levels below the economic threshold. The authors conclude that the studied flower strips offer a viable alternative to insecticide use in cereals (Tschumi et al. 2015).

In orchards and other crop areas, birds play a significant role in insect control (Mols & Visser 2002). Providing habitat, nest boxes, perches and feeding places to barn owls can, for example, create effective rodent control. Bats feed on nocturnal moths (such as the apple codling moth) and while there seems to be no experience in establishing them for pest control, they need to be protected and supported (Boyles et al. 2011).

# Robust varieties

In perennial cropping systems, especially vineyards and orchards, crop rotation and sanitary tillage is not an option. A key solution to avoid disease problems is the choice of the variety. There are many old and new varieties, which are tolerant or resistant to diseases. Constraints by consumer and/or retailers can be met via direct marketing and communication.

# Policy level

## The Common Agricultural Policy fails to meet its objectives

The EU Common Agricultural Policy (CAP) is probably the largest continuous subsidy scheme in European history. Between 1991 and 2013, CAP expenditure averaged € 50-60 billion euro per year,[47] and another € 312.7 billion is planned for 2014-2020. Established to ensure food safety after World War II and to protect the European market from competitors, CAP rapidly created a large overproduction and many negative side effects. Several reforms took place,[48] but neither socio-economic goals nor serious environmental objectives have been achieved so far. As a matter of fact the number of agricultural holdings dramatically decreased, while large farms grew larger and farmland birds continued to disappear.

The current system seems to benefit large scale, input intensive agricultural production and has led to an increase in pesticide use (see Chapter 2 on Pesticides Use).

All EU-wide and national subsidies should be checked for their potential impact on the environment and should be withdrawn from farming systems which cause high external environmental and societal costs. For the UK, the annual costs of contamination of drinking water have been estimated at £ 120 million (€ 162.37 million), the annual total external environmental and health costs of UK agriculture at £ 2.34 billion (€ 3.17 billion) for 1996 alone (range for 1990-1996: £1.15 - 3.9 billion), (€ 1.55 - 5.29 billion), (Pretty et al., 2000). For instance, it is crucial that subsidies directly or indirectly encouraging farmers to avoid/reduce crop rotation are cut. The current requirement that farms greater than 10 ha have to grow at least three crops per year is not sufficient. In areas where large farms, with areas of thousands of hectares dominate the landscape, such a requirement fails to meet its objective, because vast areas of mono-cropping continues to be possible. Subsidies aimed at increasing agricultural diversity need to be more landscape oriented, not simply focusing at farm level, and must encourage the development of practices providing real environmental benefits. This would mean prioritising subsidies for farms and regions that favour high structural diversity, increased biodiversity, ensuring proper soil and water management, enhancing natural pest control, while reducing subsidies for areas with, for instance, little biodiversity, large monocultures and limited crop rotations.

Agri-Environmental Schemes (AES), which are part of the CAP, must receive more funding and should be fully coherent with the EU strategy on biodiversity, for instance by re-establishing ecosystem services such as those performed by biological control agents. Measures that support organic farming methods and other measures aimed at reducing pesticide use (see Chapter 2) must be prioritised.The conversion from conventional to organic farming is a costly process, which also involves a lot of individual learning. More financial support is needed to compensate farmers for financial losses during the conversion period as well as for organic extension services.

# National level

## Taxation

Pesticide use is associated with biodiversity-loss and with declining ecosystem services (biological control, pollination, eco-tourism), pollution of ground water, and pesticide residues in food. Economically speaking, these negative costs represent a market failure and have to be internalised. Currently the best way to internalise external cost is by imposing taxes. The tax rate has to be bound to the toxicity and mobility of each pesticide - highly toxic and/or highly mobile pesticides have to be taxed more highly. Denmark[49] and Norway[50] have already adopted this approach. Such a tax aims at both creating a disincentive, discouraging the use of highly toxic pesticides, as well as gathering revenues for essential activities such as monitoring pesticides, compensating farmers for financial losses during the switch, and farmers' training (see below).

