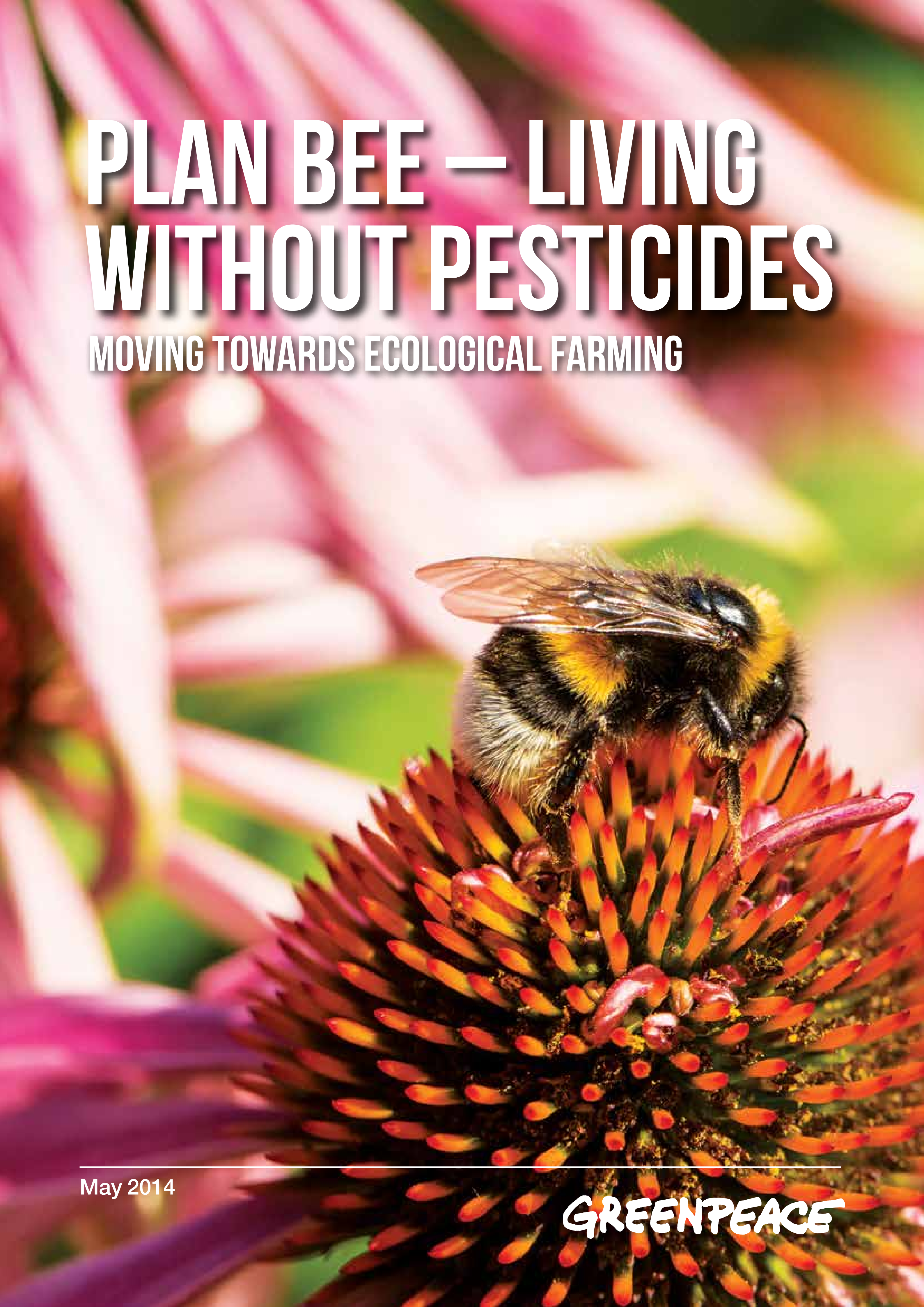
PLAN BEE — LIVING WITHOUT PESTICIDES

MOVING TOWARDS ECOLOGICAL FARMING



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PLAN BEE – LIVING WITHOUT PESTICIDES

Moving towards ecological farming

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EXECUTIVE SUMMARY

The red-tailed bumblebee (*Bombus lapidarius*)

© Prof. Felix Wäckers, The University of Lancaster, UK

The drastic decline of wild and managed bee populations recorded in recent years in Europe and North America is alarming given our reliance on these insect pollinators for biodiversity and global food security. Managed honey bees have sharply declined, for instance, by 25% in Europe between 1985 and 2005. This decline of bees has led to the concept of a global "pollination crisis" – a situation where pollination services by bees are limited and this, in turn, may cause the yield and quality of crops to deteriorate.

Scientific research shows that a diversity of wild bee species is paramount for ensuring sustainable crop production. Thus, we cannot rely solely on one species – managed honey bees – for pollination. A diversity of wild bee species is also essential to ensure food is delivered to our tables every day. Recent scientific studies have shown that chemical-intensive industrial agriculture is implicated in the decline of bees and the pollination services they provide to our crops and wild flowers. Ever increasing applications of fertilisers, herbicides and insecticides and their synergistic negative impacts on bee health (Johnston *et al.* 2014, Tirado *et al.* 2013) and loss of natural and semi-natural habitat on field, farm and landscape levels are major drivers of bee declines. Further, the modern industrial farming model also causes problems of growing resistance of pests and weeds, decreased soil fertility and water retention, contamination of ground waters, high energy input and CO_2 emissions, as well as reduced resilience and increased vulnerability to climate change. In addition, under this paradigm farmers become increasingly dependent upon seeds and chemical products from multinational companies. These are just some examples of the negative impacts resulting from current chemical-intensive industrial agriculture practices.

As an alternative, a model based on modern ecological farming methods could ensure food production and avoid the negative impacts outlined above. Scientific studies discussed in this report show that the implementation of ecological farming is feasible and in fact the only solution to the ever-increasing problems associated with chemical-intensive industrial agriculture. Ecological farming, which includes some organic agricultural methods, promotes biodiversity on farmland and supports the restoration of semi-natural habitat on farms as ecological compensation areas for bees and other wildlife. Ecological farming does not rely on the use of synthetic chemical pesticides and herbicides and, thereby, safeguards bees from toxic effects of these agrochemicals.

Overview on the content of this report

The introduction to this report highlights the importance of bees for global food security, and is followed by a chapter describing the factors causing bee declines. The next chapter looks at how farming methods and agricultural landscapes impact on bees. Recommendations, based on scientific studies to protect and restore bee populations in Europe, are made. The final chapter provides a review of scientific literature on ecological pest control. This can provide a means to eliminate the use of synthetic chemical pesticides in industrial farming. Research, considered together with existing ecological farming practices, confirms that we don't need pesticides to deal with the pests that live on the crops we want to produce.

To illustrate ecological farming in practice, Greenpeace has produced a number of video case studies. These draw on the experiences of farmers, scientists and research institutes as well as companies, and show that ecological farming techniques are practised successfully across Europe. These existing solution studies are briefly highlighted in text boxes throughout this report. Examples include ecological pest control by natural enemy insect enhancement in cotton farms in Spain, and by rose growers and pepper greeneries in the Netherlands. Other examples are cover cropping in vineyards in France and the use of flower strips around potato fields in the Netherlands, which attract natural enemy insects that control aphids.

This report clearly shows that agricultural solutions – to ensure the survival of native bee diversity within Europe and save domesticated bees – are enshrined in the concept of "Ecological Farming". Ecological Farming aims to preserve important ecosystems and their functions, thereby supporting native bee populations and the pollination services they provide. Ecological farming ensures healthy food for today and tomorrow by protecting soil, water and climate. In addition it promotes biodiversity and does not contaminate the environment with chemical inputs or genetically modified organisms. Ecological farming employs ecological pest control methods and natural means of fertilising the land. It employs use of crop rotations and cover crops, use of resistant crop varieties and mixed cropping, and promotes the continued development of scientific knowledge.

Bees in agricultural landscapes – what does the science say?

Ecological farming favours bees: Research shows that organic farming *per se* favours bee diversity and abundance.

- Organic farming of arable crops enhances herbaceous wild flowering plants within fields and field margins, which in turn supports native bee diversity and abundance.
- Organic management of grasslands for livestock enhances ground cover and diversity of herbaceous wild flowering plants, which favours bees.
- Traditional organically managed hay meadows are a very important habitat for wild bees, providing rich floral resources. The decline of bumblebees in Europe has been linked to the loss of traditional hay meadows.

Natural and semi-natural habitats are needed to support bees: The presence of high quality natural and semi-natural habitats on farms and within agricultural landscapes – such as wooded areas, hedgerows and herbaceous field margins – is crucial for the survival of wild bees. Bees need this habitat for overwintering, for the provision of nesting sites, and for food from pollen and nectar in wild flowers. Scientific studies have reported that increased areas of semi-natural habitat on farms and within the agricultural landscape favours diversity and abundance of native bees. By way of contrast, intensive industrially managed farm fields, typically consisting of large-scale monocultures with little semi-natural habitat, have the lowest diversity and abundance of bees. This is of great concern – industrial intensive farming landscapes do not support wild bees or the pollination services they provide.

Farming without synthetic chemical pesticides and with ecological pest control is possible: Ecological farming does not use synthetic chemical pesticides. Instead, measures are employed to enhance ecological pest control. This includes the encouragement of natural enemies such as ladybirds, lacewings, certain beetles, spiders and parasitoids that prey on crop pests. Some scientific studies have shown that natural enemies can suppress insect pests on crops, thereby providing a means of natural pest control.

Scientific study has also shown that the diversity and abundance of natural enemies are enhanced on organic farms. Farming landscapes that are more heterogeneous and diverse, consisting of small-scale fields and mosaics of semi-natural habitat, support greater numbers of natural enemies and hold the greatest potential for natural pest control. Conversely, the simplified farming landscapes with little semi-natural habitat that are typical of intensive industrial farming do not favour natural enemies. Further, the use of synthetic chemical pesticides can kill these beneficial species.

Functional agro-biodiversity (FAB) is a term that refers to those elements of biodiversity, on the scale of agricultural fields or whole landscapes, which provide ecosystem services that support sustainable agricultural production and can also deliver benefits to the regional and global environment, and to the public at large (ELN-FAB 2012). As a concept, it is entirely compatible with eco-agriculture. FAB utilises science-based strategies and, as a concept, can be incorporated into organic and sustainable agriculture systems. Successful implementation of FAB has included the development of seed mixes of wildflowers that are sown alongside or within crops to provide resources of floral pollen and nectar for bees. Seed mixes have also been developed that are tailored to enhance natural enemies and which are grown alongside crops.

“On the basis of recent extensive work it is now possible to provide farmers with accurate prescriptions for seed mixes and landscape management that specifically target and optimise pest control benefits, while minimising possible negative effects.”

– Wäckers (2012)

Conclusions: Ways forward to help bees and implement ecological farming

Based on the results of scientific studies discussed in this report and in previous Greenpeace reports on bees, the following recommendations can be made to help protect and enhance bee populations in agricultural landscapes, and so ensure adequate pollination of crops and wild flowers:

1. **Progressively phase out the use of all chemical pesticides (herbicides, insecticides and fungicides) throughout Europe by the widespread implementation of ecological farming.**

   Pesticides kill and harm bees, natural enemies and other wildlife, and may be unsafe for human health. The use of herbicides in industrial farming diminishes floral resources available to bees in arable fields and field margins, while the use of herbicides and mineral fertilisers on grasslands has left them impoverished and with few floral resources for bees. The solution to these problems is to employ ecological farming, which does not use synthetic chemicals, pesticides and herbicides.

2. **Habitat conservation.** Conservation of natural and semi-natural habitat within agricultural landscapes and elsewhere is essential to support wildlife biodiversity, including native bees and natural enemies. Further loss of habitats jeopardises the survival of these species, which are beneficial to agriculture and other wildlife.

3. **Semi-natural habitat restoration on farms (under agri-environmental schemes, AES) to provide floral resources and nesting areas for bees.** Research indicates that increasing the amount of semi-natural habitat of farms is crucial to support the recovery of wild bee populations and to maintain maximum pollination services to crops and wild plants. It is estimated that, for each additional 10% increase in the amount of high-quality bee habitats in a landscape, wild bee abundance and species richness may increase on average by 37% (Kennedy *et al.* 2013).

   Conservation and restoration of semi-natural habitat on and around farmland is essential for providing a rich diversity of wild flowering plants as forage for bees, as well as nesting and overwintering sites. Herbaceous field margins, fallows, semi-natural grasslands, hedgerows and woodland have all been shown to be important habitat for wild and managed bees. Traditionally managed hay meadows with late cut increase floral resources for bees and small areas can be left uncut as refuges for bees. Farming that employs smaller field sizes broken up with diversified semi-natural habitat is key to providing bee-friendly landscapes. To be effective across agricultural landscapes, it will be necessary to link semi-natural habitats on a wider scale in order to maximise benefits for bees and other wildlife biodiversity. Achieving ecological conservation areas across farming landscapes will require farmers, regulators and other stakeholders to plan and work together.

4. **Habitat enhancement with wild flower strips (under agri-environmental schemes, AES).** Native pollen and nectar flower and legume seed mixes should be encouraged under AES, to provide floral resources for bees. Employing functional agro-biodiversity to provide tailored flower seed mixes to enhance natural enemies and to employ natural pest control techniques should also be encouraged under AES where the scientific knowledge is already available. Research funding should also be made available to continue to develop functional agro-biodiversity (FAB) for natural pest control.

Political recommendations

Greenpeace calls on farmers, industry and policymakers to act upon the current, fundamental agricultural crisis and the long-term challenges that it poses. In order to save the bees and our food, we should promote moves away from bee-harming pesticides and other synthetic chemical inputs. There is a need to create incentives for increasing biodiversity in agriculture and to shift towards ecological farming. Specific policy recommendations for immediate implementation comprise the following:

1. **Immediately and fully ban all pesticides that are harmful to bees and other pollinators.** This includes chlorpyrifos, cypermethrin and deltamethrin. Further, the limited ban on the use of the systemic insecticides imidacloprid, thiamethoxam, clothianidin and fipronil should be made permanent, and expanded in scope (Johnston *et al.* 2014).
2. **Adopt coordinated Bee Action Plans**, which not only aim at more effective regulation and control of agricultural chemicals, but also facilitate the monitoring of the health of bees and other pollinators. They should also work to improve the conservation of natural and semi-natural habitats around agricultural landscapes, as well as enhance biodiversity within agricultural fields (as outlined from scientific studies and discussed in the above list of recommendations).
3. **Shift away from destructive chemical-intensive farming towards ecological farming models by increasing public as well as private funding focused on research and development on ecological farming practices**. EU policy makers should direct more funding for ecological farming solutions research under the auspices of the Horizon 2020 (EU research) programme.
4. **Farm Advisory Systems**. Member States should make proper use of the Farm Advisory Systems that CAP foresees, in order to share with farmers across Europe knowledge of bee-friendly farming practices and non-chemical alternatives to pest management.
5. **Implementation of Ecological Focus Areas**. Member States should ensure that the implementation of Ecological Focus Areas truly aims at protecting and enhancing biodiversity and agro-ecosystem functions such as pollination and the regulation of pest populations.

In addition to the above recommendations that are of direct relevance in the EU, there is a need to address the sustainability of agriculture on a global basis, including through the implementation of The International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD) recommendations.

Fruit and vegetables that were pollinated by bees. Healthy bee populations are of ecological and economic importance.

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1: INTRODUCTION

Bee collecting pollen from rape flowers, Germany.

© Fred Dott / Greenpeace

The importance of pollination

Pollination is an essential process for the fruit and seed set in flowering plants. Animals, mainly insects, act as pollinators to a vast array of flowering plants. It has been estimated that 87.5% of flowering plants species are pollinated by animals (Ollerton *et al.* 2011). Among the insect pollinators, wild bees and managed honey bees play the greatest role in pollination (Breeze *et al.* 2011). This highlights the crucial roles of bees – both in the pollination of our crops (essential for crop production and good crop yields), and in the pollination of wild flowers, thereby maintaining wild plant ecosystems. To illustrate the importance of bees in crop production, the UN's Food and Agricultural Organisation (FAO) estimates that – of some 100 crop species that provide 90% of food worldwide – 71 are bee pollinated. In Europe alone, 84% of the 264 crop species are animal pollinated, and over 4,000 vegetable varieties exist thanks to pollination by bees (UNEP 2010).

Thus, a wide range of crops rely on pollination by bees, including apple, citrus, tomato, melon, strawberry, apricot, peach, cherry, mango, grape, olive, carrot, onion, pumpkin, bean, cucumber, sunflower, various nuts, a range of herbs, cotton and lavender. In addition, bee pollination of clover and alfalfa used as fodder by the meat and dairy industry is essential (Abrol 2012).

Grain crops like wheat, rice and corn, which make up a large part of global human diets, are mostly pollinated by wind and are not affected by pollinating insects. However, yields of many other plant species either rely upon or benefit from cross-pollination by bees. In fact, animal pollination results in increased fruit or seed yield in 75% of the world's leading crops (Klein *et al.* 2007). For many plants, a well-pollinated flower will contain more seeds, with an enhanced capacity to germinate, leading to bigger and better-shaped fruit. Improved pollination can also reduce the time between flowering and fruit set, reducing the risk of exposing fruit to pests, disease, bad weather and agro-chemicals, and saving on water use (UNEP 2010).

Therefore, it is true to say that bees, both wild and managed, are critical for maintaining global food security – bees are essential for pollination of many crops and also for increasing crop yields.

Bees and crops – a diversity of wild bee species is essential for crop production

Honey bees remain the most commonly managed pollinators used by farmers, and often dominate pollinator communities in crops (Klein *et al.* 2007). Managed honey bees are a generalist species that can pollinate many types of wild flowers and many types of crops. Modern agriculture has come to depend greatly on managed hives to meet pollination service needs (Abrol 2012).

