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Statement

Biodiversity and Management of Agricultural Landscapes

Wide-ranging action is now crucial

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Biodiversity and Management of Agricultural Landscapes

Wide-ranging action is now crucial

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Foreword

The last decades have seen much discussion about the future of agriculture and the role it plays in biodiversity. It is nevertheless striking that agricultural landscapes have been feeling the effects of a dramatic decline in plant and animal species for some time. To maintain a fully functioning ecosystem on the one hand, and to continue to enable economic use of the landscape on the other, it is necessary to fundamentally rethink the framework in which our agricultural landscape operates.

The current statement summarises the state of knowledge on loss of biodiversity, its causes and consequences. This paper focuses particularly on the current agricultural framework: how can the political freedom accorded to Germany by the European Union's agricultural policy be better utilised? Which subsidies should be put to the test? To what extent is trade responsible? Is environmental law, and its implementation, up to date? On the basis of these analyses, the academies make suggestions on how to maintain and improve biodiversity in agricultural landscapes.

With this statement, the academies wish to contribute to the political discussion by highlighting the complex relationships and circumstances that are causing the disappearance of many plant and animal species. The current state of agricultural biodiversity requires immediate action by all parties involved and especially courageous decisions from policy-makers.

We would like to wholeheartedly thank all the scientists involved, especially the leaders of the working group, Katrin Böhning-Gaese, Alexandra-Maria Klein and Wolfgang Wägele.

Halle (Saale) and Berlin, October 2020

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Executive summary

Key conclusions

- In addition to **securing our food supply,** agricultural landscapes have many other functions, including **ecosystem services** such as soil fertility, water filtration and storage, and insect pollination. Agricultural land is also a man-made environment that provides **habitats** for animals and plants and, not least, is used for **recreation by humans**.

- **Agricultural biodiversity among many species groups has declined sharply in Germany, including in the country's nature reserves**. A wealth of scientific evidence shows that the decline in agricultural biodiversity impacts how agricultural ecosystems function.

- Potential economic benefits are not the only **value of biodiversity**. Ecosystem services, cultural value and conserving species for their own sake are all justifications for preserving biodiversity that go beyond economic arguments. The value of agricultural biodiversity needs to be examined in the context of diverse agricultural ecosystem services and the conflicting goals that these create.

- **Animal and plant species are declining** due to a **combination of several factors** including: the increase in fertile, yet species-poor field crops; pre-emptive and extensive use of pesticides; intensive fertilisation; larger field sizes; loss of species-rich grasslands and structural changes, transforming livestock farming into large-scale operations with less pasture grazing; loss of structural diversity in the landscape; and loss of connectivity between conservation areas. These factors are largely the result of new biological and technological innovations created to meet production targets.

- Measures to protect and promote biodiversity need to take into account the economic, political, legal and social aspects of agriculture. Stakeholders therefore need to take a **systematic approach, implementing a variety of solutions at the same time**. In addition to agricultural factors, other key areas to focus on are agricultural policies, the market economy conditions, agricultural and environmental legislation, civil society and science.

- This is an urgent matter and action needs to be taken immediately. It is not enough just to change individual parts of the agricultural system, there needs to be a **change in society as a whole**, working towards sustainable farming that incorporates measures to preserve biodiversity.

Courses of action

1. **Agricultural and conservation policies** should be more closely linked in the future. In particular, subsidies paid to the agricultural industry as part of the European Union's (EU) Common Agricultural Policy (CAP) should be more closely tied to actual quantifiable ecosystem services. CAP funding instruments should focus on specific targeted environment and nature conservation measures. It is also important to promote dialogue between stakeholders in the sector (farming businesses, conservation organisations, authorities, etc.) as well as voluntary cooperation between them, such as the ongoing Natura 2000 project, for example. These further CAP developments play a key role in making biodiversity-friendly farming economically viable for farms.

2. **Agricultural and environmental legislation:** EU agricultural legislation would create a framework to enshrine in law an obligation for farms to operate in an eco-friendly manner while avoiding any distortion of competition within the EU. In addition, conservation areas in agricultural landscapes need to be better maintained and protected, and more effort should be taken to avoid unintentional adverse effects from adjoining territories. Lastly, **shortfalls in enforcing existing legislation** need to be eliminated.

3. **Plan-based, region-specific collective approaches** need to be developed in order to change how land is used so that some areas either cease to be used for farming production, or they are farmed much less intensively. For this purpose, countryside management organisations should be assigned greater roles.

4. **Municipalities** are required to preserve, foster and increase biodiversity on their land, making them visible pioneers and opinion leaders of a biodiversity-friendly way of life.

5. **Trade and markets:** products farmed locally in biodiversity-friendly conditions should be labelled with this information when being sold. There should also be support to develop infrastructure that allows agricultural products to be further processed locally.

6. **Farms need to be supported in implementing biodiversity-friendly farming methods**, e.g. through better training and education. The public should also have a greater appreciation of such businesses' commitment to conserving biodiversity, and farms need to be given greater support if they choose to invest in conservation measures for their holdings. **Ideas beyond organic farming need to be expanded upon and continually developed**, focusing on integrated farming methods with small-scale technical or large-scale digital support.

7. The **public need to have a better understanding** of what biodiversity means for agricultural land. Model farms and educational gardens would be useful for raising awareness. Schools, natural history museums and local museums can also allocate more time and space to explaining the meaning of cultural landscapes and their biodiversity. In addition, consumer habits need to change with action taken by both consumers and retail management. Habits should shift towards consuming less meat, reducing food waste and placing greater value on food that has been grown in biodiversity-friendly conditions.

8. **A long-term, standardised monitoring system across Germany**, and research on the causes of trends and ecological links, need to be extensively developed, to allow authorities to document changes to a broad, representative range of species and habitats in the future. Such a monitoring system would also make it possible to see how well biodiversity conservation measures are working.

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1. Introduction

In several respects, biodiversity and agricultural business are at odds with one another. Agricultural land use is always focused on making targeted changes to the species make-up of an area, in order to reach production targets, and this includes significant decimation of individual species at the location. There are also sometimes conflicts of interest in areas used for agricultural purposes between maintaining biodiversity[1], cultivating food and producing energy.

In this realm of conflicting priorities, it is the state's duty to maintain the natural foundations of life for humans, out of responsibility for future generations (Art. 20a Basic Law for the Federal Republic of Germany, GG) and especially to substantiate protection for biodiversity (§1 paragraph 1 No. 1 Federal Nature Conservation Act, BNatSchG). The goals of the international Convention on Biological Diversity, the European Union's (EU) Biodiversity Strategy, Germany's National Biodiversity Strategy and Germany's National Sustainable Development Strategy, concluded in 2018, should also all be put into practice.

However, beyond conflicting interests, promoting biodiversity can also benefit agricultural production, among other things by maintaining soil fertility through the natural pollination of cultivated crops, which is equally effective and efficient, and through the use of beneficial organisms for crop protection. Maintaining agricultural biodiversity is therefore not necessarily at odds with forward-looking agricultural production.

Biological diversity includes the diversity of species, diversity within species (e.g. genetic variety) and the diversity of habitats.[2] In this context, the frequency of species is also considered, and their biomass, since both factors are of huge importance for sustaining ecological functions.[3]

The current statement considers biodiversity in the agricultural landscape, which is declining at a far-above average rate compared to other habitats.[4] Agricultural landscapes are understood as open or semi-open landscapes, largely designed by humans, which are primarily used for economic purposes. These kinds of landscapes comprise arable land, grassland (meadows and pastures), as well as interspersed small woodlands, isolated copses, individual trees, hedges, field margins or waysides, small bodies of water, individual houses, roads and small villages. Agriculture uses the largest proportion of land in Germany, accounting for over 50% of the country's area.

1 In this statement, the terms "biological diversity" and "biodiversity" are used synonymously.

2 Swingland (2001); Convention on Biological Diversity, Article 2.

3 Winfree et al. (2015).

4 EEA (2015); IPBES (2019).

Fig. 1: The partridge was formerly a common bird of cultivated landscapes . Since 1990, around 90% of the population has been lost. Most of this decline took place in the 1990s. There were further losses after a particularly harsh winter at the end of the 2000s. Nowadays, the partridge is considered critically endangered. Photo: Erich Greiner.

Agricultural landscapes have groups of stakeholders who are comparatively easy to identify, as well as legal, planning and political frameworks to work with. The relevant stakeholders in the agricultural sphere are active in the agricultural sector itself, in conservation, politics, with the authorities and in legal proceedings at community, state, country and even on a European level. However, consumer behaviour, food retail and civil initiatives also have a big influence on the shape of the agricultural landscape.

Therefore, maintaining and promoting biodiversity in agriculture, while securing future production of food and energy, is a concern and task for society as a whole. Awareness and accomplishment of the corresponding goals are part of a much bigger picture. Promoting biodiversity in agricultural landscapes in concrete terms means close cooperation between both the people living and working in these landscapes, and the stakeholders who set the frameworks for action. Although the current study is limited to agricultural landscapes alone, it also considers – where meaningful – other habitats, such as forests and towns. This statement focuses its analyses and points for action on Germany, but also uses information and data with European and global scope, and addresses decision-makers at EU level.

2. Status and development of biodiversity

There has been mounting evidence over the past few years to show that Germany is experiencing a considerable decline in its agricultural biodiversity. There have only been some specific monitoring programmes in Germany to date (e.g. flora, fauna and habitat monitoring[5] and high nature value farmland monitoring[6]) and no comprehensive long-term monitoring studies for a broad range of animals, plants, fungi and habitats. As a result, current knowledge of trends in species richness largely rests on data collected about selected species groups and habitats. Scientific analyses have been conducted on species numbers, frequency and biomass for birds, selected insect groups and plants in particular (Figs 1 – 4). There are no long-term data, or potential data are not available, on other species groups which are often particularly significant for ecosystem functions, such as soil organisms, for example. There is usually only evidence for quantitative trends at regional level, even for the better-recorded species groups, as data for the whole of Germany are rare.

2.1 Decline in bird populations

Indices showing the population of common farmland birds in the European Union (EU) have dropped to an average of 68.5% since 1990 (=100%) (Fig. 2). Even previously prevalent species have been affected by this downward trend. By comparison, the frequency of bird species in other habitats has decreased at a significantly lower rate than on farmland. For example, common woodland bird populations have only declined by an average of 12.1% (Fig. 2). Regional surveys indicate similar trends. Standardised bird counts in the Lake Constance region between 1980 and 2000 show that there was an average decline of approx. 30% in the frequency of species on agricultural land. By contrast, bird populations in woodland, wetlands and urban areas remained stable on average and, in some cases, even rose.[7]

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5 The fauna, flora and habitat (FFH) monitoring programme is an obligation according to Article 11 of European Council Habitats Directive 92/43/EEC (OJ L 206, 22/07/1992, p. 7), requiring member states to undertake surveillance of the conservation status of natural habitats and species important to Europe. Member states must draw up a report every six years detailing the main findings from their monitoring efforts and the conservation measures that they have established (Article 17).

6 The high nature value (HNV) farmland indicator was devised as part of the European Union Common Agricultural Policy so that all EU member states could meet their commitment to embedding environmental concerns in their agricultural policies and use the indicators to track the impact of their measures. The HNV monitoring programme behind the indicators was developed by the German Federal Government and the federal states, allowing authorities to record and evaluate data on HNV farmland.