## Education

Non-chemical alternatives exist and are increasingly practiced at farm level. However, the available knowledge often does not get to farmers. Highly relevant scientific journals like "Biological Control"; "Applied Ecology" or the "Journal of Integrated Pest Management" increasingly publish research on alternatives to pesticides but such knowledge has to be more accessible to farmers. Independent extension services must be the link between science and agricultural practice, "translating" scientific knowledge for farmers. Public extension services (advisory services) need more resources and encouragement for continuous learning. Improvements in extension services could be funded from the pesticide tax, so that farmers would be benefitting directly (see above).

# Improvements to the pesticides authorisation system

Under EU law pesticides' active ingredients are authorised at EU level. Regulation 1107/2009/EC setting up the authorisation process introduced two significant innovations:

1. **Exclusion criteria** – pesticide active ingredients can be refused authorisation due to their potential hazards and/or intrinsic properties;
2. **Comparative risk assessment** in connection with the principle of substitution – pesticide active ingredients which are more hazardous in comparison to others have a shorter authorisation period.

**These provisions go in the right direction but are not enough to address all the environmental problems caused by pesticides and their use. Urgent action should be focused on improving the following four main areas of concern:**

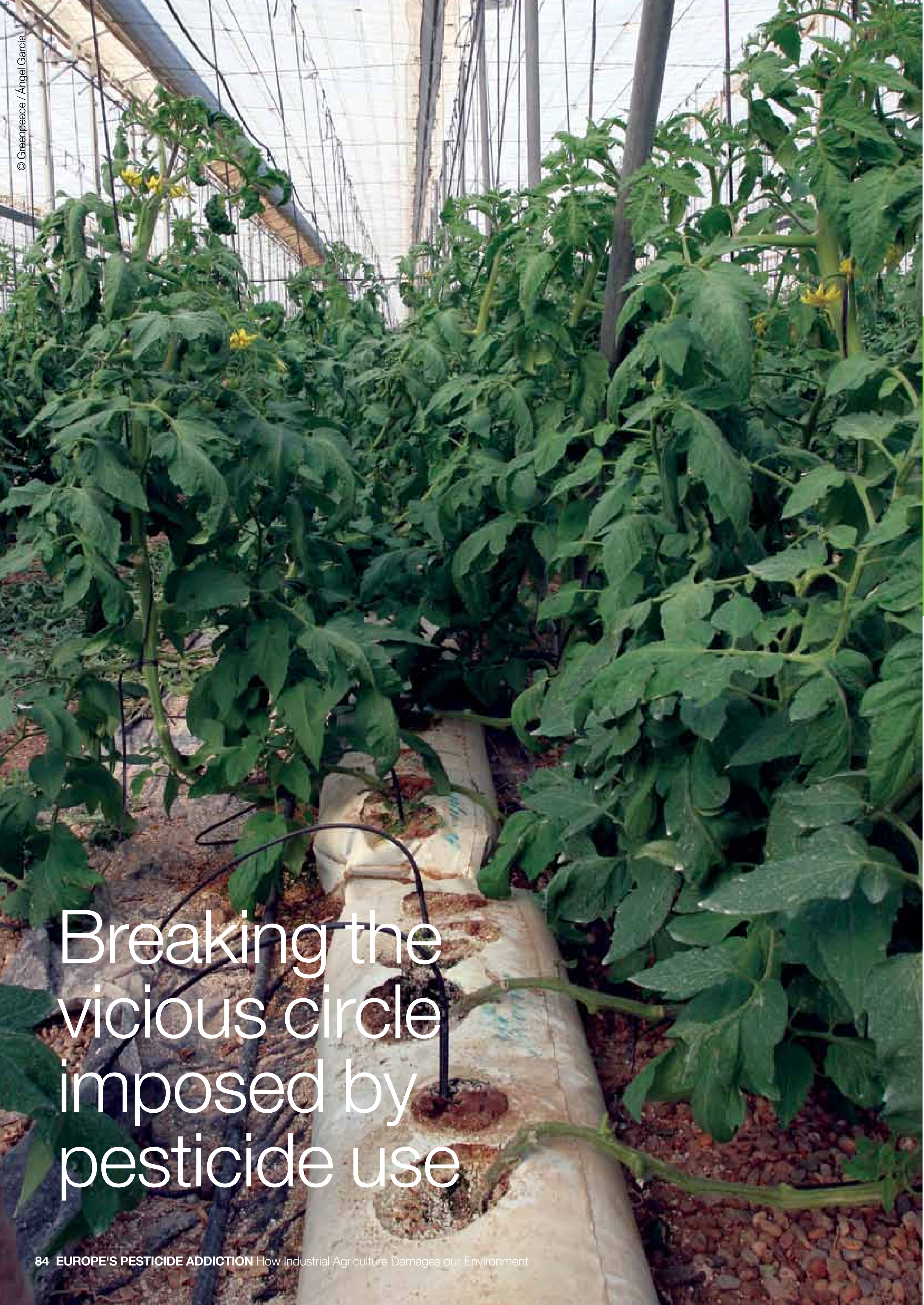
1. The current risk assessment process does not consider pesticide impacts on the whole eco-system. Population effects caused by the disruption of the food web are not reflected. Sub-lethal effects are generally underestimated.
2. Despite the fact that ecosystems are routinely exposed to pesticide cocktails, rather than only single pesticides, the cumulative effects caused by such exposure are not taken into account as part of risk assessment systems .
3. Safety testing is commonly conducted on species rather not sensitive to pesticide exposure and therefore risk assessment fails to provide the necessary information to evaluate pesticides impacts on more sensitive species.
4. Models applied to calculate potential environmental exposure do not correctly anticipate the real field exposure and lead to inappropriate risk management decisions (see Stehle S & Schulz 2015; Knäbel et al. 2014; Knäbel et al. 2012).