Wild bees include solitary bees and social nesting bees, of which there are wild honey bees, bumblebees and stingless bees. There are 20,000 species of bee worldwide, and 750 species in Central Europe (Michener 2007, Westrich 1990). While some wild bee species are generalists and can pollinate a wide range of flowers, others are described as specialists and depend on particular plant species for their survival. Thus, not all bees like the same plants. Nature specialises in diversity and so the plant species must be compatible with the species of bee (Soil Association 2013). For example, long-tongued bees are essential pollinators of field beans. Bumblebees are important pollinators of red clover and wildflower meadows (Blake *et al.* 2011). Pollination efficiency is also important for optimum crop yields. For example, mason bees are more effective pollinators of apple than honey bees. For strawberries, a combination of wild and managed bees is needed to produce fruits of market quality (Breeze *et al.* 2012)

From research, it is becoming clear that it is the diversity of wild bee species that is paramount for sustainable crop production. While commercially managed honey bees are known to be important in crop pollination and hence in crop production, there is a growing body of evidence that indicates that wild bees contribute to a substantially greater proportion of crop pollination services than previously thought (Winfree *et al.* 2008). A recent landmark study looked at 41 different crop systems worldwide and found that, even though honey bees deposit a lot of pollen, they do so quite ineffectively (Garibaldi *et al.* 2013). By contrast, visits by wild insect pollinators (mainly wild bees) to crop flowers increased fruit production by a factor of two compared to honey bees. Moreover, flowers pollinated by wild pollinators were more consistent in their fruit production. The authors concluded that “although honey bees are generally viewed as a substitute for wild pollinators, our results show that they neither maximise pollination nor fully replace the contributions of diverse wild insect assemblages to fruit set for a broad range of crops and agricultural practices on all continents with farmland”. The results of this study suggest, therefore, that managed honey bees “supplemented”, rather than “substituted for” pollination by wild bees and other insect pollinators.

Hence, research has confirmed that diverse communities of pollinators (mainly wild bees) provide more effective pollination services to crops and wild plants than less diverse communities (Breeze *et al.* 2012). In addition, research has also revealed that yields of insect-pollinated crops are more unstable when the pollinator community (in a region) consists of fewer species (Garibaldi *et al.* 2011). To ensure successful pollination and maximum crop production, therefore, diverse populations of wild bee species are essential.

Alarmingly, in recent years it has become evident that wild bee populations have experienced dramatic declines, and managed honey bees have also been badly affected. This was first recognised as a critical issue in the early 1990s, and led to the concept of a pollinator "crisis" – localised extinctions and possibly a global decline in the number and viability of pollinating species (Abrol 2012).

The decline of wild bees and managed honey bees throughout the world

Research now clearly indicates that in Europe and North America there have been substantial losses of wild and domesticated bees. It is likely that there has been a worldwide decline in these pollinators, although studies are limited (Potts *et al.* 2010). Both the number of wild bee species and their population numbers appear to have declined.

For example, the World Conservation Union (IUCN) Bumblebee Specialist Group published a report in 2013 (IUCN BBSG 2013), which stated that, for the 68 species of bumblebees in Europe, 31 species (46%) are regressing and the situation for European bumblebees is described as "serious". Over much of Belgium and the UK bumblebees are suffering an ongoing decline. For instance, in the UK, of the 16 non-parasitic bumblebees, six have declined considerably (including *Bombus subterraneus,* which has become extinct) and another four species may be declining (Potts *et al.* 2010).

Biesmeijer *et al.* (2006) reported for the UK and Netherlands a parallel decline of insect-pollinated plants and wild bee and hoverfly pollinators, for the more specialised species in particular. These authors found that solitary bee diversity has declined by 52% in England. Whereas specialist species may be considered to be most at risk, Potts *et al.* (2010) notes that generalist species are also vulnerable. In central Europe, between 25% and 68% of all wild bee species are endangered, with percentages varying between countries and regions.

For managed honey bees, there has been a 25% loss in Europe between 1985 and 2005. One known factor contributing to this decline is the parasitic mite *Varroa destructor,* an invasive species from Asia. Most wild honey bee colonies in Europe and the USA have disappeared due to this parasite (Potts *et al.* 2010).

Other pollinating insects have also undergone dramatic declines. For example, a scientific indicator of butterfly abundance in European countries found that butterfly populations declined by almost 50% between 1990 and 2011. This is mainly due to agricultural intensification in north-western regions, as natural grassland rich in biodiversity is brought under cultivation, resulting in almost "sterile" grassland with few wild flowering species left for the butterflies. Also, abandonment of traditionally managed grasslands in mountainous and wet regions, caused by worsening socio-economic conditions mainly in eastern and southern Europe, means that grasslands have become tall and rank and reverts to scrub vegetation. This is another factor in butterfly decline.

> "Wild pollinators are in decline and honey bees cannot compensate for their loss."
>
> *– Tylianakis (2013)*

> "Between 25% and 68% of all wild bee species in central Europe are endangered, with the percentages varying between countries and regions."
>
> *– Zurbuchen & Müller (2012)*

Solutions to abate and reverse bee declines – ecological farming

There are several known factors causing declines in wild bees including: habitat loss and lack of wild flowers on farms due to industrial farming methods; use of synthetic chemical pesticides on industrially managed farms that kill or harm bees; diseases and parasites; and impacts of climate change (see more detail in section 2).

Workable solutions to the first two problems include the implementation of ecological farming and, within this, the conservation and restoration of semi-natural habitat on farms and within agricultural landscapes.

Ecological farming (see Box 1), which includes some methods of organic farming, relies on ecological pest control and draws on modern science for plant breeding techniques, for instance, marker assisted breeding for seed development. It encompasses functional agro-biodiversity (FAB). An example of this is the scientific development of wild flower seed mixes that are specifically tailored to meet the requirements of bees and of species that help in pest control (natural enemies). All of these “solutions” that fall under the auspices of ecological farming are applicable to farming in Europe. The recent increase in organic farming practices in Europe demonstrates that farming without pesticides is entirely feasible, economically profitable, and environmentally safe. For the EU27, land under organic cultivation totalled 9.6 million hectares in 2011, increasing from 5.7 million hectares in 2002. Organic agriculture now accounts for 5.4% of the total agricultural land use in Europe, and includes arable crop and orchard as well as animal sectors.

Box 1: Ecological farming

Ecological farming ensures healthy farming and healthy food for today and tomorrow, by protecting soil, water and climate, promotes biodiversity, and does not contaminate the environment with chemical inputs or genetically modified organisms.

The benefits of ecological farming include:

1. Giving communities the ability to feed themselves, and ensuring a future of healthy farming and healthy food for all people.
2. Protecting soils from erosion and degradation, increasing soil fertility, conserving water and natural habitat, and reducing emissions of greenhouse gases.
3. Ecological farming is both a climate change mitigation and adaptation strategy. Ecological farming can provide large-scale carbon sinks and offers many other options for mitigation of climate change. In addition, farming with biodiversity is the most effective strategy to adapt agriculture to future climatic conditions. A mix of different crops and varieties in one field is a proven and highly reliable farming method to increase resilience to erratic weather patterns.
4. Ecological farming both relies upon and protects nature by taking advantage of natural goods and services, such as biodiversity, nutrient cycling, soil regeneration and natural enemies of pests, and integrating these natural goods into agro-ecological systems that ensure food for all now and in the future.

Carrots, cucumbers and leeks on a market stall. A lot of our produce depends on pollination by bees.

© Axel Kirchhof / Greenpeace

A dead bee. There is an urgent need for the elimination of bee-harming pesticides from agriculture. Such elimination ould be a crucial and effective first step towards protecting the health of bee populations.

© Fred Dott / Greenpeace

2: FACTORS CAUSING BEE DECLINES – IMPLICATIONS FOR AGRICULTURE

A tractor spraying pesticides on cabbage plants on a vegetable farm in Spain.

© Greenpeace / Ángel Garcia

Factors involved in wild bee and managed honey bee declines

There seems to be general agreement that declines in bee populations and in their overall health are the product of multiple factors, both known and unknown and which can act singly or in combination (Williams *et al.* 2010, Potts *et al.* 2010). The key pressures known or thought to be causing bee declines are as follows: **Land-use intensification** due to industrial farming methods resulting in habitat loss; **use of pesticides** that are toxic to bees, and **use of herbicides** on field margins that destroys the wild flowers on which bees feed; **pathogens** – diseases and parasites; and **climate change**.

Land-use intensification

Urbanisation and increasing agricultural intensification have destroyed and fragmented many natural habitats (Vanbergen *et al.* 2013). Intensified farming methods are driving the loss of valuable natural and semi-natural habitats on farms. These formerly non-cropped habitats have been destroyed to create more areas under cultivation and larger field sizes. The result is the loss of hedgerows, shrub-lands, old fields, natural grasslands, field margins and woodlands. With the demise of this natural and semi-natural habitat has come a parallel decrease in wild plant diversity. Not surprisingly, loss of these habitats and the loss of wild flowers mean loss of nesting habitat and foraging resources for bees. Indeed habitat loss is thought to be a major factor causing bee declines. Research shows that habitat loss likely causes both a reduction wild bee diversity and abundance (Potts *et al.* 2010). Industrial farming has also driven a shift from traditional hay meadows – very important flower rich habitats for wild bees - to silage production from fields virtually devoid of wild flowers which are cut before any flowers emerge (Pfiffner and Müller 2014). In addition to habitat loss, practices such as tillage, irrigation and the removal of woody vegetation destroy nesting sites of wild bees (Kremen *et al.* 2007).

Industrial farming monocultures, and more generally the lack of wild flower diversity within and around croplands, limit the amount of food that bees have access to both in space and in time. Bees can go hungry as farming becomes more intensified (Tirado *et al.* 2013). In turn, this has potentially damaging effects upon bees because they need an optimum nutrient balance for support of their growth and reproduction (Vanbergen *et al.* 2013). Flowering crops, such as oilseed rape (canola), can provide alternative food for some wild bee species that are able to exploit crop flowers effectively, but not for the more specialist species. Moreover, such crops only provide short pulses of food in the summer season for a few weeks. This is only of limited use for bees – native and managed bees need pollen and nectar resources for food throughout the whole foraging season. Different wild bee species are active at different times so floral resources are needed from early spring to late summer to provide all the bee species with adequate food (Veromann *et al.* 2012, Pfiffner and Müller 2014). Wild bees require native wild flowers present in semi-natural habitats to provide them with the necessary floral resources (Rollin *et al.* 2013).

Chemically intensive agricultural systems: use of pesticides and impacts on bees

Widespread use of pesticides is common practice in the current chemically intensive agriculture systems. Many flowers, nest sites, and the general environment around bees – including dust from farm operations – are often contaminated with chemicals, mostly pesticides. These insecticides, herbicides and fungicides are applied to crops, but reach the bees through pollen and nectar, and through the air, water or soil. These pesticides, by themselves, or in combination, can be toxic to bees acutely in the short-term or, in low-doses, with chronic effects that weaken and can ultimately kill bees. These negative impacts of pesticides on bees are discussed at greater length in the recent Greenpeace reports *Bees in Decline* (Tirado *et al.* 2013) and *The Bees' Burden* (Johnston *et al.* 2014).

Landscape-scale surveys of wild bees and butterflies show that species richness (i.e. one measure of diversity of bee and butterfly species within a landscape or region) tends to be lower where pesticide loads and cumulative exposure risks are high (Brittain *et al.* 2010).

Use of herbicides – impacts on wild flowering plants

Large-scale herbicide application in and around cultivated farm fields drastically reduces the diversity and abundance of weeds and wild flowers. This limits pollen and nectar, and thus food availability, for bees. The chemical destruction of habitats through the massive application of herbicides can have long-term consequences, particularly on the distribution of pollinating insects in agro-environments (UNEP, 2010).

Diseases and parasites

Many beekeepers agree that the external invasive parasitic mite, *Varroa destructor*, is a serious threat to managed honey bee colonies globally. Other new viruses and pathogens are likely to put further pressure on bee colonies.

The ability of bees to resist diseases and parasites seems to be influenced by a number of factors, particularly their nutritional status and their exposure to toxic chemicals. Some pesticides, for example, seem to weaken honey bees so that they become more susceptible to infection and parasitic infestation (Tirado *et al.* 2013).

Climate change

Many of the predicted consequences of climate change, such as increasing temperatures, changes in rainfall patterns, and more erratic or extreme weather events, will have impacts on pollinator populations (including wild bees). (UNEP, 2010). Climate change will very likely affect the interaction between pollinators and their sources of food, i.e. flowering plants, by *inter alia* changing the dates and patterns of flowering. Recent analysis has suggested that, under realistic scenarios of climate change up to 2100, between 17% and 50% of pollinator species will suffer from food shortages due to the temporal mismatch of their flight activity times with flowering of food plants (Memmott *et al.* 2007). The authors concluded that the anticipated result of these effects is the potential extinction of some insect pollinators and some plants, and hence the disruption of their crucial interactions.

Implications of bee declines for crop yields and wild plant ecosystems

Pollination of crops by wild bees and managed honey bees is essential for global human food security. Bee pollination of wild flowers is also essential for maintaining wild plant ecosystems and the life that depends on these ecosystems.

As demand for pollinators – both locally and regionally – increases faster than the supply, we could face limitation of pollination, currently and in the near future. This is because the growth in cultivation of high-value, pollination-dependent crops is outpacing the growth in the global stock of managed honey bees (Garibaldi *et al.* 2011, Lautenbach *et al.* 2012). Furthermore, it is now known that a diversity of wild bees is essential to provide adequate pollination services for our crops and wild flowers. Reliance on a single species – honey bees – also poses a high risk, should that species decrease, as has already been seen (Bommarco *et al.* 2013).

The International Convention on Biological Diversity specifically cites pollination as a key ecosystem service that is threatened globally (Abrohl 2012). Recent studies show that pollination services are in some cases already limited. A recent study in the UK on oilseed rape (canola) indicated that the insect pollination service in the fields that were studied was likely severely limited (Garrett *et al.* 2014). Such an inadequacy in pollination services has potentially negative implications for both the yield and quality of UK oilseed. This is of particular concern because there is an increasing reliance on insect-pollinated crops such as canola in European agriculture. The study suggested that, as canola is pollinated by generalist species, the land surrounding crop fields should be managed to enhance these species. Interestingly, this conclusion was borne out by the results of a separate study on canola farms in Northern Canada (Morandin and Winston 2006). It was found that canola farms near uncultivated areas had the advantage of more

> “If wild pollinator declines continue, we run the risk of losing a substantial proportion of the world’s flora.”
>
> – *Ollerton et al. (2011)*

diverse and abundant communities of wild bees, and consequently there was increased pollination and greater seed yields. It was suggested by the researchers that farmers could maximise their profits by not cultivating 30% of their farms area – hence benefiting pollinator populations and simultaneously increasing canola yields.

Organic farming does not permit the use of synthetic chemical pesticides that are toxic to bees, and there are also generally greater areas of semi-natural habitat on organic farms. This favours a richer diversity of wild bees (see part 3 of this report). Pollination success can be better on organic farms due to a higher diversity and abundance of bees and other pollinating insects (Pfiffner and Müller 2014). For example, a study in Sweden looked at pollination success of strawberries on organic and industrially managed farms (Andersson *et al.* 2012). Strawberries are visited by a range of insect pollinators, including bees and hoverflies. The study reported that pollination success of strawberries was significantly higher on organic farms, and the proportion of fully pollinated berries was higher on organic farms (45% on organic farms versus 17% on conventional farms). The study suggested that increased pollination success mediated by organic farming may increase both crop yield quantity and quality on farms cultivating strawberries.

BEE-STINGS: Extracts from "Living Without Pesticides"

> Agricultural politics have to take the real costs of production into account and they shouldn't be allowed to ignore factors such as environmental pollution or healthcare costs to society. […] Sustainable, organic agriculture requires a corresponding scientific foundation […] and markets are necessary and a demand for these products, which unavoidably are somewhat more expensive, yet the quality is also higher.

Hans Herren – leading expert on biological pest control, winner of the Alternative Nobel Prize 2013, Switzerland. *He emphasises the importance of adapting agri-environmental schemes to local conditions and also making use of push-pull methods applied in mixed cropping systems.*

See Appendices 1 & 2 for further information.

Many products depend upon pollination by bees, so healthy bee populations are vital for our ecosystem and for food production.

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Tractor on a field where organic potatoes are grown, at a farm in Nieuw-Beijerland, Zuid-Holland, the Netherlands.

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3: ECOLOGICAL FARMING VERSUS INDUSTRIAL AGRICULTURE – IMPACTS ON BEES

Wildflower strips offer excellent over-wintering sites and help to boost natural pest control.

© Research Institute of Organic Agriculture (FiBL), Switzerland

Introduction to farming methods and their effects on farmland biodiversity

Industrial agriculture

During the later half of the 20th century, intensification of agriculture has been associated with significant losses of biodiversity on farmland (Asteraki *et al.* 2004, Bommarco *et al.* 2013). Agricultural intensification in Europe has typically led to more homogeneous landscapes, defined by large cereal fields and a loss of non-cultivated habitats on farms – such as hedgerows, ditches, woodland, and field margins. In addition, there has been widespread loss of semi-natural grasslands due to their conversion into arable fields and coniferous tree plantations (Meeus *et al.* 1990). Semi-natural habitat loss and degradation on farms and in surrounding areas, together with the increased use of agrochemicals such as synthetic pesticides, has been linked to a loss of wildlife species in agricultural landscapes (Belfrage 2005).

The IUCN Red List of threatened species asserts that intensive farming is one of the main causes for species decline in cultivated landscapes (Pfiffner & Balmer 2011). For Europe, there is a growing concern about the sustainability of current intensive farming practices due to dramatic declines in both range and abundance of many wildlife species associated with farmland, including farmland birds, together with many plants and insects (Hole *et al.* 2005).