7 Lemoine et al. (2007).

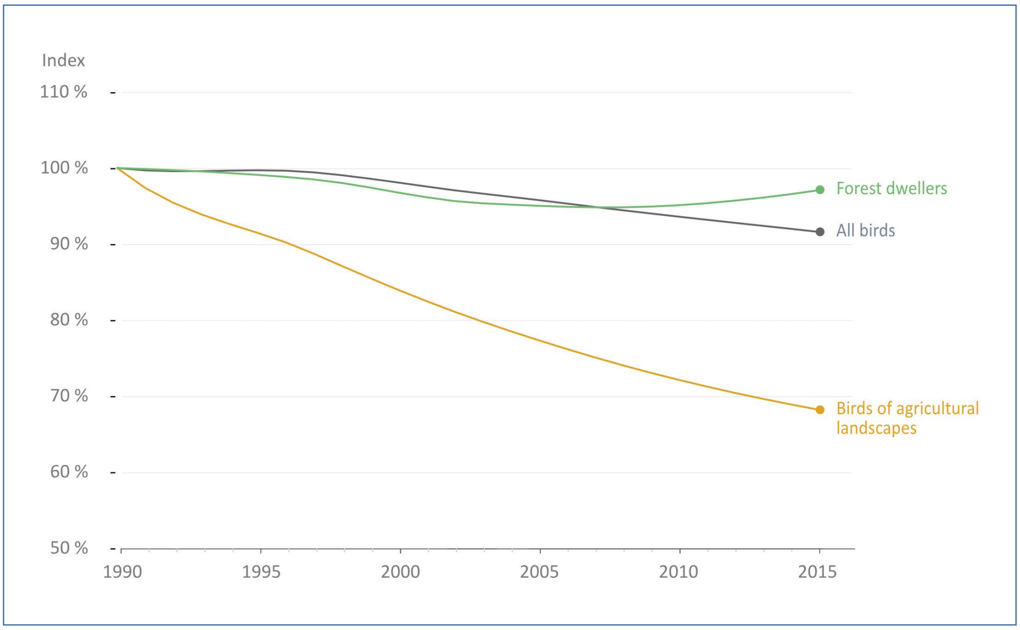

Fig. 2: Changes in the frequency of 167 bird species in 26 European countries during the period from 1990 to 2014, shown as an index. The graph also compares frequency trends for a selection of 39 farmland bird species and 34 woodland bird species. The data show continuous decline in populations of birds in agricultural landscapes. Among these species are skylark, lapwings and partridge.[8] Farmland bird populations have fallen on average to 68.5% of their 1990 numbers.

As a result, common farmland bird populations are primarily impacted. The number of skylarks, starlings and lapwings fell by more than 36% between 1998 and 2009.[9] Analysing the numbers of bird species grouped by their main habitats also revealed that the downward trend for open country species continued to worsen when comparing data from the periods 1998–2009 and 2004–2016. Over 60% of the species common to open country environments suffered declines between 2004 and 2016 (Fig. 3).

2.2 Decline in insect populations

Many studies have now shown that insect populations in the agricultural landscape are in sharp decline. The frequency of butterflies found on grassland (meadows and pastures) in 16 European countries fell by approximately one third in the period between 1990 and 2015 (Fig. 4).[10] This negative trend can even be observed over shorter periods in Germany, where data have only been available since the first national butterfly monitoring programme in 2005.[11]

There is also evidence showing that 58% of butterfly species in the Düsseldorf area disappeared between 1900 and 2000. In this case, there is an explicit causal link between the loss of land and the loss of these species.[12]

8 EBCC (2019).
9 Sudfeldt et al. (2013).
10 EEA (2013); van Swaay et al. (2016).
11 Rada et al. (2019).
12 Lenz and Schulten (2005).

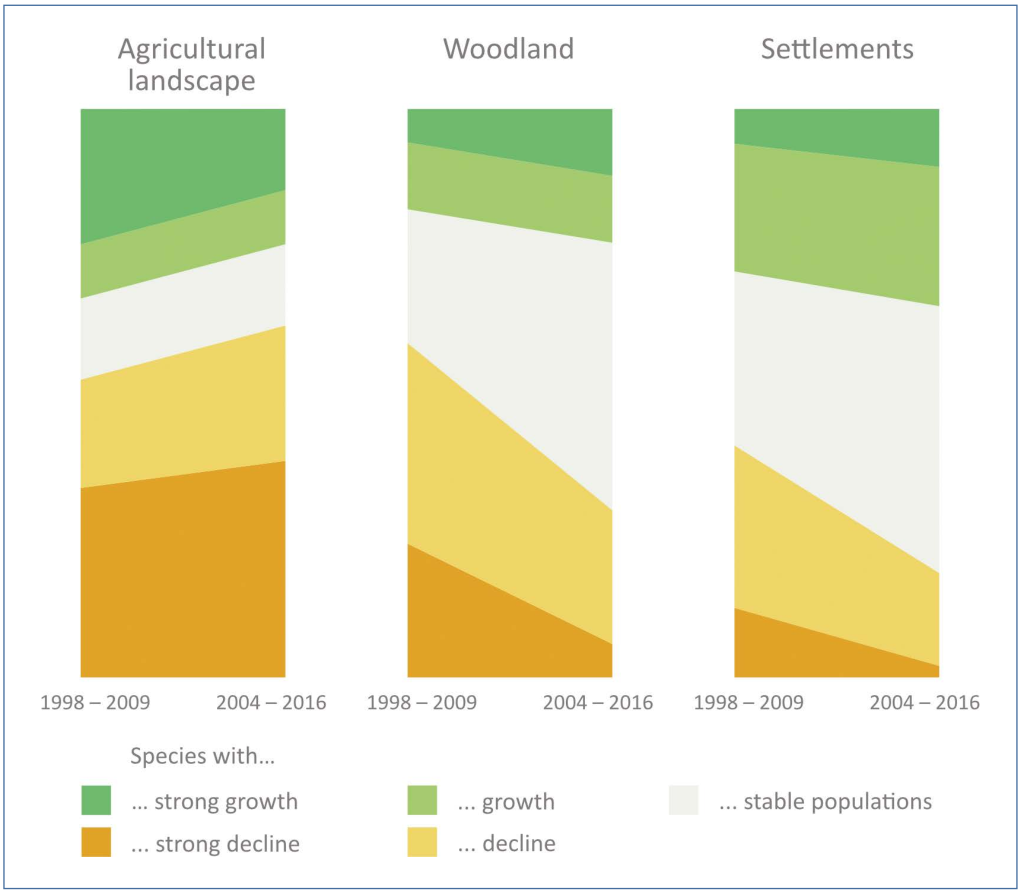

Fig. 3: Trend of breeding bird species in Germany grouped according to their main habitat. Comparison over a two-year period.[13] This shows the proportion of the bird species' populations in agricultural, woodland and populated habitats, which are in severe decline, declining, increasing, greatly increasing or stable. Compared to other habitats, an increasing number of bird species in agricultural landscapes are declining or in severe decline.

For northern Germany, furthermore, there has been a significant decline in the frequency of cicadas and orthoptera on grassland since 1951, while the number of heteroptera has increased in the same period, especially among species that are able to cope with disruption to their habitats.[14] Out of the almost 600 wild bee species in Germany, 53% are currently endangered, and there has been no noted improvement since the survey[15] was taken for the Red Lists in 1998.[16] A study of three sites across Germany ("biodiversity exploratories"[17]) also showed a sharp decline in the biomass and abundance of insects and arachnids over the last ten years.[18]

13 Data from Germany's bird monitoring programme, bird observatories and regional associations. The periods are determined by the German Federal Government's requirement to report to the European Commission to comply with EU directives on conserving birds and natural habitats. This is unpublished data from the Federation of German Avifaunists (Dachverband Deutscher Avifaunisten, DDA) and the German Federal Agency for Nature Conservation (Bundesamt für Naturschutz, BfN) 2019.

14 Schuch et al. (2012).

15 Red Lists are directories of extinct or endangered animal, plant and fungi species. They are scientific expert reports showing the endangered status for a specific reference area. The Red Lists use clearly defined criteria to evaluate the information available on the extent to which certain species are endangered. They are mainly published by the German Federal Government or the federal states.

16 Westrich et al. (2011).

17 The Biodiversity Exploratories are an open research platform for functional biodiversity research. They are funded by the German Research Foundation (Deutsche Forschungsgemeinschaft, DFG).

18 Seibold et al. (2019).

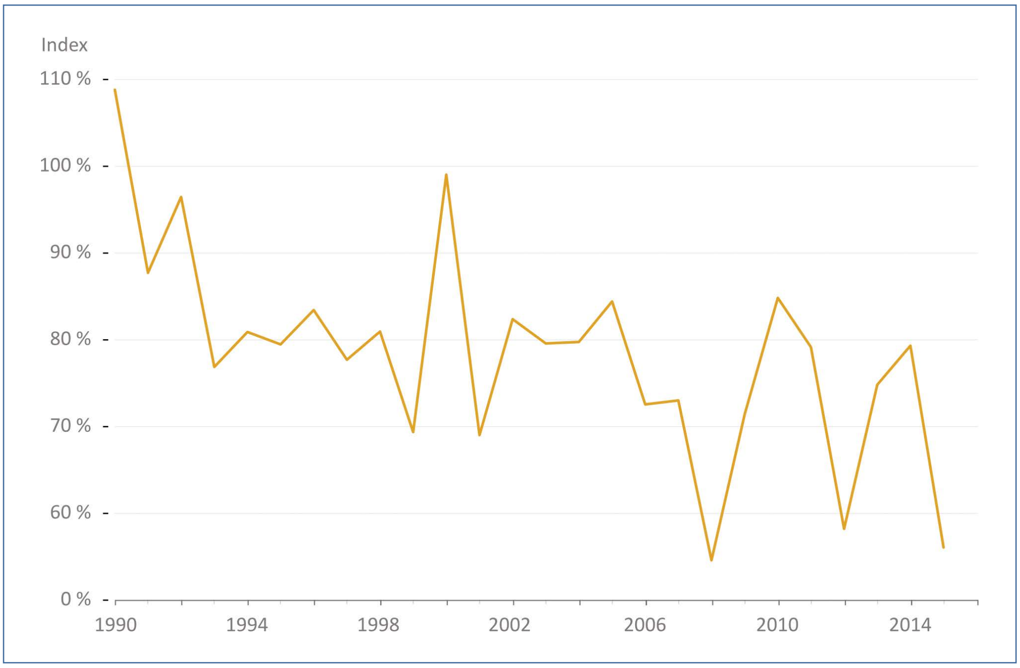

Fig. 4: Changes in the frequency of 17 butterfly species on grassland (meadows and pastures) in 16 European countries for the period 1990–2017, shown as an index. (The European Grassland Butterfly Indicator).[19]

Loss of insect variety and biomass in conservation areas

Dwindling populations are not limited to areas outside conservation areas, and biodiversity is also decreasing within them. For example, the number of butterfly species in a Regensburg conservation area fell from 117 in 1840 to 71 in 2013.[20] The number of ground beetle species observed in the Lüneburg Heath nature reserve also decreased by an average of eight every year from 1994 to 2017.[21] Furthermore, over 50% of specialised butterfly species on chalk heath conservation areas in the Moselle region became rare or locally extinct between 1972 and 2001.[22]

Collaborating with Dutch and British scientists, the Krefeld Entomological Society (Entomologischer Verein Krefeld) produced a detailed analysis in 2017 showing that not only was insect diversity in decline, but so too were their individual numbers and thus their biomass. The study caught international attention[23] , showing that the biomass of flying insects decreased in conservation areas in North Rhine-Westphalia, Rhineland-Palatinate and Brandenburg by an average of 76% between 1989 and 2016 (Fig. 5). The Krefeld study is the most comprehensive measurement of insect biomass in Germany to date, and its key conclusions are in line with Dutch monitoring data.[24]

19 van Swaay et al. (2019).
20 Habel et al. (2016).
21 Homburg et al. (2019).
22 Wenzel et al. (2006).
23 Hallmann et al. (2017).
24 Hallmann et al. (2018).