**From a purely scientific point of view part of these problems can be answered:**

1. The exclusion criteria according covered by regulation 1107/2009/EC need additional criteria, which reflect impacts on ecosystems and population effects. Systemic non-selective insecticides and herbicides should be excluded from authorisation and the authorisation process at EU level. They pose a hazard to entire populations of non-target organisms simply by the way (systemic and non-selective) they act.
2. Cumulative effects are already known for many pesticides and pesticide groups. Organophosphate insecticides (cholinesterase inhibitors), all neonicotinoids and all pyrethroids have, within their group the same mode of action (see table 4) and show additive effects on arthropods, mammals, birds and fish. In general, multiple exposure and concentration addition has to be considered in risk assessment. Methods for the evaluation of cumulative effects are known and available, (e.g. hazard index [HI]; interaction-based Hazard Index; relative potency factors [RPFs]; response/ concentration addition etc. [Løkke et al. eds. 2010; MacDonnell et al. 2013]) they need to be incorporated in the authorisation process.
3. The use of chemical tolerant (insensitive) species in risks assessment (see Mineau et al. 2013 and Morrissey et al. 2015) should be addressed by either new and/or higher uncertainty factors/ assessment factors or by consideration of species specific Hazard Quotients (see Mineau et al. 2013).
4. All pesticide active ingredients, especially newly authorised, must be subject to monitoring in the environment for five years at the expense of the manufacturer (post authorisation monitoring). This is the only way to discover errors in the exposure models used during the risk assessment process.

Fig 20: **Examples of neurotoxic Insecticides authorised in the EU with cumulative effects**

| Blocker of the GABA-regulated chloride channel | Cholinesterase inhibitors | Closure of sodium channels |
|---|---|---|
| Neonicotinoids | Cholinesterase inhibitors | Pyrethroids |
| acetamiprid | Organophosphates | Acrinathrin |
| Clothianidin | Chlorpyrifos | Bifenthrin |
| Imidacloprid | Chlorpyrifos-methyl | Cyfluthrin, beta |
| Thiamethoxam | Dimethoate | Cypermethrin |
| Thiacloprid | Ethoprophos | alpha-Cypermethrin |
| | Fenamiphos | Deltamethrin |
| | Malathion | gamma-Cyhalothrin |
| | Phosmet | lambda-Cyhalothrin |
| | N-methyl Carbamates | zeta-Cypermethrin |
| | Formetanate | |
| | Methiocarb | |
| | Methomyl | |
| | Oxamyl | |
| | Pirimicarb | |



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# Breaking the vicious circle imposed by pesticide use