On arable farms, agricultural intensification has been typified by ploughing right up to field boundaries, and converting non-cropping habitat into crop fields. On intensive livestock farms there has been loss of wild flower meadows and loss of plant diversity within grasslands. This is due to use of synthetic fertilisers, the use of herbicides that kill wild flowers, and the increased grazing pressure from high stocking densities of livestock. None of this is good news for bees and biodiversity in general – declining wild flower diversity on the land as a result of intensive arable and livestock farming reduces the quantity of food available to bees and other pollinating insects.

Loss of semi-natural habitat such as grassy field margins, hedgerows, woodland and natural grasslands destroys bee nesting and overwintering sites. Bees rely on nesting sites in relatively undisturbed perennial habitats to fulfil their breeding requirements. Semi-natural habitats within and outside farm boundaries are essential habitats for bees in agricultural landscapes (Holzschuh *et al.* 2008). It is now clear that intensification of arable and livestock farming in Europe has been associated with negative impacts on the diversity and numbers of wild bees (Féon *et al.* 2010), (see *Impacts of agricultural landscapes on bees* further on in this chapter).

Ecological farming

Ecological farming uses less intensive practices than industrial (conventional) agriculture. Ecological (and organic) farming encourages the sympathetic management of all habitats within a farm with the aim of supporting biodiversity (Gibson *et al.* 2007). It is likely that, in general, organic farms will provide greater areas of semi-natural habitats around the farm than industrially managed farms. This has indeed been found to be the case (Pfiffner & Balmer 2011). Studies in Switzerland and England have shown that the proportion of semi-natural habitat on organic farms is higher than on conventional farms. The Swiss study showed that, on average, organic farms have 22% semi-natural areas and conventional farms 13%. The greatest difference was seen in lowland and hilly regions with less intensively used meadows, and with more hedges and standard fruit trees (Schader *et al.* 2008). A study in England compared 10 organic farms with 10 conventional farms (Gibson *et al.* 2007). Organic farms had larger areas of semi-natural habitat, including woodland, hedges, field margins and rough ground (on average 13.6% of the farm area) than conventional farms (on average 7.8% of the farm area).

With more semi-natural habitat, and no permitted use of chemical pesticides, organic farming would be expected to be more favourable to supporting wildlife, and this has been shown to be the case.

BEE-STINGS: Extracts from "Living Without Pesticides"

> We don't use any pesticides. I instinctively feel that pesticides don't really have a place in agriculture. I think they do more harm than good.

Yvonne Page – permaculturist and member of Eco'logique association, France. *By growing multi-purpose and companion plants according to the principles of permaculture, no external inputs are needed on their farm.*

See Appendices 1 & 2 for further information.

Biodiversity is generally greater on organic farms compared to conventional farms. Hole *et al.* (2005) reviewed 76 studies that compared organic farming with conventional farming. This study found that organic farming management resulted in higher species richness and/or abundance of wild plants in arable fields, and of invertebrates, birds and mammals. The study concluded that organic farming could play a significant role in increasing biodiversity across lowland farmland in Europe.

Bengtsson *et al.* (2005) made a statistical analysis of 66 studies that compared species richness (one measure of diversity of species within a landscape) on organic farms and conventional farms. The study showed that species richness was, on average, 30% greater on organic farms, although results differed between individual studies and species groups. Plants, birds and some natural enemies (carabid beetles and spiders that prey on and reduce insect pests) were usually more abundant on organic farms. Known crop pests (aphids, herbivorous insects, butterfly pest species and plant-feeding nematodes) were not more common in organic agriculture. The study concluded that "in most cases organic farming can be expected to have positive effects although this will differ between organism groups and landscapes. Hence subsidies to organic farming may contribute to the maintenance of biodiversity in agricultural landscapes."

Some of the same researchers have recently published a more up-to-date analysis of organic farming (Tuck *et al.* 2014). This study further affirmed that organic farming has large positive effects on biodiversity compared with industrial farming – again showing that, on average, organic farming increased species richness by about 30%. This result has been robust over the last 30 years of published scientific studies. What the study specifically showed was a strong positive effect of organic farming on pollinating insects, particularly for farming of cereals in areas of higher land-use intensity. The influence of both landscape and farming methods (organic versus industrial intensive agriculture) on native bee diversity and abundance found in other studies are in agreement with these results (Tuck *et al.* 2014) and are the focus of discussion in the following sections.

BEE-STINGS: Extracts from "Living Without Pesticides"

"The first key advantage of organic farming is sustainability, i.e. with good techniques, soil quality and the health of plants can be preserved."

Olivier Bonnafont – organic vineyard farmer, France. *In his vineyard "Domaine Peyres Roses" about half of the land is covered by meadow of high biodiversity, comprising natural herbs, truffle oaks and flowers. In springtime some of the herbs are applied as herbal solution to prevent pest-infestation.*

See Appendices 1 & 2 for further information.

The impacts of the farming method and agriculture landscape on bees

The impacts of farming method on bees - ecological versus industrial - is discussed below, and is followed by a discussion on the effects of landscape on bee diversity, i.e. whether the landscape is composed of mainly farms with little semi-natural habitat (a homogeneous landscape) or whether the landscape consists of farms surrounded by more semi-natural an/or natural habitats (a heterogeneous landscape).

Effects of farming method (ecological versus industrial) on the diversity of wild flowers and wild bees in farm fields

The diversity of wild plants has been found to be greater on organic farms compared to intensive industrially managed farms (Hole *et al.* 2005, Bengtsson *et al.* 2005). A recent study looked at both insect pollinated and non-insect pollinated wild plants on organic and intensive industrial arable farms in Germany (Batáry *et al.* 2013). It was shown that on organic farms, there was a higher diversity and ground cover of insect pollinated plants compared to intensively managed farms – in other words, organic management benefited insect-pollinated plants. This is likely to benefit the diversity and number of wild bees because more flowers are available for foraging. Two studies in Germany have indicated that this is indeed the case (Holzschuh *et al.* 2007 and 2008).

Arable fields: Two studies have recorded a higher diversity of wild flowering plants and a higher ground cover of wild flowers within cereal fields (Holzschuh *et al.* 2007) and within permanent fallow strips alongside cereal fields (Holzschuh *et al.* 2008) on organically managed farms. Compared with their industrially farmed counterparts, the organic fields and fallow strips not only hosted a higher diversity and ground cover of flowering plants, but also hosted a higher number of species of wild bees (a higher bee diversity) and a higher total number of bees (higher bee abundance). The research indicated that organic farming methods for cereal crops may have increased bee diversity by enhancing the availability of flowers to the bees within the cereal fields. Conversely, in intensively and industrially managed fields and fallow strips, the flower diversity and ground cover was much lower because of the use of herbicides – chemical herbicides reduce the cover and diversity of flowering plant and thereby reduce the nectar and pollen resources available to flower-visiting insects such as bees. It was concluded that, from a conservation perspective, organic cereal farming could help sustain pollination services by generalist bees in agricultural landscapes (Holzschuh *et al.* 2007). It seems that flowers within organic cereal fields provided sufficient foraging resources for the bees nesting in fallow strips alongside the cereal fields (Holzschuh *et al.* 2008).

At the landscape level, rather than the level of the local field, Holzschuh *et al.* (2008) also found that agricultural landscapes with a higher arable organic land cover enhanced the number of bee species and the abundances of solitary, bumble and honey bees found in the fallow strips bordering fields. They calculated that an increase in organic cropping within the landscape from 5% to 20% had resulted in an increase in the species richness (diversity of bee species within the landscape) in fallow strips by 50%. Holzschuh *et al.*

(2008) concluded that the incorporation of organic crop fields into industrially managed agricultural landscapes can provide food resources needed to sustain a greater diversity of bees in the non-crop habitat on farms. This result is important and should be considered by Agricultural Environmental Schemes (see Chapter 3) if these schemes are to effectively enhance bee diversity, abundance and hence pollination services at agricultural landscape scales.

Studies in other European countries have found similar results. A study on a number of organic and intensively managed farms in England indicated that the higher floral diversity found in organic cereal fields compared to industrially managed cereal fields was linked with the higher diversity of bumblebees in arable fields on organic farms (Gabriel 2010). Furthermore, research on farms in southern Finland also found that bumblebee species richness (the diversity of bee species within the landscape or region) and bee abundance was enhanced on organic farms compared to intensively managed farms. This was likely to be due to the increased annual floral nectar resources found in cereal fields, and the surrounding semi-natural landscape (Ekroos *et al.* 2008). The results of this study indicated that bumblebees might be able to react quickly and effectively to small improvements in habitat quality of cultivated lands.

Grasslands: Within western European lowlands, the grasslands for livestock grazing or cutting for silage are mainly under industrial intensive management. These intensively managed grasslands cover millions of hectares. Management generally includes high fertiliser application rates and frequent use of herbicides as defoliants. As a result, intensively managed grasslands support considerably fewer wild flower species and pollinating insects than semi-natural grasslands. Organically managed grasslands are also not as biodiverse as semi-natural grasslands, but they are considered to be less intensive than industrially managed grasslands. This is due to a prohibition on the use of herbicides and chemical fertilisers, featuring instead the planting of nitrogen-fixing plants (*Trifolium spp*.) that favour some bee species (Power and Stout 2011).

A recent study in Ireland looked at wild flowers in both organically and intensively managed grasslands on dairy farms (Power *et al.* 2011). It was found that the centre of organically managed grassland fields contained a greater number of species and ground cover of insect-pollinated flowering plants than intensively managed grasslands. The study concluded that the lower wild flower cover and plant species richness in intensively managed fields is very likely due to the frequent use of herbicides on intensively managed farms.

In another study in Ireland by the same scientists, it was found that grasslands on organic dairy farms not only had increased floral resources compared with intensively managed grasslands, but also had a higher abundance of bees. Furthermore, the pollination success of the flowers was higher in the organic grasslands (Power and Stout 2011). It is likely that the higher number of bees was due to the higher number of flowers on organic farms. This is probably the result of lower cattle stocking densities on organic farms which alleviates grazing pressure and allows time for the flowers to emerge. Additionally, instead of chemical fertilisers, organic farms encourage legumes (e.g. *Trifolium* species) and these plants provide important food resources for bees. Legume plants were abundant on organic farms studied but not on intensively managed grasslands. On the intensively managed grasslands the most dominant flower species (*Bellis perennis*, common daisy) is a flower that only produces low sugar nectar and is therefore not valuable to bees. This study concluded that organic dairy farming should be encouraged, particularly where intensive practices dominate the landscape. Organic practices such as sowing *Trifolium* plant species could also be incorporated into intensively managed farms at little extra cost, and would increase bee abundance.

Another study found that extensive (traditional) management of grasslands in Switzerland was effective for enhancing bees – it increased bee species richness whereas more intensive management was less favourable (Batáry *et al.* 2010). In Hungary, agricultural grasslands were found to contain an even higher species richness of wild flowers and bees than counterparts in Switzerland. It was suggested that it is therefore important for Hungary to continue to encourage traditional grassland management for grazing without the use of synthetic fertilisers and other agrochemicals, in order to help to preserve the bee diversity within the country. The authors also reiterated the message from other scientists that "conservationists should invest more on these 'intensification-prevention schemes' as it is easier to conserve than reintroduce biodiversity".

From the foregoing, it can be concluded that ecological farming in arable cereal farms and in grasslands encourages a higher wild plant diversity and wild bee diversity and abundance on farms than industrial agriculture. It has been suggested that organic management should therefore be considered by agri-environmental schemes (AES) as one way of promoting biodiversity on farms, in particular for wild bees.

Box 2: Other important findings about effects of agricultural landscape on bees

Research by Carré *et al.* (2009) on the effect of landscape on bees also indicated that species richness declined with declining landscape heterogeneity. This study had another important finding. It showed that agricultural intensification can change community composition of bees such that it increases the more resilient bee species alongside a loss in the more vulnerable species. This is critical because a diversity of bees is a prerequisite for stable pollination services to crops and wild plants (see also Chapter 1 of this report).

Further, a study by Andersson *et al.* (2013), looked at the range of distantly related and closely related insect pollinators within insect communities on organic and industrially managed farms. This is of importance because different pollinator species have different functions with regard to pollination services. A diverse community of pollinating insects, composed of more distantly related species as well as closely related species, will deliver improved pollination services as compared to a more narrow community of insects with only closely related species. This study found that industrial farms in homogeneous landscapes had pollinator communities that were narrow compared to pollinator communities found on organic farms. These had more diverse and distantly related species and, therefore, were likely to provide better overall pollination services.

Impacts of agricultural landscapes on bees

The term "homogeneous landscapes" generally refers to agricultural landscapes dominated by farms. Conversely, the term "heterogeneous landscapes" refers to agricultural landscapes where there are semi-natural and natural habits surrounding and within the farms.

Holzschuh *et al.* (2007) also reported that in more heterogeneous landscapes, comprised of greater areas of semi-natural habitat, bee diversity responded positively to the presence of semi-natural and natural habitat. In more homogeneous landscapes, organic farming increased floral resources in farm fields and this partly compensated for the lower amounts of semi-natural habitat within the landscape.

Other studies have reported similar findings. In southern Sweden, organic and intensive industrial farming were compared – a homogeneous landscape, consisting of mainly intensive farming on the plains, with a more heterogeneous landscape, with mixed farmland and greater amounts of semi-natural habitat. The latter example contained grasslands and forest edges (Rundölf *et al.* 2008). The study investigated the diversity of bumblebee species in the margins of cereal fields on organic and industrially managed farms in both landscapes types. It was found that the species richness and abundance of bumblebees was significantly greater on organic farms in the homogeneous landscape compared with intensive industrially managed farms – partly because the richer supply of wild flowers in and around organic arable fields gave more foraging resources for the bees. Heterogeneous landscapes, which had more semi-natural habitat, also favoured the bees. The study concluded that organic farming in homogenous agricultural landscapes can be used as a tool to increase the diversity and abundance of bees. Secondly, promoting more heterogeneity within the landscapes can also be used to benefit bee diversity and abundance. Hence it is important to preserve semi-natural/natural and habitats for bees both on farms and on the lands surrounding farms.

Another study conducted in four European countries (Belgium, France, the Netherlands and Switzerland) also found that the greater the proportion of semi-natural habitats in the farming landscape, the greater the species richness of the bee community (Féon *et al.* 2010). Conversely, whereas the amount of semi-natural habitat had a positive influence on bee diversity, intensive agriculture caused a negative effect on bee diversity. In particular, intensive animal husbandry in Western Europe is even less favourable to bees than arable farming where at least some nectar and pollen is provided by flowering crops, if only in short pulses.

Landscape heterogeneity –the importance of semi-natural and natural habitats within agricultural landscapes as habitat for bees

As previously mentioned, natural and semi-natural areas provide habitat for the nesting of bees, for overwintering sites as well as better foraging resources. These provisions, however, all need to be within the flight range of wild bees. To ensure pollination of agricultural crops requires that wild pollinators, mainly bees, have all of their foraging and nesting requirements located in the same landscape. Bees are central place foragers (i.e. returning to fixed nest sites after foraging), so the proximity of nesting habitats relative to foraging habitats – for instance, crops in agricultural fields – is critical for bee-pollinated crops (Ricketts *et al.* 2008).

A study on the effects of the distance of semi-natural and natural habitats from agricultural crop fields on pollinators (mainly wild native bees) was conducted by Ricketts *et al.* (2008). This study compiled the results of 23 individual scientific studies looking at 16 different crop types on five continents, including both temperate and tropical regions. Retrospective statistical analysis showed that there were strong declines in both pollinator richness (diversity of pollinator insect species within a landscape or region) and their visitation rate to crops with increasing distance from natural and semi-natural habitat. In other words, the further away the semi-natural and natural habitats from crop fields, the lower the diversity and number of bees visiting the crops (and hence less pollination services). The study concluded that "We can expect declines, on average, in pollinators and crop pollination if further land use change increases the isolation of farms from natural habitat. These declines can be counteracted by conserving areas of natural or semi-natural habitat near farms, by managing farms themselves to support pollinators, or by adding managed pollinators to the landscape."

Other studies have noted the importance of different types of semi-natural habitat surrounding farms. Research in Sweden found that areas of semi-natural grassland habitat provided essential refugia for bees in intensively farmed areas (Öckinger and Smith 2007). This study tested the notion that small habitat fragments such as the uncultivated field margins in intensively farmed areas are, by themselves, insufficient to support populations of bees and their nesting and foraging requirements. It is likely, therefore, that larger areas of more biodiverse semi-natural habitat (such as grasslands) are needed by bees to survive in intensively managed agricultural areas. The results of the study supported this hypothesis. Bumblebee species richness and their overall numbers were significantly higher in field margins close to the semi-natural grasslands areas than in field margins over 1,000 metres away. This is most likely because of the availability of nest sites in the semi-natural grassland areas for bees, and because their foraging flight ranges restrict them to areas relatively close to their nesting sites. The authors, therefore, stressed the importance of preserving semi-natural grasslands in agricultural landscapes as habitat for bees and other pollinating insects. In addition they suggested that the restoration and re-creation of patches of flower-rich grassland vegetation would increase the species richness and abundance of insect pollinators in surrounding intensively farmed areas. It was suggested that Agri-Environmental Schemes (AES), an EU initiative in which funding is provided to farmers who voluntarily take on more environmentally friendly farming practices or habitat conservation/restoration, could help fund such measures (see further discussion in *Agri-environmental Schemes (AES)*, later in this chapter).