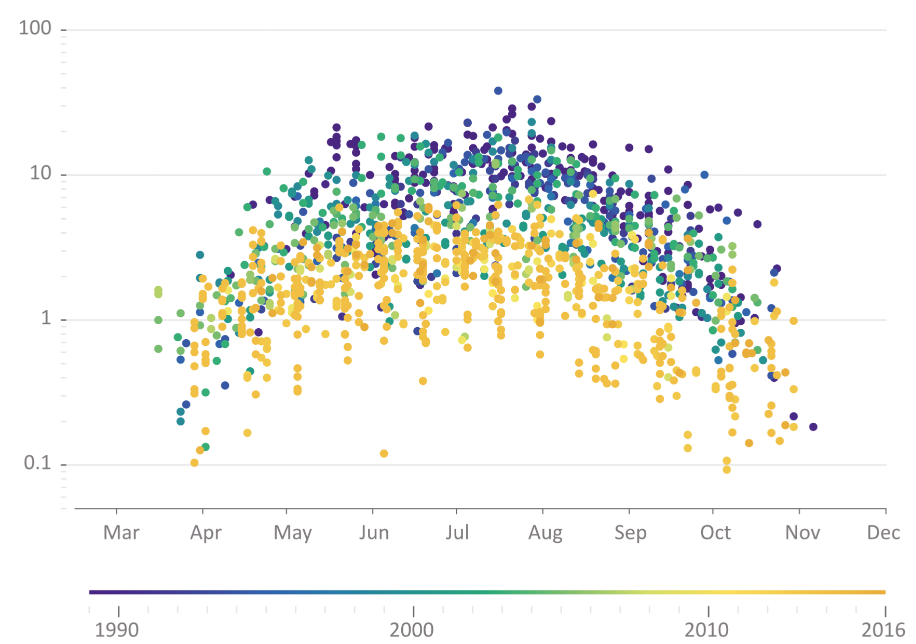

Fig. 5: Biomass measurements taken from insect traps placed in German conservation areas by the Krefeld Entomological Society during the period 1989–2014. The scatter plot shows that over the course of a year (growing season), most insects were captured in summer. The loss of insects between 1989 (in blue) and 2016 (in orange) is clear, equating to an average decline of 76% (it should be noted that the biomass scale is logarithmic).[25]

Insect decline in Europe

Similar to the situation in Germany, other European countries have also been recording local declines in insect species for several years, such as butterflies in Great Britain (1995[26]) and in Belgium (2001[27]); moths in Great Britain (2006[28]); bumblebees in Great Britain (reported in 1982[29] and 2005[30]); ground beetles in the Netherlands (1988[31]), in Denmark (1989[32]) and in Great Britain (2012[33]); roller dung beetles in Spain (2001[34]); and dragonflies in Finland (2002[35]). The first meta-analysis of changes in insect frequency and biomass on a global scale revealed that terrestrial insects are decreasing by around 9% every decade. The most severe population declines occur in North America and Europe.[36] All findings so far suggest that insect populations are falling across the board and have been decreasing for decades. Species with specific requirements for conditions provided by their habitat (e.g. flowery meadows and wetlands) are more likely to be under threat of decline, while there are fewer declines among generalist species that can cope better with disruptions to their habitats.[37]

25 Adjusted in line with Hallmann et al. (2017).
26 Thomas (1995).
27 Maes and Dyck (2001).
28 Conrad et al. (2006).
29 Williams (1982).
30 Goulson et al. (2005).
31 Turin and den Boer (1988).
32 Desender and Turin (1989).
33 Brooks et al. (2012).
34 Lobo (2001).
35 Korkeamäki and Suhonen (2002).
36 van Klink et al. (2020).
37 van Swaay et al. (2006); Beckmann et al. (2019).

Decline in insect populations: questions, doubts, counterarguments

This statement mainly analyses the connection between biodiversity and the changes in agricultural land use. However, other hypotheses regarding agricultural biodiversity loss are discussed in public forums and in scientific literature. These rationales are presented and analysed below.

- "Loss of agricultural land, urban development and the expansion of towns and cities negatively impacts biodiversity": soil sealing does indeed lead to loss of biodiversity. The share of land used for settlements and traffic across Germany has grown from 11.5% in 1992 to 13.6% in 2011. The share of land affected by soil sealing, i.e. land that has been built upon, has also risen from 5.3% to 6.2% in this period.[38] However, this does not explain why researchers have observed a fall in insect, bird and plant populations *on* agricultural land. In almost all the studies cited in this statement, biodiversity was measured with standardised methods on the same research areas over a long period of time, with no building or soil sealing taking place on these areas. In addition, there is often greater species richness and a higher frequency of many species in urban areas with gardens compared to agricultural land.[39]

- "The Krefeld study is not sufficiently scientific": many commentators in the media and some associations called into question the credibility of the Krefeld study. While one psychologist and one economist called the study the "unstatistic of the month",[40] for example, several ecological research institutes carried out independent reviews of the statistical analyses and could not find any errors. In fact, the findings are consistent with earlier and subsequent studies, lending weight to the conclusions made by the Krefeld entomologists regarding the regional decline in insect populations. This meant that researchers could use highly standardised data collection methods in other studies as well to produce evidence of declining insect populations in grassland and woodland habitats[41] and demonstrate the simultaneous decline in insect-eating birds on farmland.[42]

- "Light pollution kills insects": it is true that light sources often kill insects. Light after dark attracts many insects, making them leave their natural habitats, meaning they can no longer find food and a partner for breeding. However, light pollution only affects nocturnal insects, and a significant number of diurnal insects are suffering from population decline. Researchers have recorded a similar fall in numbers for both butterflies and moths.[43] Furthermore, the sites used in the Krefeld study[44] and the biodiversity exploratories study[45] were located far from artificial light sources. Lastly, bird populations in urban areas, where there is much greater light pollution than in agricultural areas, remained stable on average between 2004 and 2016 (Fig. 3).

38 UBA (2020).
39 Theodorou et al. (2020).
40 cf. https://www.rwi-essen.de/unstatistik/70/.
41 Seibold et al. (2019).
42 Bowler et al. (2019).
43 van Dyck et al. (2009).
44 Hallmann et al. (2017).
45 Seibold et al. (2019).

- "Vehicles on roads and motorways kill insects": cars and lorries on roads and motorways do indeed cause the death of many animals, including birds, mammals and especially insects. However, many of the survey sites used to date where sharp declines in insect populations have been observed are located far away from roads with heavy traffic.[46] Insect populations directly impact bird populations since insects are a vital source of nutrition for birds. However, this does not explain why bird populations in urban areas, where there are higher traffic volumes than in agricultural areas, remained stable on average between 2004 and 2016 (Fig. 3).

- "Mobile phone masts and wind turbines kill insects": there has been no scientific evidence so far to suggest that radiofrequency radiation harms biodiversity. It should also be emphasised that several European regions had already recorded dwindling insect populations before mobile phone systems were engineered (Germany has had a 2G network since 1992) and wind turbines were developed (wind farms began operation in 1991).[47] It is also worth bearing in mind that many areas without wind turbines are recording a fall in insect populations.[48] Lastly, it should be noted that the distance between the lowest point on a rotor blade and the ground is usually over 50 metres on modern wind turbines, and only smaller turbines extend into lower layers of air. Most insects, however, move around close to the ground.

- "Climate change has led to a decline in insects": there is some evidence to suggest that hotter temperatures in temperate climates can reduce the frequency of insects, which is true for beetles in one North American forest, for example.[49] However, according to current findings, rising temperatures in temperate climates correlate to an overall increase in species richness among insects, plants and birds.[50] This means that hotter temperatures can, on average, boost species richness (provided that precipitation does not simultaneously limit effects).

2.3 Decline in plant populations

Although there is still a need for a comprehensive and systematic long-term survey of plants of all species, several efforts to map flora have enabled researchers to identify dramatic changes in the populations of many species. Examples include distribution maps of flora in Baden-Württemberg[51] and across southern Germany.[52] These studies show considerable declines in several farmland plant species, especially those pollinated by insects[53] and those with nectar-rich flowers.[54] The decrease in herbaceous plants growing wild on farmland is particularly acute.[55] However, many species have been

46 Hallmann et al. (2017); Seibold et al. (2019).
47 Williams (1982); Turin and den Boer (1988); Wenzel et al. (2006); Habel et al. (2016).
48 Hallmann et al. (2017); Seibold et al. (2019).
49 Harris et al. (2019).
50 Hawkins et al. (2003).
51 Museum of Natural History Stuttgart.
52 Buse et al. (2015).
53 Wesche et al. (2012).
54 Bruelheide et al. (2020).
55 Meyer et al. (2013).

found to experience positive growth, such as synanthropic species that respond positively to the increasing use of nitrogen on farmland and, as a result, replace slower growing species.[56]

The declines in plant species described here and evidenced in regional studies are also reflected in the Red Lists data.[57] For example, the Red Lists for vascular plants[58] recorded a long-term decline for 129 out of 254 wild farmland plant species and a short-term decline for 108 out of 230 species. As shown by an analysis of plant species in Mecklenburg-Western Pomerania[59], researchers have also observed sharp falls in moderately common species that are not recorded in the Red Lists.

A summary of the data published to date shows that the loss of biodiversity in Central Europe and in Germany is most pronounced on farmland[60] with variations, however, between different species groups and regions.[61]

56 Duprè et al. (2010); Peppler-Lisbach and Könitz (2017).
57 BfN (2009 – 2018).
58 BfN (2009 – 2018).
59 Jansen et al. (2019).
60 EEA (2015).
61 Schuch et al. (2012); Batáry et al. (2017).

3. The values of biodiversity

The loss of biodiversity has given fresh impetus to the question of what constitutes its value. However, biodiversity is associated with an extremely broad concept of value[62] – for instance, declining biodiversity results in the loss of goods, functions, services and many other positive aspects or products beneficial to humans. Losing biodiversity means that we irretrievably lose benefits for all life on Earth, including humans, and it is currently extremely hard to ascertain how significant such missed opportunities would be. However, we can pinpoint specific implications of biodiversity loss, allowing us to identify three general value criteria that underpin the discussion around biodiversity.[63] Such values are as follows:

- Use values or instrumental values are the "services" that biodiversity offers for human purposes (3.1).

- Relational values or eudaimonistic values (i.e. values that provide well-being, "inherent values") refer to the relationship between humans and biodiversity, differing from person to person and species to species (3.2).

- Intrinsic values are absolute values of biological biodiversity that justify an immediate moral duty of other life forms to protect it (3.3).

There is a societal consensus that biodiversity should be conserved for future generations, even if its actual value in specific cases is still disputed or unknown (3.4). This is all the more relevant given that species cannot be brought back from extinction and individual species are irreplaceable. However, it is important to note that certain features of biodiversity can also be assigned negative values, for example those associated with pathogens and disease vectors or with invasive species on farmland or in woodland.

3.1 Use values and ecosystem services

Ecosystems and the organisms that constitute them provide goods and services on which humans depend. Some of their benefits also have quantifiable economic value:[64] animals, mainly insects, help to varying degrees in pollinating 87 of the 115 most commonly grown crops worldwide.[65] Based on these figures, the annual economic value of insect pollination for German agriculture totals EUR 1.13 billion, while this value stands at EUR 14.6 billion for Europe overall (calculations do not include honey pro-

62 Cf. Preamble of the Convention on Biological Diversity; Potthast (2014).
63 IPBES (2015); Díaz et al. (2015).
64 TEEB (2010); Lautenbach et al. (2012).
65 Klein et al. (2007).

duction).[66] Crops pollinated by insects also provide humans with various essential vitamins and minerals.[67] For example, for the crops that are a source of vitamin C, this affects over 90% of the production. Common crop varieties pollinated by insects such as strawberries, cherries, rapeseed plants, cucumbers and watermelons produce particularly high yields. These crops produce especially high-quality fruits when they are pollinated by wild bees, which provide a great deal of cross-pollination (Fig. 6).[68] However, few dominant bee species are responsible for pollination on farmland;[69] foremost among them are social bees, which in Germany and Europe are usually the European honey bee and the buff-tailed bumblebee. Although managing a few bee species in a targeted way can provide pollination services for many crops, there are still numerous studies and meta-analyses that show a link between pollinator diversity and the level of pollination service for crops.[70] The two are interdependent because different pollinator species pollinate crops in different areas of the field, at different times of day and in different kinds of weather, and these species can also influence each other's pollination activities.[71] This means that farmers who encourage a diverse range of flower-visiting insects in their crop fields or field margins will enjoy greater certainty that their crops will be sufficiently pollinated.[72]

In general, having many different inconspicuous animal species and micro-organisms is vital for agro-ecosystems to function. These organisms are responsible for various functions within pest control, within the recycling of nutrients and as herbivores and granivores.[73] This means that having rich biodiversity within fields and the agricultural landscape overall allows farmers to control pests more effectively and can also increase their crop yields.[74] Studies have also shown that ecosystems with richer biodiversity have lower levels of pathogens and parasites among plants and animals.[75] Furthermore, having granivores (e.g. birds and ground beetles) on arable land helps prevent the growth of invasive plant species that compete with crops.[76] Lastly, covering land with perennial herbaceous plants and grasses, flower strips and hedgerows can help prevent soil erosion, which in turn counteracts the loss of fertile farmland, among other benefits. All agro-ecosystems need rich biodiversity to keep these kinds of regulating services stable in the long term.[77]

66 Leonhardt et al. (2013).
67 Eilers et al. (2011).
68 Klein et al. (2007); Brittain et al. (2013b, 2014); Garratt et al. (2014); IPBES (2016); Wietzke et al. (2018); Castle et al. (2019).
69 Kleijn et al. (2015).
70 Dainese et al. (2019).
71 Blüthgen and Klein (2011); Brittain et al. (2013a, b).
72 Garibaldi et al. (2014).
73 Lavelle et al. (2006); Tscharntke et al. (2012b).
74 Redlich et al. (2018); Dainese et al. (2019); Martin et al. (2019).
75 Civitello et al. (2015).
76 Pannwitt et al. (2017).
77 Tilman et al. (2006); Winfree and Kremen (2009).