# 09 Recommendations

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**A wide body of empirical scientific research, already provides irrefutable evidence of the environmental impacts that pesticides cause.** This indicates once more the urgent need to move away from the current chemical dependency of industrial agriculture. The widespread presence of pesticide residues in ecosystems, with its both, known and as yet unknown consequences, makes it obvious that the only way to avoid the risks and dangers posed by pesticides use is to phase out their use in agriculture. Non-chemical alternatives to pest management are already available to farmers but need the necessary political and financial support to be mainstreamed. **Only by reducing pesticide use and ultimately converting farming systems to ecological farming practices will it be possible to address the ecological and economic problems that agriculture currently faces.**

In order to drive the needed change the following measures must be put in place as a priority:

- **Breaking the vicious circle imposed by pesticide use**. Focusing on functional agro-biodiversity is a key element. Choosing resistant varieties adapted to local conditions, setting up serious crop rotation schemes, diversifying agricultural systems at field and landscape level, improving soil management methods and implementing biological control of pests can replace pesticide use in agriculture.

- **Ensuring proper implementation of the directive on the sustainable use of pesticides**. As required by EU law, member states should put in place concrete measures and targets leading to a substantial reduction in pesticide use.

- **Overhauling regulatory controls for pesticide risk assessment**. In particular, investigating and monitoring the effects that the exposure to cocktails of chemicals can have on human health and the environment. The specific pesticide formulations used in the field should also be subject to testing and rigorous scientific assessment rather than the active ingredients alone. In addition, all available independent scientific literature should be taken into account as part of risk assessment processes, and all studies and data used in the assessment should be made publicly available. Once an authorisation has been granted, if scientific evidence emerges bringing additional information that could put into question the conclusions of the risk assessment process a re-evaluation of the active substance and the formulations should immediately take place.

- **Shifting towards ecological farming needs political and financial support**. Public research must be re-focused on ecological farming practices, and plant breeding should address the needs of ecological farmers, by delivering robust and locally adapted varieties, in participation with farmers.

- **Abolishing subsidies that promote the maintenance and upscaling of industrial agriculture practices**. Billions of euros of taxpayers' money is being poured into a broken system that continues to cause serious environmental and economic impacts. Public subsidies must instead be targeted to farmers to support the implementation of environmentally friendly farming methods. This would mean radically reforming the EU's Common Agricultural Policy (CAP) by phasing out subsidies promoting environmentally destructive practices, and making rural development subsidies conditional on the development and implementation of ecological farming methods.

- **Phasing-out synthetic chemical pesticides by prioritising chemicals with particularly hazardous properties**. This would mean banning pesticides that have bee-harming properties, are carcinogenic, mutagenic and toxic to reproduction, or which interfere with the hormone system (endocrine disrupting substances) as well as neurotoxic substances.

- **Introducing fiscal measures discouraging the use of pesticides and promoting the implementation of ecological farming practices**.



# 10

# **Annex 1:** Indicators and thresholds for environmental toxicity, transport and fate

| **Indicator** | **Threshold** |
| --- | --- |
| Highly toxic to mammals (LD50 acute, mg/kg bw) | ≤ 5 (solid, liquids)<br>≤ 100 (gases)<br>≤ 0,5 (vapours)<br>≤ 0,05 (dust/mists) |
| Very highly toxic to birds (LD50 mg/kg bw oral) | ≤ 10 |
| Very highly toxic to fish or Daphnia spec. (LC50/EC50, acute, mg/l [ppm]). Most sensitive species group. | ≤ 0,1 |
| Highly toxic to honey bee (Apis mellifera) LD50 [µg/bee] | < 2 |
| Harmful to sensitive beneficial organisms (Lethal Rate [50%] in g/ha or Percent effect [mortality, beneficial capacity]) | < 5 (LR)<br>> 79 (%)<br>"Harmful" |
| Highly toxic to algae (EC50 [growth] mg/l [ppm]) | ≤ 0,01 |
| Potential for bioaccumulation (Bioconcentration factor [BCF] or LogP KOW) | > 500 (BCF)<br>> 5 (logP Kow) |
| Long Half-life (soil, sediments, water [days]) | > 90 (soil, sediment)<br>> 50 (water) |
| Long Half-life on plant (days) | >3,8 |
| High Volatility (Vapour pressure [mm HG] at 20-25°C) | > 0,01 |
| High leaching potential (GUS Index - function of soil half-life and soil binding) | > 2,8 |

# Shifting towards ecological farming needs political and financial support

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# 11
# Literature

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# Footnotes

## Executive Summary

[1] "Putting the Cartel before the Horse: Who Will Control Agricultural Inputs, 2013?" - ETC Group, September, 2013, p.10. http://www.etcgroup.org/sites/www.etcgroup.org/files/CartelBeforeHorse11Sep2013.pdf; accessed 23.9.2015.