Natural and semi-natural woodland habitats within agricultural landscapes have also been shown to be important habitats for bees. The proportion of woodland habitat on or near farms has been related to the pollination services provided by native bees (Kremen *et al.* 2002, Kremen *et al.* 2004). A study in five European countries found that bee diversity was positively enhanced by habitats of broadleaf forest and woodland shrubs (Carré *et al.* 2009). A study in the Mediterranean showed that both mature pine forests and mixed oak woodland are important natural habitats for wild bees and protection of these habitats is essential to ensure effective pollination of wild plants and may also be important to maintain pollination services in adjacent areas of agricultural crops (Potts *et al.* 2006).

Another study in western France confirmed that semi-natural woody habitat (hedgerows and forest edges), and semi-natural herbaceous habitat (grasslands, road and field margins), are important habitat for wild bees and bumblebees as well as for domesticated honey bees (Rollin *et al.* 2013). Honey bees were more abundant on mass flowering crops (sunflower, alfalfa and canola) than wild bees and bumblebees but they also needed the semi-natural habitat for foraging. Wild bees were more frequently found in the semi-natural habitats. They particularly favoured woody habitat in spring and herbaceous habitat in summer. Bumblebees foraged on mass flowering crops more so than the other wild bees but were found to also be associated with semi-natural habitats. It was concluded that the provision of woody and herbaceous semi-natural habitat on farmland for bees is important.

Most recent research on the impacts of farming method and agricultural landscape on bees – a global study

A recent study has specifically investigated the effects of local farm management on bees, and the effects of the surrounding agricultural landscape on bees in agricultural systems worldwide (Kennedy *et al.* 2013). The study encompassed the results from 39 individual studies on 23 different crops in 14 different countries. The purpose of this research was to synthesise data from studies around the world, using a mathematical model to capture landscape composition effects on bee diversity and abundance, accounting for the floral and nesting value of all habitat types in a landscape.

The results of this research reiterated and built on conclusions from other studies (see discussion above) that bee diversity and abundance were favoured by organic farming methods and by the presence of high quality semi-natural and natural habitats surrounding fields and farms. Specifically, this study by Kennedy *et al.* (2013) found that:

1. **At the level of local farm management, bee abundance and diversity was higher in organically farmed fields. Bee diversity and abundance was also higher in diversified farm fields, that is, smaller fields with mixed crop types and/or the presence of non-crop vegetation such as hedgerows, flower strips, and/or weedy field margins or agroforestry (woodland).** In most cases, organic, diverse fields harboured the greatest abundance and richness of wild bees, whereas intensively, industrially managed simple fields harboured the lowest. For temperate regions and the Mediterranean, organic farming was the main driver of positive management effects on bees.
2. **At the landscape scale, bee abundance and diversity were significantly higher when more high-quality semi-natural and natural habitats surrounded fields.** This effect was highly pronounced in Mediterranean regions. Bees thus seem to be affected most by the amount of high quality habitat within their foraging ranges – this is consistent with habitat loss being one of the key drivers of global wild bee pollinator declines (see Chapter 2 of this report).

3. **In intensive industrially farmed fields there was low field diversity (lack of hedgerows, and uncultivated areas), and bee abundance and diversity were lowest.** These farming areas benefited most where there were high-quality surrounding habitats.

   The negative effects of intensive industrial farming on wild bees are thought to arise from a combination of the lack of wild flower foraging resources (other than mass-flowering crops), the lack of semi-natural habitats around farms (and therefore, a lack of nest sites and foraging opportunities), and a heavy reliance on the use of synthetic chemical pesticides and fertilisers. As agriculture becomes more intensified, field sizes of monocultures get larger, wild plant diversity within and around fields is reduced and pesticides toxic to bees and other wildlife are sprayed onto the crops and land. To mitigate the ever-encroaching impacts of industrial agriculture and to enhance wild bee pollinators, Kennedy *et al.* (2013) made several recommendations based on the results of their study:

   - Increase the amount of semi-natural habitat in the landscape that can be used by bees. The modelling results suggest that for every additional 10% increase in the amount of high-quality bee habitats in a landscape, wild bee abundance and richness may increase on average by 37%.
   - Switching from conventional to organic farming could lead to an average increase of wild bee abundance (by 74%) and species richness (by 50%). Enhancing within field diversity could lead to an average increase of 76% in bee abundance.
   - To further enhance pollinator diversity and abundance, it was suggested that actions include: reduction of the use of bee-toxic pesticides, herbicides and other synthetic chemical inputs; planting small fields of different flowering crops; increasing the use of mass flowering crops in rotations; breaking up crop monocultures with uncultivated features such as hedgerows, low-input meadows or semi-natural woodlands.

The authors concluded that, as a result of implementing these changes to agriculture, the resulting multifunctional landscapes could aid increased and ensured crop pollination services by wild bees, natural pest regulation, soil fertility and carbon sequestration without necessarily diminishing crop yields. Within the EU, Agri-Environmental Schemes can provide funding for farmers to voluntarily take on organic farming methods as well as conservation of farmland habitats and biodiversity.

Agri-Environmental Schemes (AES)

Agri-Environmental Schemes (AES) were introduced in Europe in the 1990s in an attempt to enhance biodiversity on farmland. This was due to a growing concern that plants and animal life were being very badly affected by the increasing implementation of intensive farming methods and loss of semi-natural habitat. AES provide financial incentives to farmers to adopt environmentally beneficial work on their land and are generally aimed at enhancing biodiversity, though some schemes have more recently been implemented specifically to enhance pollinating insects, especially bees (see Chapter 2). AES also provide options of implementing low-intensity management of pastures and organic agriculture.

The outcomes of AES have been the topic of numerous studies. A study by Batáry *et al.* in 2011 statistically analysed the results of many of these studies to determine whether AES have been a success in terms of enhancing biodiversity. For pollinating insects specifically, the analysis revealed that pollinators were significantly enhanced by AES in simple (homogeneous) landscapes consisting of farmland with little semi-natural habitat in croplands and grasslands. In more complex heterogeneous landscapes with greater amounts of semi-natural habitat the effects of AES were less marked, likely because these landscapes already support more pollinators.

Another very recent analysis of 71 individual studies on AES in various European countries also found that AES that had been implemented in order to enhance biodiversity on farms had had positive effects on wild bees and other insect pollinators (Scheper *et al.* 2013). This was due to improvements in resource availability for pollinating insects, including the provision of more wild flowers and nesting sites. The effects were most pronounced in simple landscapes with 1-20% semi-natural habitat. Regions with greater landscape heterogeneity (greater than 20% semi-natural habitat surrounding farmland) did not show the advantage of AES because results are likely concealed by the continuous colonisation of the agricultural land by bee species from the semi-natural habitat. The study concluded that the objectives of AES need to be clear if they are to be successful. Those aimed at pollination services by generalist bee species, which are largely responsible for crop pollination, would be most effective in simple landscapes. However, if the objective is to preserve intrinsic values of biodiversity – such as preserving more rare, specialist species of wild bees – the efforts need to be aimed at more complex landscapes that can support these species.

One study of AES effectiveness has investigated whether the period of increased conservation under the schemes from 1990 onwards has aided the recovery of wild insect pollinators and wild plants in Great Britain, the Netherlands and Belgium (Carvalheiro *et al.* 2013). The study found that, compared with the period 1930-1990, when agricultural land-use became more intensified, the era post 1990 saw the trends of declines of wild plants and pollinating insects slow down. Some species even showed a partial recovery after 1990, including non-bumble bees in the Netherlands and Great Britain and hoverflies in Belgium, as well as wild plants in Britain. Therefore it is possible that increased conservation efforts in agriculture are starting to pay off, at least in regions where large land-use changes leading to natural habitat loss have nearly stopped.

What is clear from many of the studies discussed above in this chapter is that preservation of natural and semi-natural habitat within agricultural landscapes is key to preserving bee diversity and abundance. Also key are the findings that organic farming methods favour bee diversity because of: (1) the presence of more semi-natural habitat on organic versus industrially managed farms; (2) a greater diversity and ground cover of wild flowering plants within and around organically managed fields and grasslands; and (3) the absence of chemical pesticides that are toxic to bees. Therefore, implementing more organic farming methods under AES could benefit wild bee diversity and their populations. In addition, there are further steps that can be taken through AES to improve floral and nesting resources for bees on all farms – this is discussed below.

Steps that can help bees in Agri-Environmental Schemes

Sowing wild flower strips for bees and other pollinating insects

Natural and semi-natural habitat loss in and around farms, and consequently also a loss of wild plant diversity, are considered to be the main reasons for the loss of wild bee diversity in agricultural landscapes (Féon *et al.* 2010). For example, research has clearly documented recent declines in bumblebees in European agricultural landscapes (Biesmeijer *et al.* 2006, Kosior *et al.* 2007). This is thought to be caused by the loss of wild flower meadows and hedgerows as a result of modern farming practices. In contrast, traditionally managed hay meadows and hedgerows provide essential pollen and nectar sources needed by the bees, and are being proposed as a way to encourage bees in agricultural landscapes. Solitary bees are less studied than bumblebees but – due to their shorter flight ranges and narrower floral requirement – they are thought to be even more vulnerable than bumblebees to the consequences of modern farming practices. This is very worrying and, as discussed earlier in this report, will need actions taken specifically to enhance their populations, such as protecting and restoring natural and semi-natural habitats in agricultural landscapes.

To help wild bees and managed honey bees survive in agricultural landscapes and provide much needed pollination services, additional flowering and nesting resources can be created on farms. One way to achieve this is to sow native perennial wildflower and grass species in field margins of crop fields (Carvell *et al.* 2004). The resulting sown

BEE-STINGS: Extracts from "Living Without Pesticides"

"In the Netherlands there are currently approximately 1,000 kilometres of flowering field margins. The farmers apply these margins to stimulate natural pest management. We help farmers to do assessment themselves. They go out in the field and check the degree of infestation by pests and their natural enemies. For most farmers, I would guess 95%, this is completely new. […] We help them to not only learn how to recognise natural enemy insects but also to assess the infestation by pests."

Marijn Boss – eco-agriculture scientists, project leader "Bloeiend Bedrijf"(Flourishing Farm), Netherlands. *70% of the conventional farmers involved in the Flourishing Farm project 2013 changed their views on applying insecticides and voluntarily decreased insecticides uses. No more preventive spraying on the calendar.*

See Appendices 1 & 2 for further information.

wildflower strips at the edges of arable fields, or interspersed between crops, can provide floral resources for bees that can last throughout the whole season if the right species of flowers are selected. It is crucial to identify the most suitable flower seed mixtures consisting of native plant species for each country to support a diversity of native bees (Veromann *et al.* 2012). A survey in England showed that intensive farming has changed the composition of plants in field margins, favouring tall competitive plants over herbaceous perennials. The latter are important forage plants for some bees and it is advised that field borders be planted with carefully selected wild flowers to enhance bee diversity and abundance in agricultural landscapes (Carvell *et al.* 2004).

Sown wildflower strips have been introduced in several European countries under AES as a way to enhance pollinating insects as well as natural enemies (see Chapter 4). In Germany, wildflower strips are promoted as "*Blühende Landschaften*", or flowering landscapes. In Sweden, experiments have shown that wildflower strips can enhance the diversity and abundance of bumblebees, and are suitable for inclusion into intensive agricultural areas (Haaland and Gyllin 2012). In England, the EF4-nectar flower mixes entail the sowing of flowering plants containing at least four key families of plants that favour bees. This scheme has been shown to significantly increase the diversity of bumblebees found within fields (Potts *et al.* 2009, Carvell *et al.* 2007) and at the landscape level (Pywell *et al.* 2006).

For example, within fields, Carvell *et al.* (2007) showed that a mixture of agricultural legumes (pollen and nectar mixture), attracted a high abundance of bumblebees including the rare long-tongued species (*Bombus ruderatus* and *Bombus muscorum*). This is advantageous for the rarer species but did not provide enough forage early in the season for the short-tongued species. This can be corrected by using the "wild bird seed mixture" that also supplies these latter species with pollen and nectar from appropriate flowering plants. In addition, another native seed mixture of diverse wildflowers and non-aggressive grasses was found to attract and provide forage for a wide range of bumblebee species, and probably also solitary bees.

The flowers bloomed throughout the season, thus providing ample nectar and pollen sources for bees. The resulting perennial vegetation from this seed mix is projected to last for a 5-10 year time scale before re-sowing is necessary. The authors concluded that by using both the seed mixtures of legumes and of wild flowers on farms, there would be benefits for bumblebees and an increase in landscape heterogeneity within the arable farmed landscape. Pywell *et al.* (2006) also confirmed the positive effect of wildflower and legume seed mixes sown in margins on bumblebees, and also discovered that a positive effect on bees was evident at a larger (10km x 10km) landscape scale.

Flower-rich margins can also be sown in intensively managed grasslands to increase floral resources for bees. Research in the UK has shown that seed mixes of wild flowers, cereal and legumes significantly enhanced the biodiversity of both bumblebees and butterflies in intensively managed grasslands (Potts *et al.* 2009). Given the large proportion of agricultural land in Europe used intensively for grazing and silage, the scientists suggested there are potentially wide-scale benefits that could be introduced by AES to benefit pollinating insects using flower margins. In addition, stopping fertiliser application together with management regimes of a single cut and/or low-intensity grazing could further improve grasslands for insect pollinators. Current research into flower seed mixes is also looking at how flowers can be selected to provide not only forage for bees and other pollinators, but also natural enemies – in other words, seed mixes that aim to benefit and conserve multiple functional insect groups (e.g. Carrié *et al.* 2012). (see also Chapter 4).

In addition to sowing wild-flower margins, it is important to introduce into intensive farming the use of clovers and/or other leguminous plant species (peas, beans) in crop rotation systems (see Chapter 4). This would not only provide soil fertility without the use of synthetic fertilisers but would also enhance bee diversity, including long-tongued bumble bees. Using such cover crops is already common practice on organic farms. It has been suggested in England that the Nectar Flower Mixes be used in crop rotations as cover crops (Breeze *et al.* 2012).

Restoring species-rich grasslands and hay meadows

Natural grasslands and traditionally managed hay meadows are important forage resources for wild bees. However, in intensive farming, grasslands are managed with synthetic fertiliser and herbicide inputs, leaving species-poor grassland that provides little forage for bees. A study in four European countries on the impacts of intensive agriculture on wild bee diversity concluded that "in order to preserve bee populations in Europe, AES should promote the preservation of semi-natural habitat, particularly flower-rich grassy habitats" (Féon *et al.* 2010). In addition, decreasing the amounts of fertilisers used on grasslands could increase wildflower cover, and further, encouraging traditional hay meadow management instead of silage means that plants are not cut and removed before they have flowered. Encouragement of traditional hay meadow management within Europe would be a simple measure that could be taken under AES that could greatly help in the restoration of wild bee populations. Traditional hay meadows consist of many wild plants, including numerous flowering plants. They also contain many leguminous plants that are important for supporting long-tongued bumblebees (Veromann *et al.* 2012).

A study in southern Sweden reported that areas of agricultural land that had a greater proportion of traditionally managed hay meadows with a late cut (harvest) increased the species richness of solitary bees, including species on the World Conservation Union (IUCN) red-list (Franzén and Nilsson 2008). The agricultural landscape in this case consisted of numerous small farms scattered in a forest-dominated landscape, and is typical of large areas of northern Europe. To benefit solitary bee diversity in such regions, the study made recommendations that traditional meadow management with late harvest, no fertilisation, and 20% left ungrazed in May to July provided optimum benefits for the bees. Further validation of these findings in different countries should be carried out. Recent research on traditionally managed hay meadows in Switzerland by Buri *et al.* (2014) discovered that when a relatively small fraction (10-20%) of a meadow is left uncut as refuges for bees there was both an immediate and longer-term positive effect on bees – species richness and bee abundance was significantly increased. Therefore, uncut refuges could be used by AES to promote bee diversity, abundance and pollination services on traditionally managed hay meadows.

Maintaining and Restoring Hedgerows and Woodland on Farmland

Hedgerows are of great value for conserving wild plant diversity and most plants in hedgerows bloom and so provide food for insects (Minarro and Prida 2013). Research has shown that native wild plants, shrubs and trees within hedgerows provide important foraging resources for wild bees and managed honey bees (Hannon and Sisk 2009, Minarro and Prida 2013, Morandin and Kremen 2013a and 2013b). In addition, hedgerows offer the best food resources through the foraging season as a whole (Jacobs *et al.* 2009), and give protection from predators and disturbances by livestock. It has, therefore, been recommended that efforts to retain existing hedgerows and promote re-planting should be endorsed under Agri-Environmental Schemes (Power and Stout 2011).

A recent study in California's Central Valley showed the benefits of hedgerow restoration on agricultural land. It resulted in increased wild bee species diversity and abundance (Morandin and Kremen 2013a). The hedgerows also supported less-common species of bees. The study concluded that restoring hedgerows in agricultural areas may be essential for enhancing wild bee abundance and diversity and for pollination services to adjacent fields of crops.

As discussed earlier in this report, woodland has been shown to be an important habitat for bees. In a study of industrial and organic farms in England, Gibson *et al.* (2007) reported that there were significantly greater areas of woodland on organic farms. This was due to a higher occurrence of tree planting efforts on organic farms.

Rollin *et al.* (2013) recommended that woody habitat (hedgerows and forest edges), and herbaceous habitat (field margins, grasslands and fallows) should be provided for under AES because wild bees, bumblebees and domesticated honey bees all rely on foraging in these habitats.

BEE-STINGS: Extracts from "Living Without Pesticides"

"There should be better cooperation with farmers, who should try to increase their use of organic solutions. This could happen more often with support from the government. And of course it is very important to continue research. There should be independent funding for research that will give us more results and fill in the current gaps in our knowledge."

Dr. Fani Hadijna – researcher at the Apicultural Institute of the National Agricultural Research Foundation, Greece. *Dr. Fani Hafijna does research on neonicotinoid pesticides and their impacts on bees. She emphasises the need for more independent funding for research.*

See Appendices 1 & 2 for further information.