Fig. 6: The type of pollination has an influence on the quality of the fruit produced. For apple cultivation, trees whose leaves have been pollinated by hand produce a very large number of small fruits with an unusually large number of pips (left). These apples are not suitable for selling. When apple blossoms are pollinated by insects, fruit growers obtain the desired yield and consumers obtain the desired apple quality (middle). In contrast, excluding insects from pollination results in a few large apples without pips which are not suitable as eating apples (right). The example shows the common "Topaz" variety, which is organically grown near Lake Constance. Photo: Alexandra-Maria Klein.

Although biodiversity includes organisms that may be harmful to particular ecosystem functions, in the long term biodiversity does help stabilise ecosystems and their functions and services. Every species has unique characteristics, which make ecosystem functions borne by several different species more secure. If, for example, a species is unable to perform its services because particular weather prevents it from breaking down organic material or visiting flowers, a species-rich ecosystem will include another species that will be able to perform the same functions in these conditions.[78] The fewer species there are on agricultural land, the more vulnerable its ecosystem is to fluctuating environmental conditions and climate change.

Biodiversity also makes a crucial contribution to the recreational value of landscapes, which is particularly important for human well-being. Initial studies have found links between biodiversity and mental as well as physical health in humans.[79]

3.2 Relational values

Biodiversity also holds cultural value for many people beyond the useful benefits. Protected natural monuments, such as ancient solitary oak or lime trees, show the long-standing connections between humans and other species, especially in agricultural landscapes.[80] These kinds of relational values are specific to particular biological individuals and groups, and their significance for society as a whole is harder to quantify compared to instrumental values. This does not mean, however, that they are not still crucial for individual people, especially since they often have a deep emotional connection. Relational values can change over generations. For example, people who grew up in poorly structured landscapes with little species diversity may not (directly) experience or notice the value of small-scale agricultural land.[81]

78 Yachi and Loreau (1999).
79 Fuller et al. (2007); Dallimer et al. (2012); Hedblom et al. (2014); Cox et al. (2017); IPBES (2018).
80 Schumacher et al. (2014).
81 BMU and BfN (2015).

3.3 Intrinsic values

Many people think that biodiversity is worth preserving not just for the aspects detailed above, but also for its own sake, and regardless of its value to humans. This includes farmland species that may owe their existence on the land to humans using the land, but which still have an intrinsic value. Intrinsic value usually means a value that cannot be valorised (mainly in economic terms), and such values are thus difficult to systematise. At the same time, the intrinsic value of biodiversity appeals to the intuition or religious leanings of people with an affinity for nature.[82]

3.4 Various values enshrined in law

The different aspects of valuing biodiversity have also been enshrined in law. The state, including legislative, administrative and judicial bodies, aims to protect biodiversity as a basic natural resource for future generations (Article 20a Basic Law for the Federal Republic of Germany, GG). The national goal for environmental protection is laid down in Section 1(1) sub-paragraph 1 of the Federal Nature Conservation Act (BNatSchG). It stipulates that nature and the countryside in both populated and unpopulated areas must be protected on account of their intrinsic value, as basic necessities for human life and health and as a duty to future generations. Furthermore, they should be protected in a way that conserves biodiversity in the long run. These obligatory goals comprise both an anthropocentric approach (i.e. biodiversity must be preserved out of responsibility for the well-being of current and future humans) and a biocentric approach (i.e. the view that the environment has value in and of itself and so must be protected for its own sake).[83]

3.5 Operationalisation of values

While biodiversity is a value in and of itself, it also has different values depending on real-world situations and goals. The process of evaluating biodiversity in specific ecosystems examines the number and frequency of species in relation to their benefits. Yet the complex nature of ecosystems, the interactions between species and their environment and the manifold values that biodiversity holds for humans all justify the fundamental value of biodiversity and why it needs to be preserved and supported. Anything that deviates from this would need to have a specific reason, such as taking precautions to prevent particular species from causing any major damage. At the same time, the impact of biodiversity loss differs depending on the ecosystem, time frame and evaluation method, and the consequences cannot usually be predicted, so assessing these impacts is fraught with uncertainty.

If there are conflicting goals – which should ultimately be seen as conflicting values – the justifications for the values need to be openly discussed. In addition to preserving and promoting farmland production capabilities, the precautionary principle mentioned above should also play a crucial role in prioritising the preservation and promotion of biodiversity given the scale and speed with which species are being lost.

82 BMU and BfN (2015): 93% of those surveyed said it was important to consider animal welfare in food production.

83 Schlacke (2019), § margin number 9 f.

Prioritising biodiversity is supported and encouraged by the majority of the German population,[84] including agricultural biodiversity in particular.[85]

Finally, embedding biodiversity standards into current international, national and federal state-specific conservation legislation shows a basic yet definitive political recognition of the values that biodiversity holds. The loss of species and other aspects of biodiversity (genetic diversity, biocoenosis) conflicts with the targets set in these regulations.

84 For example, 92% of those surveyed would like to be able to rely on the fact that no fish products from endangered species appear in shops, and 90% of them support labelling fish products from eco-friendly fisheries; BMU and BfN (2017).

85 BMU and BfN (2015): 92% of those surveyed support farmers giving greater consideration to the impact of their actions on the environment.

4. Causes of the decline in agricultural biodiversity

Causes of the decline in agricultural biodiversity are manifold and they are largely a combination of changes in farming intensity, diversity of land use and how agricultural land is structured.[86]

4.1 The EU Common Agricultural Policy

The European Union's (EU) Common Agricultural Policy (CAP) lays down the framework conditions for agriculture in Germany and shapes how German agricultural policy is structured. From 1950 onwards, agriculture in Germany and the EU was shaped by set production and economic targets[87] that focused on boosting agricultural productivity, raising the per capita income of farm workers, stabilising markets and ensuring populations had access to products at a reasonable price.[88] Agriculture was developed with a view to increasing yields and improving (primarily technical) product quality, which government incentive schemes also supported.[89]

Agricultural land was largely altered in the 1960s and 1970s so that farmers could meet the above targets. Premium pricing combined with strong protection from outside competition[90] led to surges in productivity in the EU in the 1980s. Agricultural policy experienced a turning point with the MacSharry reforms in 1992[91], and EU agricultural markets were increasingly liberalised. The integration of the EU agricultural markets with international markets in the 1990s has since led to farms having to adapt their goods more and more in line with international prices.

At present, 51% of Germany's total surface area is used for farming.[92] Of this agricultural land, 72% (36.8% of the total surface area) is arable farming land and 28% (14.3% of the total surface area) is permanent grassland (meadows and pastures).

86 Firbank et al. (2008).

87 The objectives of the CAP are now set out in Article 39 of the Treaty on the Functioning of the European Union (TFEU) from 2009.

88 Koester (2016).

89 Haber (2014), p. 78.

90 Above all due to customs and export refunds.

91 The support prices for grain and beef were progressively decreased by up to 33% and arable land set aside. The farmers received direct payments as compensation. The reform was named after the then Commissioner for Agriculture and Rural Development, Ray MacSharry.

92 UBA (2018).

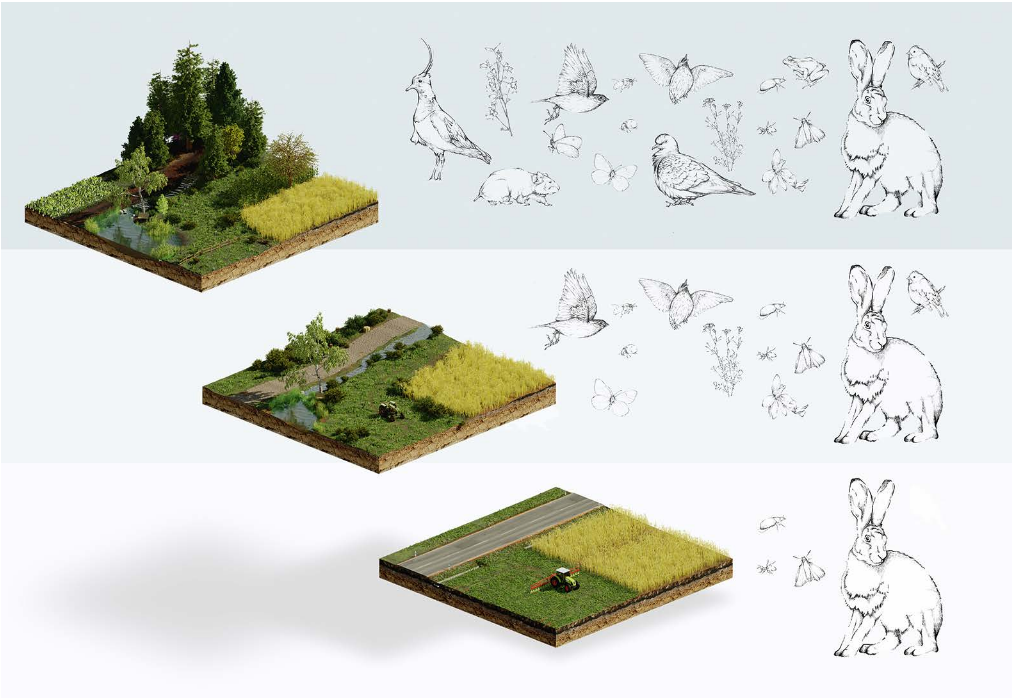

Fig. 7: The structural richness of the landscape has decreased in many places. The fewer structures there are in a landscape, the fewer animal species live there.[93]

4.2 Increase in area, loss of structural diversity

Mineral fertilisers were used on large swathes of land and soil water balance was altered to ensure greater food productivity. Plots were enlarged to accommodate modern farming equipment and their dimensions were standardised. This "land consolidation" came with a reduction in structural elements, such as tree lines, hedgerows and copses, cairns and drystone walls, cultivated strips in the field margins and scarps.

Expanding farmland while simultaneously harvesting fields across large areas prevents birds and other wild animals from finding places on farmland to make their habitat.[94] The size of crop fields with standardised farming methods plays a major role in agricultural biodiversity.[95] The general rule is that the smaller the fields are and the more suited the method of managing field margin structures is to protecting species, the more effective the measures to preserve biodiversity will be (Fig. 7).[96] However, extensive regional maize cultivation negatively impacts some farmland bird populations.[97]

93 BUWAL and BFS (1997); Tscharntke et al. (2007).

94 Batáry et al. (2017).

95 Fahrig et al. (2015).

96 Sirami et al. (2019).

97 Brandt and Glemnitz (2014); Busch et al. (2020).

4.3 More comprehensive use of crop protection products

Alongside land reforms, the deployment of synthetic chemical plant protection products on a large scale[98] enabled farmers to control pests effectively in field and specialised crop farming. Almost all arable farming land in Germany has been treated with plant protection products since the 1970s.[99] For example, insecticides were used to protect winter cereal crops on 6% of all farming land in northern Germany in 1971, rising to 100% coverage by 1983. The number of insecticides available also doubled.[100] The quantity of active substances to protect crops has remained stable since 1995 (approximately 30,000 tonnes), and the number of chemical compounds in these substances has likewise remained almost constant at 270.[101] However, substances such as insecticides have become more effective over time[102], with current products one thousand times more toxic to insects than DDT (Dichlorodiphenyltrichloroethane), which was used extensively until the 1970s. The 1990s saw the introduction of neonicotinoids, which have continued to optimise pest control on farmland. However, it became increasingly clear that these substances harm biodiversity, with bees suffering from multiple adverse effects.[103] Several neonicotinoids have since then lost their authorisations for use on open land Fungicides can also negatively impact insects directly.[104] By eliminating fodder plants, herbicides also affect the frequency and species richness of insects, which in turn affects birds higher up in the food chain.[105]

4.4 Reduced crop diversity and purer seeds

This alteration to plant production also brought other changes in farming methods, including new production methods standardised across the landscape for an increasingly narrow range of crops. This progress sped up production and harvesting processes, but in many cases it also reduced biodiversity and the number of biological pest controls such as birds.[106] Lastly, the changing agricultural landscape has given rise to other phenomena that also play a role in declining agricultural biodiversity. These include the refinement of wild seeds over the last 200 years to guarantee increasingly successful yields and the gradual disappearance of vectors for spreading wild arable plant seeds, such as migratory herding.