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[3] Chapter 2. Pesticide use in Europe.

[4] IUCN 2015: database-search on 9th of october 2015 (http://www.iucnredlist.org/search/link/56178c5c-dbe482f8)

[5] Chapter 2., Figure 2. Population trends of European mammals (EU 2015a).

[6] Chapter 4. Pesticides and birds.

[7] Chapter 3. Pesticides in the environment.

[8] http://www.pesticidesatlas.nl/; accessed 8.9.2015.

[9] Chapter 5. Pesticides and aquatic organisms.

[10] Chapter 3. Pesticides in the environment.

[11] Chapter 5. Pesticides and aquatic organisms.

## Main report

[1] http://www.greenpeace.de/sites/www.greenpeace.de/files/publications/20131028-corporate-science-fiction.pdf

[2] The TFI is the number of applications at full recommended dose, where tank mixes are separately counted. If a tank mix contains for example two pesticides at full dose, the TFI would be 2.

[3] http://www.fibl.org/en/themes/organic-farming-statistics.html

[4] See the Endure Project: http://www.endure-network.eu/

[5] http://ec.europa.eu/dgs/health_food-safety/dgs_consultations/food/consultation_20150116_endocrine-disruptors_en.htm; accessed 30.06.2015.

[6] Synergistic = more than additive.

[7] Reviewed by Reuter (2012).

[8] http://ec.europa.eu/environment/chemicals/effects/effects_en.htm; accessed 9.8 2015.

[9] Active movement.

[10] Semi-field studies are conducted in enclosed environments (e.g. in a tunnel), ideally situated within the natural ecosystem; field studies are performed in natural (agro-) ecosystems.

[11] Category 1b: toxic to reproduction in humans and GHS H360d: Can affect the unborn child.

[12] http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1440580650249&uri=CELEX:32008R1272; accessed 26.8.2015.

[13] Press Release of the German Institute for Consumer Protection and Agriculture (BVL). 15.7.2008 at:

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[15] http://focus.jrc.ec.europa.eu/sw/index.html; accessed 19.6.2015.

[16] 23% of step 3 and 31% of step 4 (i.e. more sophisticated) standard PECs were exceeded by measured surface water concentrations. When 'realistic input parameters' were used, step 3 simulations underpredicted the concentrations in surface water and sediment by 43% and 78%, respectively, which indicated that a higher degree of realism even reduced the protectiveness of the model results.

[16] http://www.efsa.europa.eu/en/efsajournal/pub/2752.htm; accessed 19.6.2015.

[17] Greenpeace 2015: Pesticides and our Health, May 12, 2015: http://www.greenpeace.org/eu-unit/en/Publications/2015/Pesticides-and-our-health---Greenpeace-report/

[18] Renewal Assessment Report, 18 December 2013

[19] Clausing, Peter (2015) The Glyphosate Renewal Assessment Report. An Analysis of Gaps and Deficiencies

[20] Opinions by Prof Greiser, Prof Rusyn and Prof Portier submitted as part of the public hearing of the German Federal Parliament on 28 September 2015, http://www.bundestag.de/bundestag/ausschuesse18/a10/anhoerungen/anhoerung_glyphosat_28_09_2015/386986

[21] Does glyphosate cause cancer? BfR Communication No 007/2015, 23 March 2015, http://www.bfr.bund.de/cm/349/does-glyphosate-cause-cancer.pdf

[22] Following an OECD Test Guideline with "Good Laboratory Practice" standard.

[23] Ibid.

[24] Safety factors are used for considering differences among individuals and species.

[25] In 1999, the EU started a classification process for persistent endocrine disruptors. Category 1 (of 3) represents the most critical class since such substances proved hormonal effects in organisms.