Conclusions – Ways forward to help bees in European agriculture

The review of scientific literature in this report clearly indicates that organic farming methods can enhance the diversity and abundance of wild bees in farm fields and agricultural landscapes. A switch to such ecological farming methods in Europe, which would include the phase out of the use of synthetic chemical pesticides (see Chapter 4), is imperative for helping the plight of both wild and domesticated bees. Also important is the conservation and restoration of semi-natural habitats on farms and within agricultural landscapes as well as the provision of selected sown wildflower strips in farm fields. AES could help by funding farmers to bring about the implementation of these measures.

In more detail, recommendations from the scientific studies discussed in this report include:

Provision of floral resources: The provision of floral resources from early spring to late summer is critical to maintaining bee species diversity. Some bees have long activity periods and fly throughout the season, whereas some have short periods of flight activity, with some species active in early spring and others in early or late summer (Pfiffner & Müller 2014).

- A variety of habitats provide the diversity of floral resources required by the many species of bees and domesticated honey bees. Herbaceous field margins, fallows, semi-natural grasslands, hedgerows and woodland have all been shown to be important for wild and domesticated bees.

BEE-STINGS: Extracts from "Living Without Pesticides"

"In the past I have used plenty of chemicals as a conventional producer, but when I started farming organically only then I realised how many mistakes I had made in the past and that I had been trying to fight the symptom and not the cause. […] With the balance brought about by organic farming there are many benefits in your cultivation. You can see that the soil is more lively, you can see the organisms that form the surrounding environment being in a balance that is not disrupted. Of course there are benefits for the planet, because the residues from chemicals take many years to degrade."

Giannis Melos – organic farmer, Greece. *As an organic citrus farmer, he uses different techniques to cope with insects. For instance, he successfully applies herbal preparations to repulse pest insects.*

See Appendices 1 & 2 for further information.

- Organic management of grasslands and traditionally managed hay meadows with late cut provide floral resources for bees. Small areas of hay meadow can be left uncut as refuges for bees. Organic management of arable fields also promotes more floral resources for bees.
- Establishing wildflower strips alongside crops tailored for bees provides additional pollen and nectar resources.

Provision of nesting sites: Natural and semi-natural habitats provide wild bees with nesting and floral resources. Particularly important for nesting at a landscape scale are small-scale habitats exposed to the sun. In central Europe such nesting habitats include bare and sparsely vegetated soil, course woody debris (dead standing or fallen logs) , and rock and stone features (rocks, dry-stone walls, boulders). Uncut vegetation containing plant stems and empty snail shells provide overwintering sites (Pfiffner & Müller 2014).

Phasing out the use of pesticides (including herbicides) and mineral fertilisers by switching to ecological farming: The use of herbicides in industrial farming diminishes floral resources available to bees in arable fields and field margins, while the use of herbicides and mineral fertilisers on grasslands has left them impoverished with few floral resources for bees. Many pesticides are also toxic to bees (see Tirado *et al.* 2013). The elimination of pesticides, herbicides and mineral fertilisers in European farming is possible by switching to ecological farming – this will favour both the diversity and abundance of bees. This is achieved by ecological pest control (see Chapter 4).

BEE-STINGS: Extracts from "Living Without Pesticides"

"We are working to go a step beyond the integrated production approach in order to grow cotton without the use of any chemicals, or at least reduce the use of chemicals to a minimum. We can do this by using organic fertilisers and treatments that respect the natural enemies of pests. Yes, I do believe that it is possible to reach the goal of growing cotton without chemicals."

Alberto Calderón – technical service of the farmers and ranchers association COAG Seville, Spain. *In a large-scale experiment in Andalusia, substantial reductions of inputs like pesticides, fertilisers and irrigation water were achieved by applying Integrated Production (IP), which Mr. Calderòn considers a bridge between intensive chemical and ecological farming.*

See Appendices 1 & 2 for further information.

A field with organic rhubarb in front of farmhouse De Aardvlo, in Bunnik, Utrecht, the Netherlands.

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4: ECOLOGICAL PEST CONTROL TO ELIMINATE THE USE OF SYNTHETIC CHEMICAL PESTICIDES

Tailored perennial wildflower strips offer food resources for natural enemies in organic horticulture (apple) cropping systems.

© Research Institute of Organic Agriculture (FiBL), Switzerland

Introduction

Many synthetic chemical pesticides used in industrial farming are known to be harmful to bees and the environment, and are also controversial because of possible impacts on human health. For "bee friendly farming" to be a possibility, it is essential that chemical pesticides are eliminated (Tirado *et al.* 2013, Johnston *et al.* 2014). Ecological farming helps protect crops without chemical pesticides: a variety of ecological farming methods enable farmers to control damaging pests without the need to use toxic chemicals. Organic farming methods directed at pest control are already widespread in Europe. Further, scientific research under the auspices of functional agro-biodiversity (FAB) is providing more practical knowhow concerning methods of ecological pest control without the use of chemical pesticides.

In agriculture worldwide, crop pests have always been a serious threat to crop production. Although agrochemicals are widely and increasingly used to combat pests, disease and weeds, there has not been a reduction in crop losses by percentage over the last 40 years, according to Oerke (2005). One of the causes of this failure is the non-selective use of chemical pesticides – these chemicals not only kill pests but can also harm beneficial species that prey on crop pests, so-called natural enemies. Natural enemies provide a means of natural crop protection by controlling pest populations (Wäckers 2012).

In natural habitats, the pest damage to plants is usually kept under control by the diversity of interactions (competition, predation, parasitism, etc) among the pests and their abundant natural enemies. Ecological pest control works by enhancing the diversity within farming systems and designing farming systems that promote a healthy population of diverse natural enemies to keep pest damage under control.

Natural enemies need habitats with abundant plant diversity and, to a greater extent, also some natural or semi-natural areas to survive. Forests, hedgerows, herbaceous field margins, fallows and meadows provide refuge for a diversity of natural enemies including carabids (ground beetles), staphylinid (rove beetles), spiders, coccinellids (ladybird beetles), syrphids (hoverflies), chrysopids (lacewings),) and parasitoids (parasitic bugs that ultimately kill, sterilise or consume their insect host) (see Bianchi *et al.* 2006).

Wild flowering plants in semi-natural non-crop habitat on farms provide the nectar and pollen needed as food by many natural enemies. Also, the majority of natural enemies rely on non-crop habitats for overwintering because bare fields are not suitable for their hibernation. After overwintering in non-crop habitat, the natural enemy insects can emerge in spring and move into crops where they may prey on crop pests providing the ecosystem service of natural pest control (Geiger *et al.* 2008).

The use of synthetic chemical insecticides may kill natural enemies, thereby hampering natural pest control. A study in Nicaragua looked at the influence of insecticide use on the main pest of cabbage crops, the diamondback moth (Bommarco *et al.* 2011). There were increased rates of parasitism of the moth by a parasitoid in unsprayed fields compared to those sprayed with insecticides. In addition, there was a higher abundance of two types of generalist natural enemy (spiders and a predatory wasp) in unsprayed fields. In comparison, in insecticide treated fields, the lower natural enemy abundances and lower moth parasitism rates indicated that the natural enemies were vulnerable to insecticide applications. Insecticide treated fields had higher leaf damage in the cabbage crop from the diamondbacked moth – likely reflecting both insecticide resistance of this pest and lower rates of predation and parasitism from natural enemy insects due to the use of synthetic chemical insecticides.

Ecological pest control

Several strategies have been developed to improve crop protection – a multilevel approach is taken (see figure 1). Most effort is put into the first steps that work by incorporating biodiversity into the farming systems to indirectly, but efficiently, protect crops from pests (steps 1-3).These steps are the most essential for ecological crop protection, and are the focus of this section of the report – the elimination of chemical pesticides from agriculture using ecological pest control.

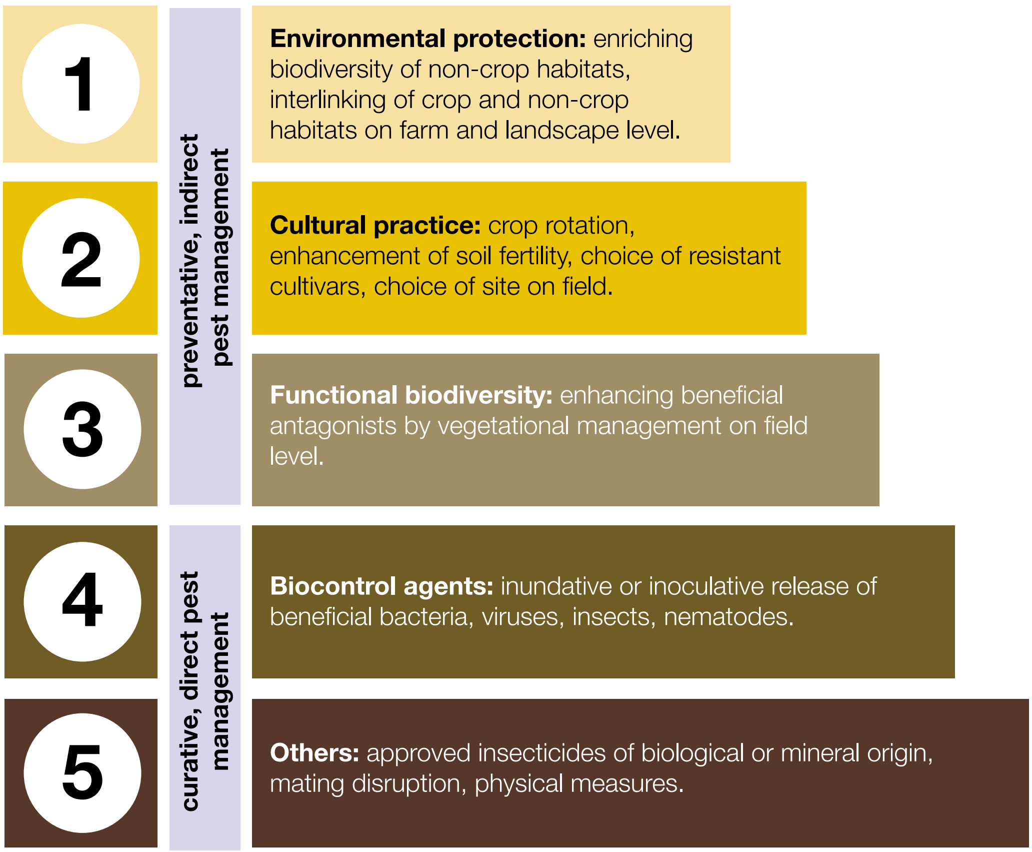
Step 1 involves enhancing semi-natural habitat around farms for the benefit of natural enemies and other beneficial wildlife. Scientific studies clearly show that more semi-natural and natural habitat in the agricultural landscapes favours natural enemies and ecological pest control (see *Effects of agricultural landscape on natural enemies*, later in this chapter). These are the same steps which are taken to increase habitat for pollinators.

Step 2 involves the adoption of optimal cultural practices. This includes diverse crop rotation to keep a healthy soil and improvement of soil fertility through the use of cover crops. These measures can also help to encourage natural enemies (see *Using cultivation methods to enhance natural enemies and natural pest control,* later in this chapter). In addition, the selection of resistant or tolerant crop plants (cultivars) is advisable to avoid crop damage from plant diseases (see *Ecological pest control through the development of resistant varieties and diversification*, later in this chapter).

Step 3 involves the enhancement of natural enemies by managing hedgerows and planting wildflower strips as food resources and habitat. This is known as functional biodiversity – in other words, enhancing plant biodiversity that is specifically geared to increasing a functional group of invertebrates, in this case natural enemies. The sowing of wildflower strips to support and encourage natural enemies and sowing grassy ridges (beetle banks) as habitat for natural enemies is discussed in *Using cultivation methods to enhance natural enemies and natural pest control,* later in this chapter.

Steps 4 and 5 are direct and curative measures of pest control, and respectively include the use of biocontrol agents and the use of approved insecticides of biological or mineral origin. These measures are only used if required at later stages of crop production (Forster *et al.* 2013). An example for the use of biocontrol agents is the use of pheromones to manipulate or disrupt the natural behavior of insect pests. This involves mating disruption or use to attract and trap/kill the insects. Typically only the pest being targeted is affected with no impacts on other biodiversity (Welter *et al.* 2005). In Europe, pheromones are widely used in the production of apples, oranges, olives and tomatoes and are extremely effective.

Figure 1. Multilevel approach to improve crop protection



Source: Forster *et al*. 2013

Ecological farming and natural pest control by natural enemies

Organic farming methods have been shown to favour the biodiversity and abundance of natural enemies on farms and this, in turn, can result in enhanced control of insect pests (eg. Crowder *et al.* 2010, Krauss *et al.* 2011). Greater numbers of natural enemies have been found on organic farms compared to industrially managed farms, including spiders (Schmidt *et al.* 2005, Oberg 2007) carabids (ground beetles) (Irmler 2003), lacewings (Corrales and Campos 2004), syrphids (hoverflies) and coccinellids (ladybirds) (Reddersen 1997). A recent statistical analysis of several studies showed that all species groups of natural enemies (except the coleopterans – beetles) showed a positive response to organic agriculture (Garrett *et al.* 2011). In addition to organic farming methods, habitat heterogeneity on organic farms may also have been an influence on the study results since increased semi-natural habitat is known to increase natural enemy abundance.

The natural enemy biodiversity that is conserved on organic farms ideally promotes natural pest control processes that compensate for the fact that application of insecticides to kill pests is disallowed under organic certification requirements. Increased abundance of natural enemies, however, does not always necessarily mean that increased natural pest control will result. There are currently few studies that have scientifically measured pest suppression by natural enemies (Letourneau and Bothwell 2008). Nevertheless, a synthesis of studies from both temperate and tropical regions concluded that, in agriculture, there is a strong link between higher natural enemy diversity and suppression of plant-eating insect pests (Letourneau *et al.* 2009).

BEE-STINGS: Extracts from "Living Without Pesticides"

"Roses and aphids belong together, a rose will always attract aphids. And the purpose of aphids is actually to serve as food for a number of other insects and birds. So when you create an environment that is attractive for predators, that is attractive for the insects who are supposed to eat the aphids, then they will automatically start eating the aphid plague till it ceases to be a plague."

Hans van Hage & Geertje van der Krogt, organic rose nursery, Netherlands. *Hans and Geertje run the only certified organic rose nursery in the Netherlands, using natural enemy insects to control aphids.*

See Appendices 1 & 2 for further information.

An example of increased pest suppression by natural enemies on organic farms was shown for some arable farms in South Germany (Krauss *et al.* 2011). This study compared organic and industrial farms growing triticale, a cereal used for animal fodder. The organic fields had five times higher plant species richness, 20 times higher insect pollinator species richness, and three times higher abundance of natural enemies. Due to the higher abundance of these natural enemies of aphids, the abundance of cereal aphids in organic fields was five times lower than in industrially managed fields. Organic farming, in this case, clearly promoted natural enemies and natural pest control. This study also showed that insecticide spraying of the triticale fields on industrially managed farms in an attempt to control aphids was only effective in reducing aphid numbers in the very short term. After two weeks the aphids increased rapidly with the long-term negative effects exerted by the insecticide on natural pest control.

A further study looked at differences between organic and industrial farming of wheat in Switzerland (Birkhofer *et al.* 2008). Organically managed fields hosted a twofold higher spider abundance, which contributed to the significantly lower abundance of aphid pests compared to industrially managed farms. This study also found that the two-times higher aphid abundance in industrially managed crop fields was likely to be due to the use of mineral fertilisers and herbicides. The increased nitrogen content of the managed crops benefited the plant-eating aphid pests. Conversely on organic farms, the use of farmyard manure as fertiliser promoted better soil quality, and together with organic farming methods fostered natural enemies, enhanced nutrient cycling and pest control. A study by Garret *et al.* (2011), also found a positive effect from the use of manures and plant composts on natural enemies and a negative effect of these natural fertilisers on insect pests. This aspect warrants further systematic study.

“Diversified landscapes hold the most potential for the conservation of biodiversity and sustaining the pest control function.”

– Bianchi et al. 2006

Organic farming clearly has a significantly positive effect on both wild bees (see Chapter 2) and on natural enemies and in many cases on pest suppression. A recent study by Bianchi *et al.* (2013a) used mathematical model simulations to look at the feasibility of implementing more organic farming into agricultural landscapes from the point of view of pest control. They found that industrial farming with insecticide use can easily lead to lose-lose situations whereby both organic farms and industrial managed fields suffer from increased pest loads compared to a scenario where no insecticides are used. However, if more organic farming was implemented gradually there may be transient increases in crop losses resulting from higher pest burdens because of the reduction in use of insecticides. On the other hand, a more rapid and extensive adoption of organic agriculture would be favorable for pest management. "These results emphasise the need to consider pest management strategies at the landscape scale, which will often require concerted effort among the various actors including farmers and regulators".

Effects of agricultural landscape on natural enemies

Semi-natural and natural habitat within and surrounding farms harbour biodiversity, and act as reservoirs for wild flowers and insects. Several studies have found that these habitats support a rich diversity of natural enemies (see Bianchi *et al.* 2006). Woody and herbaceous vegetation around farms can act as sources of pollen and nectar for many natural enemies. For example, chrysopids (lacewings), coccinellids (ladybirds), syrphids (hoverflies) and parasitoids have been shown to use nectar sources in semi-natural habitat adjacent to crop fields and then spread into surrounding crops where they may suppress pest populations (see Bianchi *et al.* 2006).

The diversity and abundance of natural enemies may decline with increasing distance from non-crop habitat. For example the abundance and diversity of parasitoid communities have been shown to decrease with increasing distance from non-crop habitat resulting in reduced parasitism of crop pests (Kruess & Tscharntke 1994, 2000, Tscharntke *et al.* 1998).