98 Plant protection products are substances that protect crops from pests. Occasionally this statement and the insect conservation action programme use the term pesticide. This term is used in addition to plant protection products and biocides, which prevent non-plant dwelling pests from causing damage using non-mechanical means (e.g. using worming agent with livestock or anti-mosquito agents).

99 Friege and Claus (1988), cited in Leuschner et al. (2014).

100 Kromp (1999).

101 UBA (2018b).

102 Simon-Delso et al. (2015).

103 German National Academy of Sciences Leopoldina (2018).

104 Heimbach (1988).

105 Rands (1985); Freemark and Boutin (1995). The Scientific Advisory Board on the National Action Plan on Plant Protection Products (Wissenschaftlicher Beirat zum Nationalen Aktionsplan Pflanzenschutz) published information in 2019 on the risk to agricultural biodiversity from using plant protection products.

106 Redlich et al. (2018).

4.5 More indoor livestock farming, less grassland

Keeping and rearing dairy cows has changed in recent decades. As dairy cows became ever more productive, dairy farmers needed more and more energy-rich feed on grassland.[107] They then enhanced their species-rich and moderately productive grasslands with fertiliser, herbicides and special grass mixes or ploughed them into land for growing feed.[108] Changes in livestock farming drove this trend further. The rule in the 1950s and 1960s was to cut permanent grassland no more than three times a year or only keep a moderate stocking density on the land.

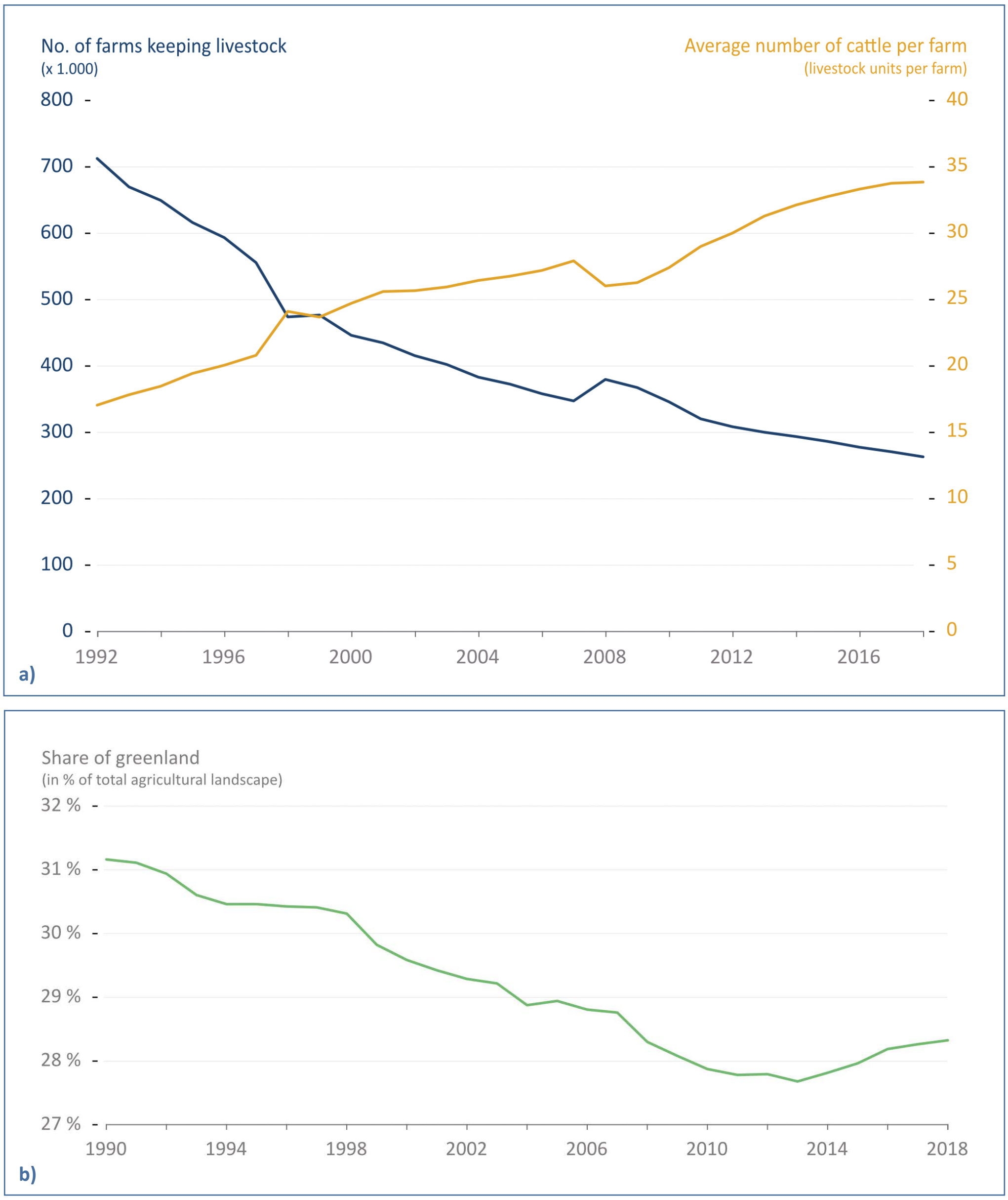

Fig. 8: Trends in livestock farming (cattle and sheep) and permanent grassland in Germany: a) number of farms keeping cattle and sheep and the stocking density (cattle and sheep) in livestock units (LU)[109]; b) share of all farmland in Germany used as grassland.[110]

107 Hampicke (2018).
108 Hampicke (2018), p. 35.
109 Destatis (2019a).
110 BMEL (1992, 2005, 2012, 2019).

Now, livestock are largely kept indoors while meadows and pastures are extensively fertilised, and the grass is largely cut for feed, usually six or seven times a year.[111] The number of flowering plants has dramatically declined as a result. As more and more livestock are kept indoors, there is less manure on grassland, thereby removing it as a source of food and habitat for many insects. Stocking densities are also increasing while small-scale holdings that keep animals indoors with regular outdoor grazing are becoming progressively less common (Fig. 8).[112] For example, only 2% of dairy farms held over 100 cows in 1999. By 2018, this figure had increased to 18%.[113] Overall grassland areas in Germany shrank between 2003 and 2012, and 5% of all permanent grassland disappeared completely.[114] Intensive land use destroys biodiversity.[115] Species-rich grassland in Germany is now one of the most endangered habitats.[116]

4.6 The nitrogen issue

So as to maintain soil fertility and ensure plant growth, nutrients are added to arable land. In regions with a high population of livestock, manure or slurry also needs to be disposed of. Furthermore, fermentation residue occurs in biogas plants which, when spread like manure, can lead to over-fertilisation of soil. Nitrogen, in particular, plays a problematic role for ecosystems in this process. A comprehensive study on how grassland use impacts plant diversity and vegetation composition in Germany found that fertilisation has an adverse effect on both the number of species and number of Red List species.[117] It also found that the number of wild farmland plant species growing on intensively farmed land in central and northern Germany fell by 23% between the 1950s/1960s and 2009. The composition of species present in the remaining habitats points to an increased nutrient supply from fertilisation as a possible cause.[118]

4.7 Increased intensive land use

There is a great deal of evidence showing how more intensive land use usually harms biodiversity. For example, a global meta-analysis revealed that land use intensification on arable land and grassland can increase yields but can also significantly reduce species richness.[119] It should also be noted that intensification at the expense of biodiversity is not always the best way to increase yields. Biological pest controls can be used to increase yields on low-intensity farmland in landscapes with sufficiently heterogeneous structures.[120]

111 Leuschner et al. (2014).
112 BMEL (2015); Destatis (2019a, b).
113 Milchtrends.de (2019); Destatis (2019c).
114 BfN (2014).
115 Plantureux et al. (2005).
116 BfN (2014).
117 Gilhaus et al. (2017).
118 Meyer et al. (2014).
119 However, species loss does not always occur within high-intensity systems or if intensification is implemented incrementally in low-intensity systems, see Beckmann et al. (2019).
120 Dainese et al. (2019); Martin et al. (2019).

Intensification efforts have only managed to achieve steady, long-term yield growth in suitable locations. Unsuitable locations, conversely, have not been economically viable, causing farmers to abandon the land.[121] Large plots of land in regions such as the Black Forest were left fallow or underused as far back as the 1960s,[122] adversely affecting plant and animal species that depend on low-intensity land use (in the high nature value farmland system[123]) to thrive.

4.8 End of the EU set-aside policy

Fallow land supports species richness, for example among birds.[124] The share of fallow land has fluctuated a great deal over time (Fig. 9), due to changes to European agricultural policy. The set-aside policy was introduced in 1992 as an instrument of EU agricultural policy to limit surpluses from farming. Set-aside areas (usually fallow) reduced the production volume, with positive ecological side-effects.

The set-aside requirement was gradually abandoned from 2007 onward after prices started to rise on world agricultural markets in 2005. As a result, the share of fallow land fell from 6–7% to around 2% in 2009 (Fig. 9). Driven by environmental concerns, ecological focus areas (EFA) were introduced as part of the new "greening" measures in 2015. However, this did not return the amount of fallow land to previous levels.[125]

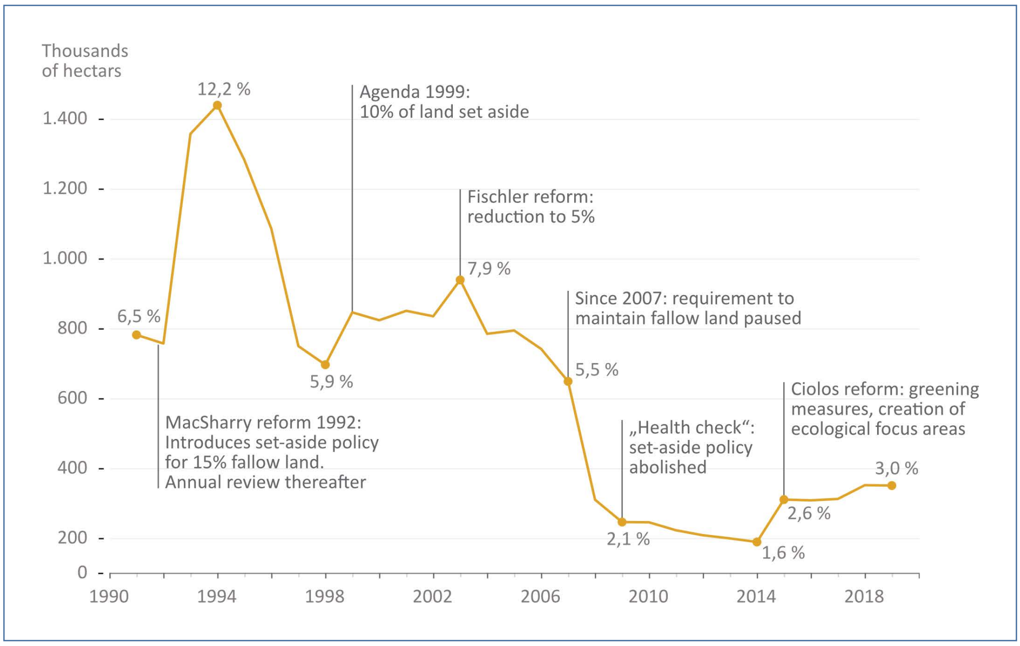

Fig. 9: Amount of fallow land as a result of the set-aside requirement and "greening" measures in Germany. The percentages correspond to the specific share of fallow land within all arable land.[126]

121 Strijker (2005).
122 Reger et al. (2007).
123 Strohbach et al. (2015).
124 Henderson et al. (2000); Firbank et al. (2003).
125 Pe'er et al. (2017).
126 BMEL (2015); Destatis (2019d).

4.9 Comparative analysis of individual factors and summary

A wide variety of studies have analysed how specific factors in land-use change have impacted species groups. There are very few studies that measure the effects of the multiple factors detailed in this chapter in one single test and thus make them comparable. A Europe-wide study investigated how intensive farming in wheat production impacts[127] wild arable plants, ground beetles and farmland birds as well as the potential effectiveness of biological pest control.[128] The study revealed that areas using more herbicides, insecticides and fungicides recorded a reduced number of wild plant, ground beetle and farmland bird species. It also showed that biological pest controls for insects and plants became less effective when more insecticide was used.