[26] According to EU Pesticides Database at: http://ec.europa.eu/food/plant/pesticides/eu-pesticides-database/public/?event=homepage&language=EN; accessed 10..8.2015.

[27] PubMed of the US National Library of Medicine, National Institute of Health, is one of the largest online databases for biomedical literature; http://www.ncbi.nlm.nih.gov/pubmed.

[28] http://www.efsa.europa.eu/en/topics/topic/pesticides; accessed 10.8.2015.

[29] EFSA proposes "uncertainty toolbox" for its scientific assessments (Press release, 18.6.2015) at: http://www.efsa.europa.eu/en/press/news/150618c?utm_content=hl&utm_source=EFSA+Newsletters&utm_campaign=3dab29ae88-HL_20150818&utm_medium=email&utm_term=0_7ea646dd1d-3dab29ae88-59442481

[30] International Union of Pure and Applied Chemistry (IUPAC), Pesticide Properties Database (PPDB) at: http://sitem.herts.ac.uk/aeru/iupac/Reports/204.htm

[31] Toxic Unit: Ratio of substance concentration to a toxic threshold, showing how close the substance concentration comes to the concerned toxic effect.

[32] A simulation of a small part of the environment in a laboratory.

[33] LD50: Concentration which causes the death of 50% of the test species within a short time period.

[34] Atrazine, metribuzin, aldicarb, endosulfan, lindane and dieldrin.

[35] Neonicotinoids' physicochemical characteristics enable their entrance into plant tissues and their translocation to all its parts making the plants toxic to any insects (and potentially other organisms) that feed upon the plant. This protects the plant from direct damage by herbivorous (mainly sap feeding) insects and indirectly from damage by plant viruses that are transmitted by insects (TFSP 2015).

[36] An independent group of scientists advising as a specialist group to two IUCN Commissions, the Commission on Ecosystem Management and the Species Survival Commission; http://www.tfsp.info/

[37] According to the Toxic Load Indicator database (TLI) at: http://pestizidexperte.de/tli.php; accessed 5.10.2015.

[38] Measured environmental concentration / Calculated Trigger value for groundwater calculated by PELMO and SCI-GROW models.

[39] Maximum environment concentration (MEC) / predicted no effect concentration (PNEC).

[40] e.g. highly acute toxicity thresholds like ≤ 10 mg/kg bw oral for birds; Bioaccumulation by BCF >500; persistence by half-life in soil >90 days; for details refer to the table in Annex 1.

[41] EC approval status available at; http://ec.europa.eu/food/plant/pesticides/eu-pesticides-database/public/?event=activesubstance.selection&language=EN; accessed July 2015.

[42] Universiteit Leiden (CML) en Rijkswaterstaat-WVL: http://www.pesticidesatlas.nl/

[43] European Environment Agency (EEA) Waterbase; http://www.eea.europa.eu/data-and-maps/data/waterbase-rivers-10#tab-metadata; accessed 30.9.2015.

[44] Imidacloprid is listed in the database under the chemical name: 1-[(6-chloro-3- pyridinyl) methyl]-N-nitro-2-imidazolidinimine).

[45] Greenpeace Report: Bees in Decline. A review of factors that put pollinators and agriculture in Europe at risk. Greenpeace Research Laboratories. Technical Report 2013 http://bees-decline.org/

[46] There were too few studies on neonicotinoid pesticides to make a qualified assessment for that group.

[47] CAP expenditure over the years as a share of the EU budget: http://ec.europa.eu/agriculture/cap-post-2013/graphs/graph1_en.pdf: accessed 5.10.2015.

[48] History of the CAP: http://ec.europa.eu/agriculture/cap-history/index_en.htm

[49] Denmark's pesticide tax: http://www.endure-network.eu/de/about_endure/all_the_news/denmark_load_index_now_guides_pesticide_tax: accessed 5.10.2015

[50] Spikkerud et al. (2005: Guidelines for a Banded Pesticide Tax Scheme, Differentiated According to Human Health and Environmental Risks. Norwegian Food Safety Authority.

Greenpeace is an independent global campaigning organisation that acts to change attitudes and behaviour, to protect and conserve the environment and to promote peace.

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