To find out the influence of landscape heterogeneity on natural enemies, Bianchi *et al.* (2006) conducted a statistical analysis of 24 published studies from Europe and the USA. This research showed that complex landscapes (with a mosaic of semi-natural habitats) were more favorable to natural enemies than simplified landscapes (with little semi-natural habitat).

In 74% of the studies, natural enemy populations were higher in more complex landscapes. Bianchi *et al.* (2006) then investigated what type of semi-natural habitat favoured natural enemies. They found that grassland, herbaceous and wooded habitats were all associated with enhanced natural enemy populations. They concluded that "since different non-crop habitat types may support distinct plant, herbivore and natural enemy communities, diversified landscapes may hold the most potential for the conservation of biodiversity and sustaining the pest control function".

Bianchi *et al.* (2006) also noted that very few of the individual published studies in their synthesis had looked at pest suppression by natural enemies, and conclusions could not be drawn on this subject. However, some studies and circumstantial evidence pointed towards increased pest suppression in complex landscapes.

For example, in Romania and Poland, Ryzkowski & Karg (1991) recorded higher biomass of insect pest species in crops located in simple landscapes compared with more complex landscapes. In some regions in Germany where landscape mosaics of forest, arable crops and networks of hedgerows exist, there is no need for chemical pesticide use to control aphid pests on crops – natural pest control suffices.

Further, a recent study in California investigated tachnid parasitoids, an important group of natural enemies in the control of vegetable pests (Letourneau *et al.* 2012). This study found that semi-wild perennial vegetation in agricultural landscapes is important as habitat for the support of tachnid parasitoids. The study showed that these parasitoids have the potential to cause significant mortality of agricultural pests in annual vegetable crop fields. The study suggested that maintaining semi-wild perennial habitat areas as refugia to support parasitoids can increase biodiversity and provide ecosystem services of natural pest control in annual crop fields.

A recent look at the effect of landscape complexity on natural enemies (Chaplin-Kramer *et al.* 2011) statistically analysed the results of 46 individual studies. This research revealed that natural enemy diversity and abundance both responded positively to landscape complexity. Thus more complex and biodiverse landscapes hosted a greater number and variety of natural enemies. These results were further confirmed in another study by Shackelford *et al.* 2013 – they noted that landscape complexity can have positive effects on natural enemies in general, in terms of abundance and species richness combined, and at local and landscape scales combined. This analysis of many studies found that some pollinating insects and natural enemies both responded positively to increasing landscape complexity.

Compared to simplified large-scale landscapes consisting of vast monocultures with little semi-natural habitat, it can be said that diversified small-scale landscapes consisting of a variety of semi-natural habitat provides the right conditions for natural enemies. It is therefore important to protect and enhance natural and semi-natural habitat on and surrounding farms to encourage natural pest control.

Other modern approaches to ecological pest control in farming

Functional Agro-Biodiversity (FAB) is defined as "those elements of biodiversity at the scale of agricultural fields of landscapes, which provide ecosystem services that support sustainable agricultural production and can also deliver benefits to the regional and global environment and the public at large". EU farmers and policymakers increasingly acknowledge that biodiversity and agricultural production are not in conflict, but can ultimately strengthen each other, as experience has already shown.

Functional agro-biodiversity uses science-based strategies for optimising ecosystem services in sustainable farming and is at a pioneering stage in European agriculture. Functional agro-biodiversity research and implementation into farming has included specific tailoring of wildflower seed mixes to enhance both pollinating insects (see Chapter 3) and natural enemies (see earlier in this section).

> "Biodiversity plays a pertinent role in the provision of ecosystem services including those that are essential to sustainable agricultural production."
>
> *– ELN – FAB (2012)*

> "On the basis of recent extensive work it is now possible to provide farmers with accurate prescriptions for seed mixes and landscape management that specifically target and optimise pest control benefits, while minimising possible negative effects."
>
> *– Wäckers (2012)*

Integrated Pest Management (IPM) aims that users of pesticides switch to practices and products with the lowest risk to human health and the environment among those available for the same pest problem (EU):

- Careful consideration of all available plant protection methods.
- Subsequent integration of appropriate measures that discourage the development of populations of harmful organisms.
- IPM emphasises the growth of a healthy crop with the least possible disruption to agro-ecosystems and encourages natural pest control mechanisms.
- IPM aims to protect crops from damage caused by pests, diseases and weeds by preventative actions such as the use of resistant cultivars and enhancement of natural enemies.
- Monitor pest and evaluate the pest population in a crop and decide whether intervention with chemical pesticides is required.
- Give priority to non-chemical methods. Reduce pesticide usage by employing natural pest control methods in the first and foremost and only use pesticides when deemed it is necessary (Cardosa 2013). Keep use of plant protection products (PPPs) and other forms of intervention to levels that are economically and ecologically justified and reduce or minimise risks to human health and the environment.

An extensive review of IPM research and implementation in European farming has recently been published (ENDURE 2010).

IPM differs from FAB and ecological and organic agriculture in that chemical pesticides are permitted. Greenpeace do not advocate IPM as a way forward for agriculture because of the use of synthetic agrochemicals.

BEE-STINGS: Extracts from "Living Without Pesticides"

First of all, it's essential to health, because we're applying fewer chemicals and that's fundamental! Secondly, it's good for our environment: we respect crucial auxiliary pollinators. Without them we wouldn't be farmers.

Charo Herrero – cotton farmer, Spain. *By applying principles of Integrated Pest Management (IPM) the cotton capsules open quicker and infestation by Lepidoptera larval pests is prevented.*

See Appendices 1 & 2 for further information.

Box 3: Beetle banks

To enhance natural enemies that prey on cereal aphids, overwintering habitats called "beetle banks" within cereal fields are created. These are made by creating low ridges/banks sown with perennial tussock-forming grasses, and they quickly establish and support high densities of predatory spiders and beetles (Gurr *et al.* 2003, Mcleod *et al.* 2004). Grassy beetle banks are created in the centre of crop fields. In springtime, the predatory beetles and spiders migrate from these habitats into the crop, thereby providing a service of pest control of aphids (Gurr *et al.* 2003). Beetle banks are successful and have been widely established in farms in Europe. In addition, it has been shown that, in the case of wheat fields, any losses in revenue from loss of land needed to create beetle banks is more than offset by the reduced need for pesticides due to natural pest control (Landis *et al.* 2000).

Using cultivation methods to enhance natural enemies and natural pest control

Sown wildflower strips

As discussed above, natural and semi-natural habitats on and surrounding farms support natural enemies. Many rely on flowers to provide nectar and pollen as food and herbaceous habitat as overwintering sites. With the loss of herbaceous habitat due to industrial farming methods, research now clearly indicates that natural enemies face food shortages in the absence of flowering vegetation. To counteract this problem and enhance the populations of natural enemies, there are cultural practices that can provide nectar and pollen resources and shelter for overwintering (Wäckers 2012). Practices involve sowing strips of wild flowering plants alongside cropped areas as nectar and pollen resources, and sowing grasses as refugia (beetle banks – see Box 3).

Wildflower strips are a simple and effective way to attract natural enemies and to help provide natural pest control. Sown strips can be positioned at the edges of arable fields or used to divide larger fields and ideally connect to other natural and semi-natural habitat so there are corridors and networks of habitat for the insects. In the early 1990s two different basic seed mixtures were developed for annual and perennial crops. Field tests in Germany, Austria and Switzerland have since resulted in further development of wildflower seed mixes. Seed mixes have been adapted to suite specific regions (Pfiffner and Wyss 2004). Moreover, it is recognised that seed mixtures must be also specifically tailored to enhance natural enemy species and not harbour and enhance agricultural pests (Winkler *et al.* 2009). This "targeted approach" means that plants are selected that are especially suitable for the species delivering the pest control, while excluding plants that are preferred by nectar/pollen-feeding pests.

The diversity and abundance of natural enemies including carabids (ground beetles), spiders, hoverflies and chrysopids (lacewings) has been shown to be increased by wildflower strips. In addition, wildflower strips act as overwintering habitat for insects and have been shown to enhance significantly the abundance of beneficial insects on agricultural land. This is due to their plant diversity, structural complexity and their permanent and undisturbed vegetation layer (Pfiffner and Wyss 2004). There are a number of successful examples in agriculture of natural pest control using sown wildflower strips.

- A study on commercially grown tomatoes in Italy using organic farming methods investigated whether natural pest control was enhanced by semi-natural herbaceous field margins and sown wildflower strips (Balzan & Moonen 2014). The study found that the sown wildflower strips supported a higher abundance of natural enemies and parasitoids later in the growing season. This resulted in enhanced aphid parasitism in the tomato crop and a reduced amount of leaf damage from pests. This reduction in pest damage from multiple pests due to natural enemies in sown wildflower strips occurred later in the growing season. Earlier in the season the study showed that the semi-natural herbaceous field margins were important habitat for natural enemies. Lower aphid counts and pest damage in the tomato crop were recorded suggesting this semi-natural habitat is important for early colonisation of the crop by natural enemies. The study concluded that the conservation of herbaceous field margins in conjunction with sown wildflower strips represent complementary strategies to enhance natural enemies and pest control in this geographical region.

BEE-STINGS: Extracts from "Living Without Pesticides"

"To increase the duration of photosynthesis, use windbreaks to intensify transpiration. If there are windbreaks, they host ladybirds, which neutralise aphids. This makes pesticides unnecessary. At the grassy bottom of the fence there are beetles. Beetles neutralise slugs, also making pesticides unnecessary."

Marc Dufumier – agroecology scientist and agronomist, France. *As a widely renowned rural development worker, he teaches agronomy at the 1st Agronomy University of France based in Paris.*

See Appendices 1 & 2 for further information.

- A three-year experimental study in the south of the Netherlands reported that sown selected annual flower strips and perennial grassy field margins along and through potato and wheat fields resulted in increased natural enemy numbers and reduced numbers of aphids. As a result, there was no need for insecticide spraying of the crops (van Rijn *et al.* 2008). In the Hoeksche Waard, South Holland, farmers are trying to implement FAB approaches to reduce pesticide usage. Annual and perennial filed margins have been sown together with enhancing semi-natural habitat on farms. As a result, no chemical insecticide was used on wheat and potato crops in four out of six years (Bianchi *et al.* 2013b).
- On a blueberry farm in Michigan, USA, wildflower strips were sown to enhance pollinating insects and were successful in this aim. In addition, the flowers attracted natural enemies – wasps, ladybirds, lacewings and predacious beetles – which are known to attack pests of blueberries. As a consequence, there was less of a need to spray with insecticides resulting in an 80% saving on insecticides (Conniff 2014).
- In France, as part of the Terrena Vision 2015, flowering strips are being sown in vineyards to enhance natural enemies of the grape berry moth (Bianchi *et al.* 2013b). Other studies have also reported successes of flowering strips in orchards and vineyards (see Pfiffner and Wyss 2004).
- Experimental work in Switzerland has selected three plants, including cornflowers, that are recommended for companion planting with cabbage crops to enhance target parasitoids of the main lepidopteran cabbage pest. Promising plants have also been selected for sowing perennial flower strips in apple orchards to enhance natural enemies (Pfiffner *et al.* 2013).

“Agro-ecosystem diversification is amongst the most promising strategies to keep diseases and pests under control.”

– Costanzo & Bárberi (2013)

It is important now that information be passed onto farmers so they can implement natural pest control more widely on farms across Europe. Wäckers (2012) notes: "There is an urgent need among policymakers setting agri-environment scheme prescriptions and practitioners managing the agricultural landscape for practical advice on targeted seed mixes and management of non-crop elements for ecosystem service delivery."

To provide a tailored approach for the widespread implementation of wildflower strips in agriculture, researchers in the Netherlands and the UK have compiled data on more than 100 plant species and their suitability for supporting pollinating insects and natural enemies. This database will permit important and relevant information for tailoring flowering seed mixes for site specific and crop-specific pest control and pollination services (Wäckers 2012).

Equally important is that FAB programmes to enhance ecosystem services of pollinating insects and natural enemies are implemented on a landscape-wide scale. Presently, flower strips are implemented at the field and farm scales, but insects operate at landscape scales. For example, flower strips may not be effective at enhancing natural enemies and pollinating insects if surrounding fields are frequently sprayed with broad-spectrum insecticides, or if there are few areas of semi-natural and natural habitat in the surrounding environment. Therefore, cooperation between multiple actors and stakeholder groups is required to implement FAB programmes throughout different regions of countries so pest control can be effective at a landscape scale. Although this may seem daunting, there are compelling examples that concerted action can be successful, such as in the Hoeksche Waard in the Netherlands (Bianchi *et al.* 2013b).

BEE-STINGS: Extracts from "Living Without Pesticides"

> Spraying plants [with chemicals] also damages the plants. There's less photosynthesis because spraying forms a protective layer. With insects you can control pests really well and the food produced this way is super clean.

Jim Grootscholte – organic pepper producer, Netherlands. *As an innovative farmer he experiments with different bio-control techniques. Against aphids, he successfully uses seven different species of natural enemy insects that live on aphids.*

See Appendices 1 & 2 for further information.

Crop rotation and cover crops

In organic farming, crop rotations, cover cropping and application of plant and animal manures are the main means for enhancing soil fertility and maintaining a "healthy" soil (Zehnder *et al.* 2007). Crop rotations are the best means to control soil-borne pathogens and have been the mainstay of plant protection in the past. However, in more recent years, crop rotations are less frequently implemented as part of industrial farming practice, and there is a greater reliance on agro-chemicals to combat crop diseases (Finckh *et al.* 2012).

Crop rotation has also been reported by several researchers to lower the numbers of pest insects on crops grown with organic compared with synthetic of fertiliser (Finckh *et al.* 2012). Organic farming often also uses organic mulches such as straw that has been shown to suppress some insect pests, thought partly to be due to increased predation from natural enemies (see Zehnder *et al.* 2007).

Planting cover crops such as brassicas, legumes, and other flowering plants in the off-season usually increases organic matter in the soil and helps soil protection and weed suppression (Finckh *et al.* 2012). Cover crops have also been shown to help reduce crop pests (see Gurr *et al.* 2003). In addition, cover crops such as legumes and clover can provide urgently needed pollen and nectar for pollinating insects (Finckh *et al.* 2012). A recent study in Spain found that planting winter cereal cover crops in olive groves increased the number of parasitoid populations in the olive canopy (Rodríguez *et al.* 2012). These natural enemy species prey on the olive moth, the most common insect pest of olive trees, and it was suggested that the practice of cover cropping in olive groves be more widely implemented.

Ecological pest control through the development of resistant varieties and diversification

Despite the mainstream research agenda being focused on chemical pest control for the last decades, many studies have found successful agro-ecological ways to manage specific pest problems. There are many approaches, given that ecological farming is very context specific. The guiding principle is increasing and maintaining biodiversity as the insurance against pest damage through natural pest protection and increases in agro-diversity, and this will need certain reconfiguration of the farming system as a whole (Tittonell, 2013).

Genetically uniform planting, the usual practice in industrial monocultures, is a shortsighted strategy to combat pests. Pest evolution is usually quicker than human interventions, and thus pest-resistant cultivars are not a durable strategy. A growing body of research confirms that incorporating biodiversity at different scales (from cultivars to landscape) is the most promising strategy for effective and sustainable pest control.

Within this framework, there are many examples of successful ecological pest protection based on biodiversity, working with pest-resistant varieties in agro-ecological contexts:

- In a unique cooperation project among Chinese scientists and farmers in Yunnan during 1998 and 1999, researchers demonstrated the benefits of biodiversity in fighting rice blast, the major disease of rice, caused by a fungus (Zhu *et al.,* 2000). By growing a simple mixture of rice varieties across thousands of farms in China, they showed that disease-susceptible rice varieties inter-planted with resistant varieties had an 89% greater yield and 94% less disease incidence than when they were grown in a monoculture. Fungicidal sprays were no longer applied by the end of the two-year programme. This approach is a calculated reversal of the extreme monoculture that is spreading throughout agriculture, and being promoted by some agribusinesses focused solely on plant genetics (Zhu *et al.,* 2000, Zhu *et al,* 2003, Wolfe, 2000).

BEE-STINGS: Extracts from “Living Without Pesticides”

> I think pests have ceased to be seen as pests. It belongs in a mindset of a different way of looking at nature by dividing it up into good and bad and rather than seeing it as a whole, a whole living thing, that gets ill, gets better.

Steve Page – permaculturist and member of Eco’logique association, France. *By growing multi-purpose and companion plants according to the principles of permaculture, no external inputs are needed on their farm.*

See Appendices 1 & 2 for further information.

- In the UK, raspberries provide a unique example of a crop plant conventionally bred to contain several types of genetic resistance to pest aphids. Research in this system further emphasises the need to combine pest-resistant cultivar with other pest-protection measures based on biodiversity, such as intercropping or mixed cultivar stands, as key foundations of durable pesticide-free production methods (E. Birch *et al.*, 2011).
- "Genotypically diverse plantings of willow received as much as 50% less damage from leaf beetles than willow monocultures because beetles preferentially fed in patches of more suitable hosts (i.e. resource concentration hypothesis) and had difficulty finding palatable willow varieties when they were grown in mixtures (i.e. associational resistance)." Peacock & Herrick (2000), cited in Tooker & Frank (2012).
- "Research with wheat has detected resistance to at least 28 bacterial, fungal and viral pathogens, four species of nematodes and nine species of insect (McIntosh 1998). Importantly, many of these resistant varieties are available and form the basis of IPM programmes worldwide." Tooker & Frank (2012).
- In the long term, the conservation of ancient cultivars and wild relatives will be essential to identify new resistant varieties. Landraces and wild races often pose resistance conferred by a number of different genes, and thus they can contribute to pest protection without the risk of genetic uniformity, which can improve the durability of the resistance. Multiple resistance traits can be easily handled through modern breeding techniques, like QTL mapping and marker-assisted selection (Costanzo & Bárberi, 2013).