In another study, ten possible influencing factors[129] for four species groups (plants, earthworms, spiders and wild bees) were analysed in four regions across Europe.[130] Major findings from the study are that mineral nitrogen fertiliser and the number of pesticide applications adversely affected the number of plant and bee species and individuals.

If we consider all these studies in the context of one another, we can assert that each factor or combination of factors detailed in this paper contribute to the decline in biodiversity, frequency and biomass of species on farmland. Each will, however, have varying degrees of influence and act on different scales. For example, there is evidence that cleared landscapes have had an impact on bird diversity at field and farm level but not at regional level.[131] The findings also show that there were significant differences in species richness among plants, worms, spiders and bees at field level on land using traditional and organic farming methods, but these differences were marginal at farm and regional level.[132]

Countermeasures have been taken in response to the growing standardisation and intensification of farmland use. These measures are incorporated in the German federal states' agri-environmental programmes ("Kulturlandschaftsprogramme") and the CAP. However, such measures have not yet managed to reverse the trend, or have done so only marginally, both for the species groups affected and the factors causing the declines.[133]

127 The farming scale recorded details on: farming methods (conventional/organic), crop rotation, share of farmland with agri-environmental measures, field sizes, the quantity of insecticides, herbicides and fungicides applied and number of applications, the use of nitrogen and organic fertiliser, ploughing and using machinery to remove weeds. Additional information was recorded at the landscape level: average field sizes within a 500m radius of the test sites and the number of different crops.

128 Geiger et al. (2010).

129 Geographic location (farm, region), agricultural management (crop type, mineral nitrogen input, organic nitrogen input, mechanical field operations and the use of plant protection products) and diversity in the surrounding landscape in a 250m radius around the fields.

130 Lüscher et al. (2014).

131 Jeliazkov et al. (2016).

132 Schneider et al. (2014).

133 Kleijn et al. (2011); Pe'er et al. (2017).

Direct causes of the decline in agricultural biodiversity

The causes of the decline in agricultural biodiversity are predominantly due to a combination of changes in how agricultural land is used, how it is structured and the insensitive exploitation of the land. The relative importance of these causes cannot yet be evaluated. The main causes of the loss of agricultural biodiversity are:

- **Changes to land use and crops grown on the land:** (i) reduction in species-rich land use systems (e.g. because grassland has been turned into arable land, or due to intensification on formerly low-intensity grassland); (ii) increase in intensive, high-yield land use that has little species diversity (e.g. for maize, rapeseed, wheat, viticulture).

- **Unbalanced crop rotations:** (i) dominance and partly long-term growth of less-productive crops; (ii) loss of multiple cropping (growing several crops or varieties at the same time); (iii) less diverse crop rotations.[134]

- **Changes in livestock farming:** the sharp reduction in cattle-rearing farms has led to a decline in hay fields, small pastures, cattle manure and manure yards as habitats and sources of food for many micro-organisms, insects and birds.

- **Highly effective herbicides and pesticides:** (i) reduced use of biological and mechanical methods for pest and weed control; (ii) regular pre-emptive and widespread application of highly effective plant protection products including herbicides (to eliminate weeds), fungicides (to control fungi growth), insecticides (to eliminate insects) and vermicides (deworming products) in livestock farming; (iii) pesticides used on farmland contaminating adjoining land and surface waters, including groundwater pollution.

- **Soils with high levels of nutritional value covering large areas:** (i) efficient chemical fertilisation, partly up to the field margins and paths; slurry spreading, including on sparse grassland; (ii) grass clippings not being removed from field margins and bordering paths, leaving nutrients in the soil; (iii) sowing seeds for legumes (fabaceae) for use as “greening” measures.

- **Expanding field sizes, loss of structural diversity in the landscape:** (i) sharp decline in tree lines, hedgerows, copses, cairns and drystone walls and low-intensity, low-nutrient strips in the field margins and fallow land; (ii) acute reduction in the biotope network.

- **Lack of protection, small field sizes and connecting conservation areas on farmland:** (i) lack of land-use concepts suited to low-intensity farming; (ii) lack of buffer zones around conservation areas to minimise the contamination of surrounding land by fertiliser and plant protection products; (iii) lack of habitat bridges due to structural loss in the agricultural landscape.

134 Steinmann and Dobers (2013).

5. Contextual factors to working in the agricultural landscape

To take effective action against the causes of the decline in agricultural biodiversity (chapter 4), it would first be helpful to analyse the contexts within which farming stakeholders work and how their actions impact biodiversity. The role of agriculture (chapter 5.1) is critical in this respect. Since the possible actions for farms to take are heavily influenced by market-based mechanisms, government subsidies and regulatory frameworks, this chapter will focus on the role of the market economy (5.2), the role of agricultural policies (5.3) and the role of agricultural and environmental legislation and its application (5.4). Finally, as this statement looks at macrosocial perspectives, we will also examine the role of civil society (5.5) and science (5.6).

5.1 Role of agriculture

Agriculture is changing. In addition to food production, the last 20 years have seen the use of agricultural raw materials for energy production. Material use (bio-economy) is a growing branch of the economy. The climate in which agriculture[135] is operating has also changed. The liberalisation of European Union (EU) agricultural policy since 1992 has enabled, for example, the (global) market prices for agricultural products to have a direct influence on production decisions in agricultural businesses. Land ownership relationships, as well as the land price and leasing prices, have an impact on land use, and thus on biodiversity. Intensive cultivation and its consequences for biodiversity can therefore be seen as a result of economic optimisation. A further example, discussed below, shows that the regional and local agricultural climate, in other words the local landscape structure, influences the biodiversity in arable landscapes. A rich and diverse landscape structure can counteract the negative effects of intensive arable farming.

Using grassland is closely linked with livestock farming

The use of grassland is closely linked with livestock farming. Although some types of land use for keeping cattle in meadows and pastures are detrimental to biodiversity, species-rich grassland could not be preserved at all without livestock. Low-intensity meadow and pastureland use can foster ecosystem-appropriate biodiversity. When grass is cut to be used, the biomass is evenly removed and the land use is increasingly standardised; conversely, selective grazing supports spatial diversity.[136] In 2010, cattle on 55% of German farms were kept on pastures.[137]

135 There are many different stakeholders in farming. At the centre of these are the farms themselves, operating as family-run and family-owned businesses or partnerships formed under German civil law, meaning the owners are considered natural persons and are personally responsible for the business. However, if they operate as cooperatives or private limited companies („GmbH“ in Germany), they are treated as legal entities and internal committees govern the organisation’s responsibilities (executive committees, supervisory boards, general assemblies).

136 Isselstein et al. (2005); Tälle et al. (2015).

137 Destatis (2011).

Arable farming: variety and type of farming are decisive for biodiversity

When it comes to arable farming, however, the diversity of crop production can, over space and time, create a host of options to help preserve and support diversity among plants, animals and microorganisms.[138] Before farms can achieve a high degree of crop diversity and employ a wide variety of farming methods, they need to ascertain whether growing lots of different produce makes economic sense for their operation; agricultural market conditions are still a decisive factor here (chapters 5.2 and 5.3).

Making long-term decisions about cultivating certain crops lays the foundation for the biodiversity that will accompany crop production[139], although such biodiversity is heavily dependent on how the crops are grown. Making short-term decisions about tillage, irrigation, fertilisation and crop protection can cause changes to the composition of biodiversity in the agricultural landscape. We can clearly see this in action with the use of plant protection products: they are intended to kill species that cause damage to crops, but they can also have an effect on many harmless or useful species.[140] By contrast, greater biodiversity can usually be found on farmland with low-intensity land use, agri-environment-climate measures or organic farming (which uses fewer pesticides and mineral fertilisers), for example.[141]

How land use impacts biodiversity mainly depends on the intensity of the land use in question, particularly the use of fertilisers and plant protection products. It makes financial sense to use a greater amount of pesticides and fertilisers with arable crops and cultivation systems that have low production costs and generate high revenues. By contrast, farmers generally use fewer pesticides and fertilisers in less productive systems (e.g. arable farming in locations with limited yield potential).[142]

Beyond organic farming, innovative cropping systems supported by technology on a small scale or digital tools on a large scale (e.g. employing remote sensing data on soil moisture, leaf colour and weather development) hold enormous potential for supporting biodiversity. One example of this is autonomous machinery for weed control and the use of small self-driving robots to sow seeds, minimise pests and harvest crops, known as “precision farming”.[143]

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138 Benton et al. (2003); Rusch et al. (2013); Meyer et al. (2019); Moss et al. (2019).

139 Meyer et al. (2019).

140 German National Academy of Sciences Leopoldina (2018); IPBES (2019).

141 Stoeckli et al. (2017).

142 Stoeckli et al. (2017).

143 Ball et al. (2015); Herlitzius et al. (2018).

Organic farming

The European Council regulation on organic production[144] sets out the framework for organic farming. It contains binding regulations for growing crops and rearing livestock (Article 4 f.) and lays down the conditions for a control and certification system (Article 27 ff.) in the event a distributor intends to label its products as organically produced (Article 23). One of the characteristics of organic farming is the restriction on particular production factors, such as restrictions in acquiring livestock feed as well as the ban on synthetic chemical plant protection products and highly soluble mineral fertilisers. Plant protection products using naturally derived compounds are, however, permitted. Pesticides that are authorised for use in organic farming are placed on a whitelist and undergo an authorisation procedure (e.g. *bacillus thuringiensis*, copper, vegetable oils and plant extracts). In 2018, organically farmed land in Germany totalled 1,483 thousand hectares (8.9% of land), and 29,395 farms (11.7%) currently operate in line with organic farming directives.[145] Organic farming in most EU member states receives funding as part of agri-environmental-climate schemes.[146]

Organic farming is not to be confused with "integrated farming". The latter allows for area-appropriate use of mineral fertiliser and chemical crop protection measures according to the "threshold of damage" principle. In this respect, integrated agriculture uses other means of production but considers, similarly to organic farming, the ecological requirements and adjusts its cultivation measures to the natural conditions (variety selection, crop rotation, farming techniques, plant nutrition and crop protection).

One meta-analysis revealed that organic farms increase species richness by around 30% on average.[147] Environmental performance from organic farming, on the other hand, varies depending on the farm and location.[148] This means that how agricultural production systems impact biodiversity partly overlaps with the impacts from structural conditions, such as field size and surrounding landscape (Fig. 10).[149] Nevertheless, organic farming clearly has greater benefits for biodiversity compared to conventional farming systems, especially on arable land and relatively uniform and intensively exploited agricultural land. However, smaller differences between the two are observed on grassland.[150]

By contrast, organic farming produces lower yields depending on the crop and location. Various overview studies have estimated that the difference in yields between organic and conventional farming is around 20–25%.[151] However, there are other studies, such as those about apple cultivation, that have examined over 80 fields across Europe, and although they noted that there were 30% more beneficial organisms in organic production, yields were 50% lower than those achieved by integrated farming.[152] In addition, land is required for biological

144 Council Regulation (EC) No 834/2007 of 28 June 2007 on organic production and labelling of organic products, Art. 2(a). European Council, 2007, OJ L 189 of 20/07/2007, p.1. The regulation states that organic production is "the use of the production method compliant with the rules established in this Regulation, at all stages of production, preparation and distribution".