BEE-STINGS: Extracts from "Living Without Pesticides"

> "Finally, an important and fundamental aspect is that – without decreasing income – reducing pesticides usage means less health risks for workers, farmers and field contractors. These people are the ones who are most often exposed to the highest concentrations of chemicals."

Lorenzo Furlan – manager of Agricultural Research Department, Italy.
He experiments with pesticide reduction methods, among others crop rotation, specific crop turnover in the ground and tree-rich surroundings of the fields to host beneficial insects.

See Appendices 1 & 2 for further information.

APPENDIX 1

OVERVIEW: PLAN BEE – LIVING WITHOUT PESTICIDES

Heroes of the Greenpeace video project

Ecological farming in practice – exemplary solution case studies from across Europe.

Country	Participant	Occupation	Product	Keywords
Austria	DI Martin Filipp	Scientist, farmer	Apples	Pheromones, granulises virus, neem oil.
	Erich Stekovics	Farmer	Tomatoes	Large collection of tomato varieties, complex crop rotation, naturally grown cultivation.
France	Astrid & Olivier Bonnafont	Farmer	Wine grapes	Organic production, field biodiversity, herb spray, plough with horse.
	Em. Prof. Marc Dufumier	Scientist, rural development worker	-	Ecological agriculture, systems approach
	Eric Escoffier	Farming advisor	-	Permaculture trainer
	Yvonne & Steve Page	Permaculture practitioners	A variety of fruit and vegetables	Sustainable garden, permaculture
Germany	Gypso von Bonin	Farmer	Rapeseed	Biodynamic farming, complex crop rotation, experiments with lavender oil, lactic acid and a homeopathic drug.
	Prof. Dr. Rudolf-Udo Ehlers	Production company	Nematode producer	Using natural elements to suppress pests.
Greece	Dr. Fani Hatjina	Bee scientist	-	Research on neonicotinods and bee health.
	Giannis Melos	Farmer	Various organic products including citrus fruit	Organic production, selection of varieties, unattractive surroundings for pests.
Italy	Dr. Lorenzo Furlan	Scientist	Maize	Pesticide reduction, repulsive surroundings, natural extracts as dung.

Country	Participant	Occupation	Product	Keywords
Netherlands	Merlij M Bos Ph.D.	Scientist, farming advisor	Mainly arable	Pesticide reduction, flowering field margins.
	Jim Grootscholte	Farmer, greenhouse	Bell peppers	Natural pest control, natural enemies.
	Hans van Hagen & Geertje van der Krogt	Farmers	Roses	Organic, balanced design, one third of the farm consists of natural vegetation.
	Jan van Kempen	Farmer	Arable	Pesticide reduction, flowering field margins.
	Henri Oosthoek	Production company	Beneficial insect producer	Production, natural enemies, insects.
Poland	Dr. inz. Stanisław Flaga	Scientist, bee breeder	-	Agricultural specialist, organic apple orchard, solitary bee breeder.
	Dr. Piotr Medrzycki	Scientist	-	Biological means of pest control.
	Tomasz Obszański	Farmer, founder of producers' cooperative	-	Ecological farming, microbiological and natural ways to fight pests.
Romania	Ion Toncea	Scientist, farmer	Broad selection of harvest	Crop rotation, selection of the best cultivars and increasing biodiversity, neem extract as a seed coating.
Spain	Alberto Calderon	Agrarian technician	Cotton	Pesticide reduction.
	Charo Guerrero	Farmer	Cotton	Pesticide reduction.
Switzerland	Dr. Claudia Daniel	Scientist	Rapeseed	Organic, silicate rock dust application, repellent essential oils.
	Dr. Hans Herren	Scientist, advisor	-	Ecological agriculture, push-pull methods in mixed cropping systems.

The videos can be found here: ***www.sos-bees.org/solution***

APPENDIX 2
DETAILS: PLAN BEE – LIVING WITHOUT PESTICIDES

Heroes of the Greenpeace video project

Ecological farming in practice – exemplary solution case studies from across Europe.

AUSTRIA: Dipl. Ing. Martin Filipp – organic apple grower

Location of project	Bogenneusiedl, Austria.
Description	Dipl. Ing. Martin Filipp is a researcher at the University of Applied Life Sciences in Vienna (BOKU) and has conducted field research on the ecological farming of fruits. He also runs a certified organic apple farm where he works with different biocontrol methods to protect his apple trees. The main problem for apple farmers is the caterpillar of the codling moth (*Cydia pomonella*), which he treats with pheromones (mating disruption), which work until an infestation level of 2% is reached, and with granulosis virus, which attacks the grubs and can be sprayed from mid-May until September. To treat rosy apple aphid he uses neem oil containing natural Azadirachtin.
Category	Commercial.
Outcome / Results	Filipp's farm produces good yields and he sells his products through many channels. Some, such as apple juice, can be purchased year round and is sold in cooperation with supermarkets and FoodCo-ops.
Key recommendations	Filipp indicates that most farmers only receive information on chemical pesticides and that they are often afraid to try new things if the results are uncertain. He openly speaks out, therefore, for more money for research on ecological farming, especially for innovative alternative projects that favour biodiversity, beneficial animals and intercropping. Furthermore, he wishes that supermarket chains would start looking beyond the same two organic apple varieties. That would enable him to grow and sell alternative varieties, as he already does to Food Co-ops.

AUSTRIA: Erich Stekovics – innovative tomato producer

Location of project	Frauenkirchen, Neusiedlersee, northeastern Austria.
Description	Erich Stekovics is a very innovative and successful tomato farmer. He has the world's largest collection of tomato varieties.Every year around 1,000 varieties of tomato plants thrive in his fields. His seedbank includes seeds from 3,200 varieties, producing fruit in every conceivable colour, shape and size. Erich works with a complex crop rotation. Among other things, he grows chillies, cucumber, strawberries, apricots and garlic. His fields are located nearby Lake Neusiedler, where there is a mild climate and around 300 days a year with sun. His plants are never irrigated nor tied up and supported, he just allows the plants to grow naturally on the fields. He mainly works with drought resistant varieties. There are eight permanent employees plus his family working in the business.
Category	Commercial.
Outcome / Results	He manages to extract delicious flavours from the different varieties he grows. He produces sauces, preserves and chutneys, which can be purchased from the farm shop and in select gourmet shops. He also sells seedlings to customers. From July to September daily public tours are held through the colourful tomato fields.
Key recommendations	Stekovics advocates a revaluation of food that will make customers willing to pay "real prices".

FRANCE: Astrid & Olivier Bonnafont – organic viticulturists, Domain Peyres Roses

Location of project	Cahuzac-sur-Vere in the Tarn, southern France.
Description	Astrid and Olivier Bonnafont and their four sons run an organic vineyard. As viticulturists, they also oversee the production, fermentation and maturation of the wine. They aim to achieve harmony between the grower and the natural environment, and to produce a product that is close to nature and based on natural ingredients. Their farm consists of 15 acres of clay-limestone soil. This is a calcareous clay soil with high limestone content that neutralises the natural acidity of the soil. To maintain high soil quality, they plough the fields with their horse. The slopes are south-southeast facing and the area is characterised by its regional winds, which provide ideal conditions for grapes. Domaine Peyres Roses recognises the importance of natural biodiversity in its cultivation practices. About half of its 15 acres of land is covered by meadow with natural herbs, truffle oaks and flowers. In springtime some of the herbs are used to produce sprays as bio-control agents for the vines.
Category	Commercial.
Outcome / Results	Domaine Peyres Roses produces certified organic wine. No environmental pollution, the landprovides a good quality natural habitat for many species of flora and fauna.
Key recommendations	A ban on all herbicides because they are detrimental to beneficial plant life.

FRANCE: Em. Prof. Marc Dufumier – Professor Agronomy

Location of project	Paris, central/northern France.
Description	Em. Prof. Marc Dufumier teaches agronomy at the 1st Agronomy University of France based in Paris, and is widely renowned as a rural development worker. He emphasises: "… agriculture based on agroecology is the one that tries to make the most intensive use of renewable natural resources". His motto is that "agroecology is what agronomy should never have ceased to be." He speaks to the merits of ecological agriculture that recognises the complex relationship between plants, animals and microorganisms in the atmosphere and in the soil.
Category	Scientist.
Outcome / Results	The objective of an ecological farmer is no longer simply just a plant or just the soil. It is a complex ecosystem transformed by the farmer, but much less fragile than in industrial agriculture.
Key recommendations	Use all grants and payments under the Common Agricultural Policy to pay farmers to produce good products and to promote beneficial environmental services eg. pollination. CAP should be used as a tool, to provide an extra incentive to allow farmers to operate an ecological agriculture transition.

FRANCE: Eric Escoffier – permaculture trainer

Location of project	Southeast France.
Description	Eric Escoffier is one of the authorities on permaculture in France, trainer and consultant, part of "Permaculture without borders" and "Wise hands - permaculture" NGO. He works with the principles of permaculture. This involves a different way of looking at nature as compared to conventional farming. The practical application of permaculture emphasises the reuse and recycling of all kinds of (organic) materials. In a perfectly designed system nothing is regarded as waste or has to be disposed of. No pesticides are used because in the view of Eric Escoffier, pesticides do more harm than good in agriculture, considered as a whole.
Category	Commercial.
Outcome / Results	Permaculture as a farming approach is working in places all around the world (Veteto, Lockyer; 2008). Permaculture systems do not produce waste and they do not need external inputs (apart from water).
Key recommendations	Teaching farmers how to apply permaculture.

Veteto JR, Lockyer J (2008). Environmental Anthropology Engaging Permaculture: Moving Theory and Practice Toward Sustainability, Culture & Agriculture Vol. 30, Numbers 1 & 2 pp. 47–58.

FRANCE: Yvonne & Steve Page – permaculture practitioners

Location of project	Limousin region, central/southern France.
Description	Yvonne and Steve Page produce fruit and vegetables using permaculture methods. In their permanent gardens they grow a variety of crops which they distribute through a variety of channels. Even insects that can seriously damage crops are welcome in their gardens. As they see it, it is only necessary to limit insect pests, and their main tool is a tight focus on diversity of plant species. By growing multi-purpose plants and companion plants, they help the ecosystem, improving soil fertility and plant resistance to disease.
Category	Commercial.
Outcome / Results	They have been farming like this for many years. They achieve good yields and market their products through direct and indirect channels. Sales to professionals wanting to promote agriculture with respect for nature.
Key recommendations	That we stop supporting industrial agriculture that greatly pollutes the environment. Industrial agriculture uses a lot of energy, water for irrigation, together with pesticides and fertilisers.

GERMANY: Gyso von Bonin – biodynamic farmer

Location of project	Ruthen, Sauerland, central Germany.
Description	Gyso von Bonin runs a large organic farm, cultivating 18 crops and raising numerous animals. His total farm holding consists of 200 hectares, of which 15 hectares are planted with rape. He practises organic farming using a biodynamic model, following the teachings of Rudolf Steiner. The area has a hilly character, including steep slopes and temporarily flooded valleys. Most of the farm land is surrounded by forest. The soil mainly consists of a sandy loam. Bio-dynamic farming recognises the importance of crop rotation. Bonin is currently conducting field trials with alternative pest control methods in rapeseed. He is experimenting with lavender oil, fermented bread (lactic acid), and the production of a homeopathic drug.
Category	Commercial.
Outcome / Results	Bonin's rape yields are approximately half of the yields of his colleagues who grow rape in a conventional way. The crop yields differ from year to year. Financially, however, he is not disadvantaged. On the one hand his costs are much lower, and on the other hand the revenue from his rape is much higher (€750/ton versus €350/ton).
Key recommendations	Implement a tax on N-fertilisers, promotion of beneficial insects, promotion of legume planting, public research money for organic breeding.

GERMANY:
Prof. Dr. Rolf-Udo Ehlers – industrial manufacturer of nematodes, E-nema GmbH

Location of project	Kiel, northern Germany.
Description	Prof. Dr. Rolf Udo Ehlers, a member of the International Organisation of Biological and Integrated Control [IOBC], is a renowned scientist who is deeply engaged in European research projects concerning bio-control methods. He is the founder of the business E-nema GmbH, producing large quantities of nematode worms to be used in pest control . From an agricultural perspective, nematodes fall into two broad categories: (1) predatory nematodes that kill garden pests; and (2) pest nematodes that attack plants or spread plant viruses by acting like a vector. Prof. Ehlers and his research group at the University of Kiel founded E-nema GmbH after developing a liquid-cultivation technique to culture insect-pathogenic nematodes in a bioreactor.
Category	Commercial.
Outcome / Results	E-nema GmbH has been working as an industrial manufacturer of nematodes since 1997 and the company is continually expanding. Currently the company is the leading international producer of insect pathogenic nematodes. By commercialising the technique, E-nema GmbH has contributed to environmentally safe methods of plant protection.
Key recommendations	EU policies that support the introduction of biocontrol. Ehlers states that EU member states need to promote the implementation of biocontrol in the EU.

GREECE: Dr. Fani Hatjina – scientific researcher, apiculture

Location of project	Apiculture Institute of the Hellenic Agricultural Organisation "Demeter", Nea Moudania, Greece
Description	Dr. Hatjina is mainly conducting research on neonicotinoids and their impacts on bees, in the laboratory and in the field. The work also aims to test real-life situations on different crops. The programme was started because beekeepers experienced problems from impacts of pesticides used in the fields. Beekeeping is a traditional occupation in Greece, and more and more young people are entering this field of work because they have the possibility of producing a good honey and to earn a very good income. The programme covers: 1. Laboratory tests to evaluate effects of stressors on honey bee physiology (gland development, respiration, fat body). 2. Semi field tests to evaluate effects on foraging behaviour, disease prevalence, colony status, and thermoregulation. 3. Field tests for monitoring effects on colony level, disease prevalence and fertility. 4. Laboratory and field tests to evaluate effects of food additives on welfare and health of bees. 5. Testing biological agents against honey bee pests is an additional activity.
Category	Experimental.
Outcome / Results	From several studies it has become apparent that imidacloprid in sublethal doses has a significant detrimental effect on different aspects of bees' behaviour and health. Based on the results of the research, she advises beekeepers to avoid areas where these pesticides are used and to provide fresh "clean" pollen, especially during spring. She also advises beekeepers to use native bees with a higher tolerance to toxic pesticides, and to put pressure on the government for green practices and a ban on neurotoxic chemicals.
Key recommendations	At international scientific fora on bees, Dr. Hatjina emphasises the need to shift to agriculture using fewer pesticides. She believes that any dramatic change in our ecosystem will result in an artificially corrected ecosystem, which eventually will become unsuitable for people. For the sake of future generations, it may be necessary for companies to accept a cut in profits in order to safeguard our environment. Also, she calls for support from the state to ban the worst and most toxic pesticides. Furthermore, she emphasises the need to strengthen independent funding for research on other species of bees, for large-scale studies and approval of new tests.

GREECE: Giannis Melos – organic citrus cultivation

Location of project	Troizinia, central/southern Greece.
Description	Giannis Melos is an organic farmer who cultivates, among other things, oranges and lemons, which are very attractive to bees. Melos discovered organic farming while he was looking for a solution to improve both his financial situation and improve his cultivation methods. Currently, he uses different techniques to deal with insect pests. First, he focuses on choosing the right cultivation at the right time. Then he uses preparations that make the surrounding area unattractive to pest insects and drives them away. And finally, as an emergency measure, Melos also kills insects by using different kinds of plant extracts.
Category	Commercial.
Outcome / Results	Melos has healthy plants, and produces good quality products that enable him to make a living. Important benefits from the balance brought about by organic farming include noticeably better soils and good conditions for wildlife in the surrounding environment.
Key recommendations	Melos advocates the reform of education for farmers. He is proposing the creation of small flexible teams of farmers who can be “mentored” by an expert in organic farming methods. In this way the farmers can learn enough to be able to produce a satisfying and profitable quantity of organic products.

ITALY: Dr. Lorenzo Furlan – researcher on corn, focusing on pesticide reduction

Location of project	Vallevecchia, Veneto region, northeast Italy.
Description	Dr. Lorenzo Furlan is an agricultural researcher focusing on pesticide reduction in European corn cultivation. He aims to develop cultivation methods that enable farmers to maintain their income while reducing their impact on the environment. He focuses on reducing pesticide usage while maintaining, or even increasing, soil fertility. He demonstrates that, for maize, it is possible to apply an IPM approach that results in a dramatic reduction of soil insecticide use (microgranules, seed coating). The methods (based on Directive 128/2009/CE principles) that are used in IPM procedures are: (1) pest population levels have to be estimated by means of monitoring and models; (2) treatment may then only be carried out where and when monitoring has found that levels are above set economic thresholds; (3) if economic thresholds are exceeded, agronomic solutions – mainly rotation – should be considered to avoid damage to maize crop. If economic thresholds are exceeded and no agronomic solutions are available, biological or physical treatment, or any other non-chemical pest control method, should be considered as a replacement for chemical treatment, if available. Integrated Pest Management (IPM) differs from Functional Agro-biodiversity (FAB) and ecological and organic agriculture in that chemical pesticides are permitted. Greenpeace do not advocate IPM as a way forward for agriculture because of the use of synthetic agrochemicals.
Category	Experimental.
Outcome / Results	Concerning the agronomic aspects and problems of farmers, Dr. Furlan says integrated pest management methods produced excellent results in maize production without the use of neonicotinoids on most plots. By understanding possible risk factors of crop damage involving insects in the soil, the usage of soil insecticides could be reduced by more than 90%. The reduction of pesticides helps the environment by reducing negative effects upon beneficial insects. Less pesticide use also lowers the health risks for workers, farmers and field contractors.
Key recommendations	Dr. Furlan believes that policies should be directed towards helping the transition from conventional to innovative agriculture. This could be achieved if the transition risks to farmers are covered by some form of insurance. Innovative forms of insurance policies should be supported by the EU. This would allow investments in pesticides (or plant protection products) to be converted into insurance policies beneficial for farmers and the environment. In order to increase the application of new integrated pest management technology, what is needed today is independent technical assistance on location, which can show farmers how these techniques work, and assist them, especially in the early stages of the conversion process.

NETHERLANDS: Merijn M Bos, Ph.D. – project leader of Flourishing Farm

Location of project	Louis Bolk Institute, central Netherlands.
Description	Merijn Bos is an agricultural ecologist working mainly on agrobiodiversity. He has led the project "Bloeiend Bedrijf" (Flourishing Farm) since 2011. As part of this project, approximately 600 farmers have planted over 1,000km of flowering field margins in the Dutch arable landscape in 2013, to stimulate natural pest management. Conventional farmers are regularly guided by production managers, who are paid from the revenues of marketing pesticides. In this project farmers learn to recognise natural enemies and threshold levels of insect pests. Farmers form small, local groups and, assisted by an expert, they practise in their own fields. Another aim of this project is educating farmers on biocontrol methods. Integrated Pest Management (IPM) differs from Functional Agro-biodiversity (FAB) and ecological and organic agriculture in that chemical pesticides are permitted. Greenpeace does not advocate IPM as a way forward for agriculture because of the use of synthetic agrochemicals.
Category	Experimental.
Outcome / Results	Bos indicates that arable farmers, who are used to prophylactic use of insecticides, change their view on crop protection and start using synthetic chemical pesticides based on field observations and the presence of beneficial insects. In 2013, 70% of the conventional potato and cereal growers involved in the project changed their view on applying insecticides and, as a result, used less insecticides.
Key recommendations	Bos advises politicians that pesticides can be managed in a more sustainable way by organising agricultural projects including education and interaction between farmers, as practised at Flourishing Farm. This could lead to much stronger innovation in agriculture in the Netherlands and the EU.

NETHERLANDS: Jim Grootscholte – bell pepper farmer, 4Evergreen

Location of project	's-Gravenzande, western Netherlands.
Description	Jim Grootscholte produces sweet bell peppers on a large scale in greenhouses. He is a very innovative farmer and experiments with various biocontrol techniques. Since 2007 he has been engaged in PuraNatura. This foundation aims to support the production of tasty, affordable, safe and clean vegetables. In 2008 he received USDA NOP organic certification; he is not qualified for European organic certification because he grows his plants in coconut substrate and not in soil. Grootscholte mentions that he tries to achieve an ecological balance in his greenhouses, pest species are always present. Currently, he makes use of seven different species of aphid enemies. He has three employees who continuously monitor aphid levels, and based on their observational data he decides which, and how many, natural enemies will be introduced.
Category	Commercial.
Outcome / Results	The business is doing very well. In January 2014 the innovative capacity of 4Evergreen was recognised: Grootscholte's project received the Horticultural Business Award 2014.
Key recommendations	4Evergreen now exports its produce mainly to the US, because EU organic regulations do not allow production on coconut substrate, as this company does. Jim calls upon governments to revise the organic regulation.

NETHERLANDS:
Hans van Hage & Geertje van der Krogt – organic rose nursery De Bierkreek

Location of project	Ijzendijke, southern Netherlands.
Description	Van Hage and Van der Krogt run the only certified organic rose nursery in the Netherlands. De Bierkreek grows roses in harmony with the environment and with nature. The perspective from which they work is to create the right conditions for natural ecological processes to take place. Therefore, De Bierkreek focuses on cultivating the roses with good quality food (nutrition) and a good growing bed (soil quality), while shielding them from stress. In the case of an outbreak of a pest, they ask themselves what method nature has come up with to control it. Then they create the conditions needed for this to occur. A lot of attention is focused on the design of the container area. One third of the farm consists of natural grass strips with brushwood and bushes, interspersed with pollarded trees, hedges, wood strips and water pools, because natural enemy insects need these habitats to survive and flourish. The nursery has a closed water system and the roses only receive rainwater. The water basin is equipped with an “Algeastop”, an ultrasound system that kills algae, and supports a large school of fish, *Scardinius erythropthalmus* (common rudd), to control the water flea population.
Category	Commercial.
Outcome / Results	Bierkreek nursery produces many different rose varieties and sells them throughout the world. Its slogan is “A plant with aphids is a healthy plant”! No environmental pollution.
Key recommendations	Bierkreek Nursery is urgently looking for garden centres willing to address the challenge, and growers willing to be innovative. Garden centres that offer roses, phlox, petunias and anything grown in containers are made to sell them with aphids that are already infected by parasitic wasps.

NETHERLANDS: Jan van Kempen – arable farmer and participant in Flourishing Farm

Location of project	Zuid-Oost Beemster, northwestern Netherlands.
Description	Jan van Kempen is a Dutch arable farmer who participates in the Flourishing Farm project. He is very enthusiastic about increasing functional agro-biodiversity on his fields. He points out the benefits of offering habitats to natural enemies, the enthusiasm of people who pass by the land on their bikes and his own happiness while harvesting his crops.
Category	Commercial.
Outcome / Results	Van Kempen runs his arable farm successfully. He hardly applies insecticides in his potato fields, which are now surrounded by flowering field margins.
Key recommendations	Based on the results achieved by the project, Van Kempen says there are many enthusiastic farmers and that policies should be devised to support farmers financially. CAP should deal with sustainable farming practices that combine flowering field margins with reduced insecticide use. Agri-environment schemes such as those that are part of “Bloeiend Bedrijf” are excellent opportunities for accomplishing greening measures.

NETHERLANDS: Henri Oosthoek – large-scall producer of beneficial insects, Koppert

Location of project	Berkel en Rodenrijs, western Netherlands.
Description	Henri Oosthoek is one of the managing directors of Koppert Biological Systems, world leader in biological control and pollination for professional growers. Koppert breeds large-scale bumblebees for pollination, and natural enemies to control pests and diseases. Besides these, micro-organisms and biostimulants are produced to grow healthy and vigorous plants and stimulate soil life. The company's products are mainly used in greenhouse production systems but also increasingly in arable farming, in horticulture and in ornamental plant production.
Category	Koppert works in a commercial way and operates an extended R&D department conducting laboratory, semi-field and field experiments.
Outcome / Results	The business has proven very successful. Koppert currently has distributors and subsidiaries in 80 countries worldwide. Among the advantages that Oosthoek sees for consumers is the fact that it helps growers supply cleaner (from chemicals) and healthier products. For the producer he hopes that better prices can be achieved because the goods are with less or no chemical residues. Producers also have less or no expense on chemical pesticides.
Key recommendations	Oosthoek has concerns about the overuse of chemical fertilisers and agrochemicals, and calls upon governments to give research institutes the necessary financial resources to continue developing knowledge of these methods, as resources are limited and worldwide production has to increase as the demand in the coming decades will double while the available land diminishes.

POLAND: Dr. inż. Stanisław Flaga – solitary bee breeder

Location of project	Małopolska, Poland.
Description	Dr. inż. Stanisław Flaga is chief agriculture specialist in the marshall's office in the Małopolska region. As a specialist in ecological farming, he publishes widely on alternatives to pesticides and on biological pest-control methods. Furthermore, Dr. Flaga is one of the most renowned professional breeders of solitary bees in Poland, working to save endangered species. He runs a successful company, cultivating his own organic orchard with traditional species of apples.
Category	Commercial / experimental.
Outcome / Results	Ecological methods that can be also used in conventional farming are cheaper than conventional ones. They give products of greater nutritional value than conventional ones and can be used in the long term with no negative effects for the environment. Observing the effects of herbicide application, Dr Flaga noticed increasing aphid population growth. He realised that herbicides were the cause of the problem and decided, therefore, to stop using them. Subsequently, he learned about aphid predator organisms and about their need of specific flowers as a habitat. With that knowledge as a basis he gradually changed his agricultural model to organic methods. For the environment the advantages are enormous because ecological methods can be used long-term with no harm to the environment.
Key recommendations	Dr Flaga thinks ecological farming creates opportunities for sustainable human development, which means development that can completely fulfil our living while protecting the environment. It could be key to solving local environmental problems and providing crucial elements in the economic development of local communities.

POLAND: Dr. Piotr Mędrzycki – researcher, bee health and neonics

Location of project	Bologna, Italy.
Description	Dr. Piotr Mędrzycki is a researcher in Bologna, where he is involved in the APENET project. He studied at Warsaw Agricultural University and after completing his MSc he moved to Italy to study for PhD on biological means of pest control. The APENET project is a multidisciplinary monitoring and research project, mainly aimed at evaluating bee health status, in relation to neonicotinoids and fipronil application. The assessment is carried out EFSA at the request of the European Commission. His research is performed under laboratory as well as under field conditions.
Category	Experimental.
Outcome / Results	Researchers have discovered that there is no relationship between seed coating with neonicotinoids (or fipronil) and crop yields. However, the ban on this class of pesticides resulted in an observed reduction of honeybee colony collapses.
Key recommendations	Dr. Mędrzycki thinks that we should first ban highly toxic pesticides, and we should do it locally, independently of European decrees. The most important thing, for example in Poland, is to find funds to support scientific research in the field of agro-ecology. This would lead to environmentally friendly cultivation methods, and pesticide use would decrease as a consequence.

POLAND: Tomasz Obszański - founder of producers cooperative

Location of project	Małopolska, Poland.
Description	Tomasz Obszański is an ecological farmer who is personally involved in Podkarpacka Organic Farmers Association, Organic Food Valley Cluster and in many other associations connected with ecological farming. He is the founder of a producers' cooperative that is very important in Poland. Also, he carries out many educational activities such as instruction in alternative cultivation methods. He uses microbiological and natural methods of fighting pests such as intercropping.
Category	Commercial.
Outcome / Results	Crop yields are comparable to yields in conventional farming. He believes that wild pollinators and bees help him to produce better quality fruits and earn more money. "Our farm would not exist without pollinators."
Key recommendations	Obszański states that Poland is a great country for ecological farming, because there are plenty of small family farms that could change their production model from conventional to ecological farming. This transformation is not difficult, and would lead to the production of healthy food. There is a huge demand for such produce. Food producers and customers are waiting, this is a perfect opportunity.

ROMANIA:

Dr. ing. Ion Toncea –- founder of Romanian sustainable agricultural association

Location of project	Calarasi, southeastern Romania.
Description	Dr. ing. Ion Toncea is founder and president of the sustainable agriculture association of Romania. He is a university teacher in agricultural sciences and a farmer. He is working with traditional techniques as the basis for his research. He adapts these to local crops and local conditions. In his work he is continuously trying to support farmers with technical information and with meeting their seed requirements and to adapt farming technologies to climate change. In his fields he grows different varieties of vegetables, cereals, sunflowers, soy, cotton and medicinal plants. He has not used any chemical substances for 20 years. To keep his crops healthy and productive his main tool is a minimum of a four year crop rotation. Other tools include the selection of the best cultivars, increasing biodiversity, and growing legumes to provide nitrogen fixation. As a natural pesticide he makes use of neem extract as a seed coating.
Category	Commercial.
Outcome / Results	Dr. ing. Toncea states that his motivation is results orientated and based on the fact that his research is helping farmers improve their farming methods. His farm management allows for a high biodiversity that brings benefits for the whole farm. Another benefit he identifies is chemical-free and safe food. He intends to keep researching and finding new and useful methods for ecological farming. Economic benefits are achieved by not using chemical pesticides and fertilisers.
Key recommendations	For politicians to increase subsidies and support for organic farming and to clarify and stabilise egulations concerning this agricultural sector. Also, it is extremely important that work to develop eco-agriculture specific plant breeding programmes is financed.

SPAIN: Alberto Calderon - agricultural technician

Location of project	Andalusia, Spain.
Description	Alberto Calderon is an agricultural technician who works with a programme to assist organic and Integrated Production Groups (IPG) of cotton farmers to adopt more sustainable farming methods. During the season of 2011/2012, 48,276 hectares were cultivated under integrated production, representing 72% of the cotton planted surface area in Andalusia. The 67 IPGs working during that season included 4,109 farmers and 206 technicians providing field assistance. The programme prohibits the usage of plastic pads and flood irrigation. Instead, new methods are introduced regarding water usage. Irrigation schedules take into account root depth, the plants' moisture status and the physical characteristics of the soil. This more efficient management of initial irrigation promotes larger root distribution, allowing the plant to use deeper water and reducing the overall demand for water. The programme includes plant and soil analyses to determine the amount of additional fertilisation needed. The standards regarding fertiliser application are considered. The current management allows for quicker opening of the cotton capsules and reduces attacks by lepidopteran larvae, the crop's primary infestation. These larvae are less attracted to hardened vegetable tissues. For infestation control non-chemical methods should be used whenever possible. Integrated Pest Management (IPM) differs from Functional Agro-biodiversity (FAB) and ecological and organic agriculture in that chemical pesticides are permitted. Greenpeace do not advocate IPM as a way forward for agriculture because of the use of synthetic agrochemicals.
Category	Experimental.
Outcome / Results	The average number of treatments with pesticides per season dropped from 6.5 to 2.5. Also, new and more effective methods have been developed to control caterpillars but have less impact on auxiliary and pollinating insects. Furthermore, the use of *Bacillus thuringiensis* is being expanded to a greater cultivated surface area. Calderon sees this integrated production as a step towards growing cotton without chemicals. During the programme, a 30% reduction of irrigation water has been achieved and fertilisation has on average been reduced by 40%. These reductions have made crops evolve towards greater environmental sustainability, controlling vegetative growth of the plant.
Key recommendations	Calderon wants to tell politicians that farmers need to receive fair prices for their work and produce. He also asks for research to look for alternatives to the current industrial system.

SPAIN: Charo Guerrero – cotton farmer

Location of project	Andalusia, Spain.
Description	Charo Guerrero is a Spanish cotton farmer who participates in an experimental research project to grow cotton in a way that is more respectful to the environment. She advocates that farmers should unlearn the lessons taught by companies claiming that their products are the best option. Lifelong farmers should trust their own judgment more, they know very well how to work their land. Integrated Pest Management (IPM) differs from Functional Agro-biodiversity (FAB) and ecological and organic agriculture in that chemical pesticides are permitted. Greenpeace do not advocate IPM as a way forward for agriculture because of the use of synthetic agrochemicals.
Category	Commercial.
Outcome / Results	Guerrero says that she is proceeding in the right direction. The results of experiments with integrated production are promising, but she would like to produce organic cotton in the future. “Our method of cultivation is better for our health and better for the environment because we use less chemicals. We have reduced the costs.”
Key recommendations	To be able to produce organic cotton in Spain, Charo asks politicians to have the political will to support small farmers and finance research projects that can deliver the necessary tools.

SWITZERLAND: Dr. Claudia Daniel – organic rapeseed research, FIBL

Location of project	Frick, Switzerland.
Description	Dr. Claudia Daniel, a researcher at FIBL, is developing a strategy to control pollen beetles in oilseed rape. The project was spurred by demand from organic farmers to develop an insecticide-free means to control pollen beetles. Dr. Daniel expects that the uptake of newly developed alternatives will depend on the costs. If viable, non-insecticidal control strategies for pollen beetles are available, (perhaps supported with subsidies) more farmers will be willing to use them. During the last years Dr. Daniel has been successfully investigating the effects of silicate rock dust for pollen beetle control. Currently, she is working on a pollen beetle repellent based on essential oils.
Category	Experimental.
Outcome / Results	Results from the research on silicate rock dust are implemented in organic and in IPM strategies for pollen beetle control.
Key recommendations	Long-term financing for alternative plant breeding programmes is needed to develop robust / tolerant varieties (to pests, diseases, weeds). Presently, plant breeding is mainly focused on yield and composition and not enough on plant protection characteristics.

SWITZERLAND:
Dr. Hans Herren – 2013 winner of the Alternative Nobel Prize Right Livelihood Award

Location of project	Switzerland.
Description	Dr. Hans Herren is an internationally recognised scientist who holds numerous awards and serves on the boards of various organisations, including the International Assessment of Agricultural Knowledge, Science & Technology (IAASTD). He speaks about agriculture in both global and regional terms, while stating that agricultural practices need to be very much localised and adapted to prevailing ecological conditions, as well as to local food needs and preferences. Concerning crop protection, he emphasises adaption to local conditions and making use of push-pull methods in mixed cropping systems.
Category	Dr. Herren has conducted experimental research in Africa for many years. Currently, he represents the work of Biovision and works as an agricultural advisor. The Biovision Foundation for Ecological Developement was founded in 1998 with the aim of sustainably improving life for people in Africa, while conserving the environment as the basis for all life.
Outcome / Results	Dr. Herren believes that R&D in the past 50 years has been too heavily focused on plant breeding and on fertiliser use, and too little on how ecologically based agricultural systems work. Currently, there is a need for more dialogue with conventional farmers, they are the ones needing to make the paradigm shift. Agronomic benefits that he says contribute to result from more sustainable farming methods are better conditions supporting ecosystem services, better soil fertility and resilience to climate change. The crops produced are of better quality and have more nutritional value. He also mentions the reduced dependence on external inputs and the agri-business monopoly, increased profits and more independence for farmers in their choice of what to grow and how to grow it (food or animals). Ultimately there is less inequality and more affordable food for people in rural areas.
Key recommendations	Dr. Herren is working as an adviser at different levels of policy making. He says that new policies are needed to support small holder farmers, sustainable and localised agriculture and to make agriculture part of the climate change solution. He says it is time to stop supporting a few large vested interests in the agri-food business and to make room for sensible, socially responsible enterprises to address the food value chain. Governments also need to regain control of R&D in the food and nutrition sector. Food security—food as a human right—cannot be left in the sole hands of the private sector. That should be the responsibility of governments.

The videos can be found here: ***www.sos-bees/org/solution***

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