145 BÖLW (2019).

146 Boncinelli et al. (2016).

147 Tuck et al. (2014).

148 Badgley et al. (2007); Ponti et al. (2012); Seufert et al. (2012); Knapp and van der Heijden (2018).

149 Hole et al. (2005); Tscharntke et al. (2012); Sanders and Heß (2019).

150 Tuck et al. (2014).

151 Lakner and Breustedt (2017).

152 Samnegård et al. (2019); Haller et al. (2020).

nitrogen fixation. As a result, the findings vary greatly depending on soil quality, crops planted and individual farm management.[153] Organic farming has fewer or neutral benefits (depending on the indicator and/or function) if its environmental performance is calculated based on it producing lower yields.[154] As a general conclusion, some crops, soils and locations are better suited to organic farming than others.[155]

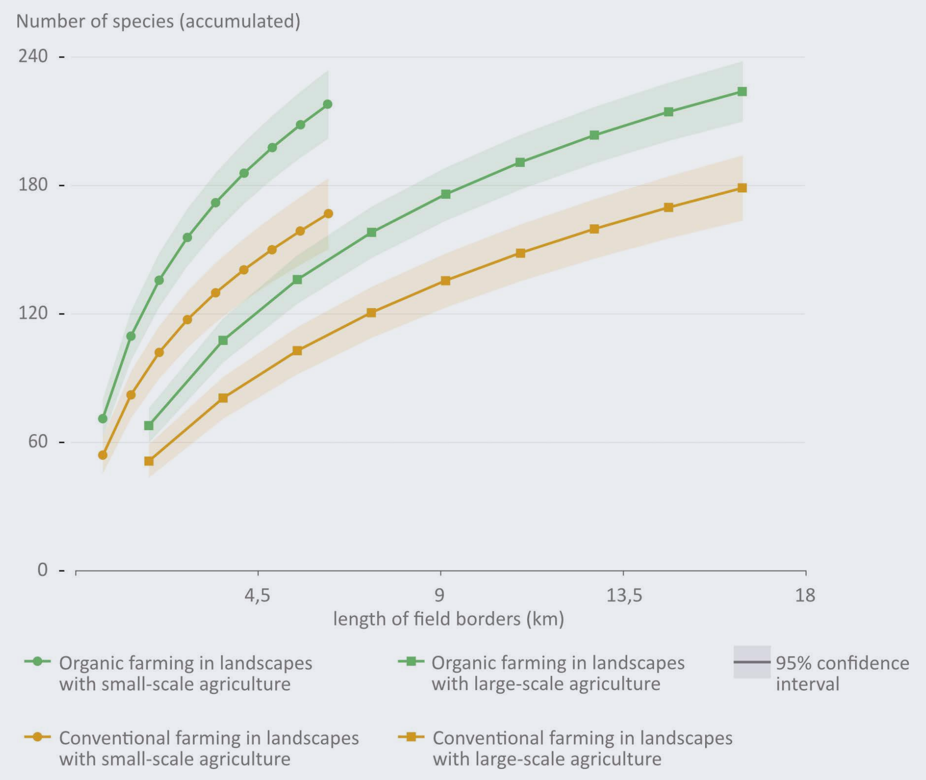

Fig. 10: Relation between the number of plant, insect and spider species and the length of the field borders (field periphery) in conventionally and organically grown winter cereal crops in small and large structured landscapes. On average, species richness is greater on organic farmland than on comparable areas of conventional farmland, and it increases the more the land is divided up into plots (i.e. longer field borders overall mean smaller individual fields on the same land). The data points represent species richness in different field sizes. Figure adjusted in line with Batáry et al. 2017.[156]

153 Badgley et al. (2007); Ponti et al. (2012); Seufert et al. (2012); Knapp and van der Heijden (2018).
154 Seufert and Ramankutty (2017).
155 Jänsch and Römbke (2009); Rodrigues et al. (2016); Pedneault and Provost (2016).
156 Batáry et al. (2017).

Farms adopt these kinds of innovative strategies if they are environmentally conscious and have access to reliable information, government subsidies and data on expected profits.[157] There are high-quality data on pest management and fertilisation that help farmers manage systems with fewer pesticides and fertilisers.[158] Biodiversity can also be considered a public good in and of itself and be compensated.[159]

Landscape structure can offset intensive agricultural use

Structural landscape features, such as hedgerows, individual trees or field margin structures, make agricultural landscapes considerably more beneficial to biodiversity. Depending on the farming system used, a diverse landscape structure can offset the effects of intensive land use on agricultural land.[160] Furthermore, if field margin strips are wide enough, they can minimise the impacts of farming on habitats bordering the farmland, such as rivers and other bodies of water and conservation areas. Farmers can actively decide whether to conserve, maintain or restore these kinds of structures. This decision-making process is not just the remit of farms, however, as they do not decide how to shape the entire agricultural landscape alone, and many decisions are made jointly with municipal or user associations (water boards, hunting associations, countryside interest groups and "Realgemeinde" agricultural cooperative communities).

Lease land: divergent development in the East and West

In addition to the factors noted above, farming also undergoes major changes as the amount of leased farmland changes. For example, the amount of leased land in West Germany has steadily grown over the last few decades, while it has decreased considerably in East Germany since the start of the 1990s (Fig. 11). The increased lease and purchase prices for agricultural land are the result of increased productivity, higher global market prices and more intense competition. In the medium term, they often force renting tenants to generate a correspondingly higher yield on the rented areas so as to remain competitive. Farmers may then manage their leased land in a less sustainable manner to achieve these returns.

Land ownership influences biodiversity

Landowners are often responsible for making decisions about long-term measures to support biodiversity. As a result, whether farms own or lease their land and which ownership structures apply to the surrounding landscapes make a big difference towards how farms take individual decisions about preserving and promoting biodiversity. Among other things, the competitive leasing market inhibits extensive land use on rented areas, for example in the scope of agri-environmental programmes. However, only a few advisory services currently exist for farms that lease their land and wish to take more measures to protect and support biodiversity.[161]

157 Liu et al. (2018).
158 Damos (2015).
159 Madureira et al. (2007).
160 Batáry et al. (2011).
161 NABU (2019).

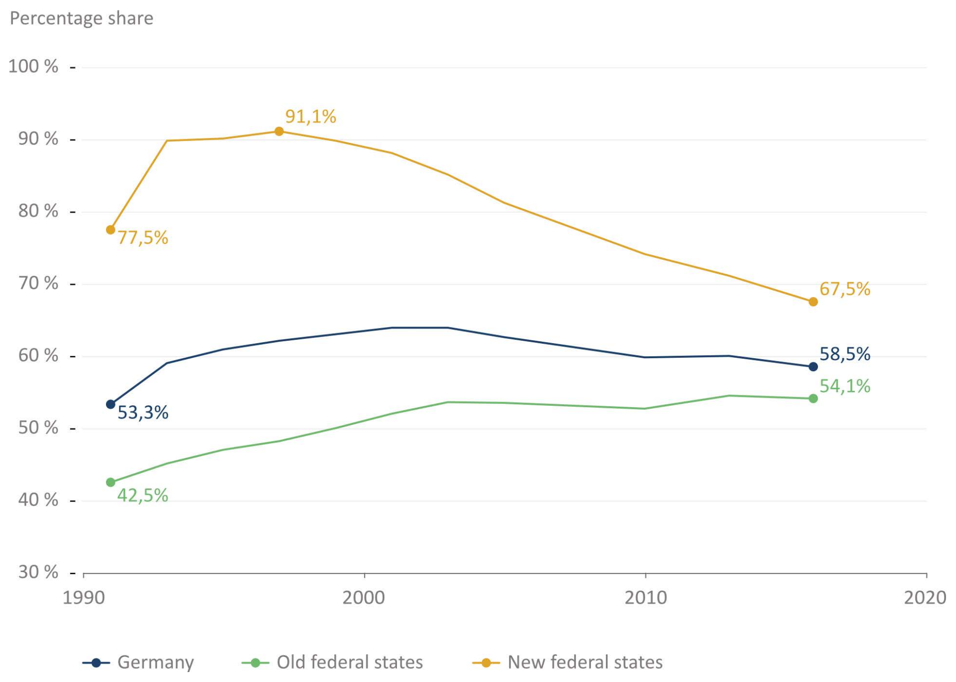

Fig. 11: Share of leased land in the Federal Republic of Germany in the period 1990–2016 (in %).[162] Data for former and new federal states are shown separately starting from 1990.

Potential global effects of pro-biodiversity agricultural production in Germany

A common argument put forward when discussing how to make German farming more biodiversity-friendly is that extensification of farming practices, especially through organic farming, would benefit biodiversity in Germany, but this could increase the demand for agricultural land outside of Germany due to changes in the trade flows of agricultural products ("telecoupling" or "indirect land use change"). Reconfiguring German agricultural production to organic farming models on a large scale could therefore alter natural habitats in other countries as others try to secure the global food supply and compensate for any yield losses caused by the transformation. This means that transforming farming practices in Germany could possibly accelerate the decline of biodiversity in other countries.[163]

This line of argument is part of a complex and heated scientific debate.[164] Firstly, organic farming only exists on an extremely small scale worldwide with just 69 million hectares of farmland (representing 1.4% of the land used for agricultural production globally).[165] Additional studies state that organic farming would make a greater contribution by diversifying farms in developing countries , or cite changes in eating habits (e.g. proportion of meat in diet) when considering the space requirements for agriculture.[166] Furthermore, under certain conditions

162 BLE (2018).
163 Balmford et al. (2018); Meemken and Qaim (2018).
164 Seufert and Ramankutty (2017).
165 Willer and Lernoud (2019).
166 Reganold and Wachter (2016); Muller et al. (2017).

organic farming can increase yields in developing countries.[167] There has been no empirical evidence as yet to show that the extensification of land use in Europe would increase land consumption elsewhere, such as in the tropics.[168]

Rising demand for (agricultural) resources and growing world trade are **the main reasons for the destruction of semi-natural habitats**. Currently, both global and local land use are largely shaped by the demand for soft commodities to be utilised for bioenergy (mainly biofuels) and by rising meat production.[169] Global food production is becoming increasingly spatially disconnected, with demand being met from a great spatial distance. Land used to grow crops for export expanded by 100 million hectares globally between 1986 and 2009, while land used for local food supply remained almost unchanged. Generally, food is exported from highly productive areas to less productive ones.[170] The main soft commodities imported into the EU are soya beans and soya bean press cakes, coffee, cocoa and palm oil.[171] A study has shown, for example, that the increased demand for palm oil from Indonesia has adversely affected the use of the country's farmland and rainforest, thereby damaging local biodiversity.[172]

Furthermore, **local factors** are driving land use changes that pose a threat to the environment. The destruction of semi-natural ecosystems, for example through fires in Brazilian rainforests, is often associated with a lack or inadequate enforcement of environmental laws. Certain economic factors only come into play when local authorities allow others to interfere with the local ecosystem, either on purpose or by virtue of their powerlessness. Subsidies and financial incentives for agricultural businesses only escalate this situation. The expectation of high returns and a lack of logging restrictions imposed by authorities means, for example, that 68% of foreign capital invested in companies producing beef and soya beans in Brazil's Amazon region comes from tax havens.[173] While industrialised nations have low population growth, stable diets and thus no increasing need for agricultural products, it is predicted that the demand for agricultural products will grow in countries with transitional or emerging economies. A shift in eating habits towards high-energy foods is the main reason behind this development.

5.2 Role of agricultural policies

Farms in Germany have been receiving transfer payments via the EU's Common Agricultural Policy (CAP) since the end of the 1960s. Until 1992, agriculture was subsidised within the EU via politically supported, high agricultural prices, which led to intensive production. Since 1992 (after the MacSharry reforms), the support for agricultural prices was progressively reduced by the EU and replaced by compensation payments (coupled direct payments). From 1992–2005, the coupled direct payments still had an influence on production decisions. Since 2005 (Fischler reforms), the majority of these

167 Reganold and Dobermann (2012).
168 Heinrich et al. (2013).
169 Schader et al. (2015); Marques et al. (2017); Grass et al. (2020).
170 Kastner et al. (2012).
171 FAO (2019); calculations in line with http://www.fao.org/faostat/en/#data.
172 Tscharntke et al. (2012); Grass et al. (2020).
173 Galaz et al. (2018).

payments have been area-based direct payments (first pillar of the CAP), decoupled from production. This means that the premium does not depend on the kinds of crops grown or how many animals are being kept. This decoupling resulted in less intensive production. Since 2000, these direct payments have instead been linked to an obligation to meet certain EU requirements under environmental, animal welfare and consumer protection legislation and to maintain agricultural land in a "good agricultural and environmental condition" (known as "cross compliance"). As many agricultural landscapes continued to deteriorate, the EU linked direct payments to the fulfilment of additional environmental regulations in 2013 ("greening" in the first pillar of the CAP), stipulating particular requirements for crop diversity, preserving permanent grassland and creating provisions for ecological focus areas.[174]

Agri-environment-climate measures have an effect, but still only play a minor role

Going beyond the above, the EU promotes agri-environment-climate measures (second CAP pillar) to protect biodiversity and the environment. These measures go further than the environmental requirements of the first pillar[175] and are financed and designed by member states.[176] In addition to the revenues generated on the market, the area-based direct payments (first CAP pillar) contribute substantially to farm income. Between 2010 and 2016, farms generated an average operating income of EUR 86,839 a year, and direct payments totalled an average of EUR 26,765 a year, representing 30.8% of operating income.[177] However, it can be shown that direct payments increase rents and do not fully benefit the farms; instead, the money is passed on to landlords. In contrast to this, funds for agri-environment-climate measures (second CAP pillar), which are exclusively geared towards environmental objectives, generally play a secondary role, with farms generating an average annual revenue of EUR 3,402 (3.9% of their annual operating income) through these schemes.

Measures focused on nature conservation do not offer any economic incentives

All things considered, the ecological impact of the CAP conservation measures is inadequate in practice: there is evidence that the first pillar greening measures are having little impact, despite the considerable financial resources invested.[178] They are also far less effective than regulatory measures when viewed in terms of their costs and benefits.[179]

Agri-environment-climate measures (AECM) indeed contribute to protecting biodiversity in some cases.[180] One weakness of the second pillar AECM is, however, that they do not contain any economic or otherwise operationally useful incentives to protect or promote biodiversity beyond the reimbursement of costs. The AECM are only occasionally geared towards specifically protecting species and selected habitats.[181] The administrative burden and complex legal conditions of the second pillar discourage

174 Art. 43–46 of EU Regulation No 1307/2013, OJ L 347 of 20/12/2013, p. 608; laid down in German legislation via the direct payments implementing act and direct payments implementing regulation.

175 Art.28 ff. of Regulation (EU) No. 1305/2013 on support for rural development by the European Agricultural Fund for Rural Development (EAFRD) OJ L 347, 20/12/2013, p. 487.

176 In Germany, the agri-environmental and climate-change mitigation measures are the responsibility of the individual states.

177 Calculations for 2010–2016 based on data from the Farm Accountancy Data Network (FADN) 2019, public database.

178 Schmidt et al. (2014); Hart (2015); Alons (2017); Röder (2017, 2019); Pe'er et al. (2017).

179 Möckel et al. (2014), p. 357 ff.

180 Batáry et al. (2015, 2017); Lakner et al. (2020).

181 Kleijn and Sutherland (2003); Kleijn et al. (2006); Oppermann et al. (2012); Pe'er et al. (2014); Batáry et al. (2015).

many farms from voluntarily implementing these AECM. As a result, these policy instruments ultimately do not have the optimum effect on biodiversity conservation.[182] If the EU wishes to preserve and promote biodiversity, EU agricultural policies need a fundamental overhaul to reverse the trend of agricultural species decline.

5.3 Role and application of agricultural and environmental legislation

Extensive regulations exist at international (Convention on Biological Diversity), EU (legislation on preserving species and habitat)[183] and national levels (German legislation on conservation, soil protection, fertilisation and plant protection products)[184] to support the preservation of biodiversity. These regulations also apply to farms that impact biodiversity on both their farmland and in the surrounding landscape.

The agricultural sector enjoys considerable latitude under nature conservation and soil protection legislation

Whether the land or the species living on it are subject to special protection determines which provisions apply regarding biodiversity on agricultural land. If no special protection status applies (e.g. habitat protection[185]) then only the rules on best practice apply. The best practice requirements under fertilisation[186] and plant protection legislation[187] are binding and, in part, very specific, meaning they can be effectively enforced by the authorities in individual cases. In contrast, the best practice principles under the Federal Soil Protection Act[188] and Nature Conservation Act[189] are less specific and only serve as agricultural directives.[190] Moreover, the impact regulation under nature protection legislation does not apply to agricultural measures for everyday farming methods, meaning that the agricultural sector enjoys considerable latitude under nature conservation and soil protection legislation. Where the requirements for best practice differ between fertilisation and plant protection legislation, on the one hand, and nature conservation and soil protection legislation, on the other, is in the fact that the former primarily serve to implement EU law.[191]

Deficits in legal practice

Although regulations on best practices under fertilisation and plant protection legislation are drafted with more specific provisions, there are still deficiencies in their enforcement. This is due to the number and size of farms and farmland, the authorities'

182 Weingarten et al. (2015); Zinngrebe et al. (2017); Schüler et al. (2018).

183 Directive (EU) 2009/147/EC of 30 November 2009 on the conservation of wild birds, OJ L 20 of 26/01/2010, P. 7; Habitats Directive (92/43/EEC) (Note 5).

184 German Federal Nature Conservation Act (BNatSchG), Federal Soil Protection Act (BBodSchG), Fertiliser Ordinance (DüV), Fertiliser Authorisation Ordinance (DüMV), Plant Protection Act (PflSchG).

185 Section 31 ff. BNatSchG.

186 Section 1(1) subparagraph 1 in conjunction with Section 3 ff. DüV.

187 Section 3(1) sentence 2 PflSchG.

188 Section 17(2) BBodSchG.

189 Section 5 BNatSchG.

190 German Federal Administrative Court judgement of 01/09/2016 – 4 C 4.15, decision 156, 94 ff. margin number 17 ff. In land law, the non-binding nature follows from Section 17(1) BBodSchG. Cf. Section 14(2) sentence 1 BNatSchG; German Federal Administrative Court judgement of 13/04/1983 – 4 C 76.80, MDR 1984, 516 f.; German Federal Constitutional Court ruling of 1988 – 4 B 55.88, NVwZ-RR 1989, 179 f.; German Federal Administrative Court order of 26/02/1992 – 4 B 38.92; order of 04/06/2003 – 4 BN 27.03, NVwZ-RR 1992, 467 f.; German parliamentary paper 13/6441, p. 51; Prall (2016); Gellermann (2019).

191 Such as the Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources, OJ L 375 of 31/12/1991, p. 1 and the Directive (EU) 2009/128/EC of 21/10/2009 establishing a framework for Community action to achieve the sustainable use of pesticides, OJ L 309 of 24/11/2009, p. 7.

lack of capacity and the transfer of auditing responsibilities to chambers of agriculture (Landwirtschaftskammer).[192]

In some cases, land management regulations also consider the protection of the surrounding landscape. For example, fertilisation and crop protection measures arising from the Fertiliser Ordinance (Düngeverordnung) and Plant Protection Act (Pflanzenschutzgesetz) must be implemented within set distances from bodies of water, while pest management measures must be implemented away from other useful systems, habitats and conservation areas. However, not all bodies of water (e.g. small ones) are included in the Fertiliser Ordinance and the Plant Protection Act, resulting in a gap in protection.

Agricultural land and conservation areas overlap extensively in places. For example, there are over 125,000 hectares of arable land and almost 16,000 hectares of orchards and vineyards within "fauna, flora and habitat conservation areas" (FFH areas[193]). Parts of these agricultural lands are designated as nature reserves.[194] If a farm's land lies within one of these conservation areas, the farm is subject to particular requirements under conservation and water legislation and specific regulations for nature reserves. However, many of these regulations[195] do permit farming to be carried out with fertilisers and plant protection products within the conservation areas and virtually without restrictions.[196] Nevertheless, an area granted conservation status usually comes with production limits and a reduced land resale value. Experiences from Saxony show that agricultural businesses are prepared to implement the Natura 2000 measures if their implementation is voluntary and combined with suitable agri-environment-climate measures from the second pillar.[197]

Although there are legal provisions to promote biodiversity-friendly farming, these have not yet gone far enough to preserve agricultural biodiversity effectively. Firstly, many regulations are not binding (they only require consideration, "Beachtenspflicht") and lack explicit terms, making it difficult for farms to observe them in practice. Additionally, authorities are not enforcing the regulations, meaning that the responsible regulatory bodies are not sufficiently monitoring compliance, and any breaches of the regulations are rarely or inadequately sanctioned.

5.4 Role of the market economy

Market processes are a decisive influence on agricultural production in Germany. Production decisions in many market segments react to international prices for goods and production-critical resources.

192 Möckel et al. (2014), p. 280 ff; Möckel (2015) suggests introducing provisions for the right to withdraw permission together with obligations requiring operators to tackle the deficiencies in enforcing regulations as these measures would entail audit requirements.

193 According to the decision by the EU (1992), FFH areas, which protect habitats and species, should form a European network of protected areas (Natura 2000) together with bird conservation areas.

194 Brühl (2018).

195 The insect protection action programme proposes banning plant protection products and reducing fertilisation, BMU (2019).

196 German Federal Administrative Court judgement of 06/11/2012 – 9 A 17.11, decision 145, 40 ff. margin number 89 on Agriculture and Natura 2000 areas; Möckel et al. (2014), p. 306 ff.

197 Lakner et al. (2020).

Biodiversity as an externality

Biodiversity is considered a public good in this context and is not assigned a market value. Protecting biodiversity is therefore immaterial to a market centred around supply and demand and has not yet been factored in. For example, solutions for the reconciliation of conflicts arising from food production versus preserving biodiversity do not make provisions for the latter. The decline in biodiversity caused by agricultural production is considered an "externality" from an economic perspective.

Externalities and biodiversity

In economic theory, externalities are the effects of an economic activity that are not incurred as part of the contractual transaction but are instead incurred by third parties (either by other economic stakeholders or by society as a whole). A distinction is made between positive effects, which create external benefits, and negative effects, which generate costs. An example of the costs of agricultural production may be nitrogen compounds leaching into the groundwater or pesticide drift. On the other hand, farmland that provides flowers for bees or nest habitats for birds, for example, can be perceived as a positive externality of agriculture.

One characteristic of agriculture-related externalities is that they are nebulous, making them difficult to measure. This means that it is challenging for farms to determine whether their own activities are creating externalities. This is especially the case where biodiversity is concerned and it would be necessary to identify changes in bird and insect populations. However, if we assume that we know what the externalities of farming are, farms would need to accept the additional costs to minimise negative impacts on third parties (e.g. nitrates leached into groundwater) or enhance positive impacts (e.g. greater biodiversity) at farm level.

Externalities occur due to a lack of, or vague, regulatory conditions, as well as insufficient compliance with directives, laws and controls. They are a basic characteristic of many environmental problems. Ultimately, externalities are passed on to all citizens.[198] One example of this is the introduction of a fourth treatment stage in waste water treatment plants to minimise the amount of pesticide pollution in waste water as a result from farming.[199]

There are various measures to internalise externalities, including regulatory change and economic incentives (such as directing agricultural subsidies towards ecosystem services and biodiversity). However, to complicate matters, when such measures exist, they are often not consistently implemented or sufficiently deployed.

There have now been several scientific studies to assess the total external costs and benefits of biodiversity. One study estimated that the value of animal-based pollination services amounted to EUR 154 billion[200], while a meta-analysis of 53 studies estimated the total value of aggregated pollination services at USD 3,250 per hectare.[201]

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198 Bourguet and Guillemaud (2016); Pretty et al. (2018).
199 UBA (2015).
200 Gallai et al. (2009); Lautenbach et al. (2012).
201 Kleijn et al. (2015).

Increased appreciation of biodiversity-friendly products

Market-based instruments can be used to give agricultural stakeholders as much decision-making freedom as possible and incorporate agricultural externalities in market processes (see chapter 4 and the "Externalities and biodiversity" box). Another market-compatible approach to improve agricultural biodiversity protection is to raise public awareness about agricultural products produced using biodiversity-friendly methods (e.g. organic farming, minimal pesticide use, such as integrated pest management, and conserving/supporting field margin structures[202]). In a 2018 environmental awareness survey, 68% of respondents said that they thought environmental protection needed to be prioritised in the agricultural sector, while 65% considered the decline in species richness among flora and fauna a major issue for domestic farming.[203] Both results suggest that citizens – who are also consumers – are interested in biodiversity-friendly farming. This raises the question as to how far these inclinations are reflected in supply and demand on the market and an increased willingness of consumers to pay for biodiversity-friendly food produced on such farms.

By paying a higher price for these products, consumers are effectively paying for any extra costs incurred in producing goods in biodiversity-friendly conditions and, at the same time, for the additional ecological value of these products. This in turn enables farms to use farming methods that support biodiversity. A study looking at Germany and Canada estimates that the potential market share for this kind of sustainable consumption is 20%. It is estimated that this could increase by another 10–20% using targeted marketing and information campaigns about sustainable consumption.[204] However, the opportunity to address externalities with consumer behaviour is limited, since biodiversity is a public commodity. Therefore, there is an incentive for consumers to "free ride", which reduces the willingness to pay. Consequently, political intervention is required to internalise externalities.

5.5 Role of civil society

Biodiversity has been widely studied in scientific research and the protection of biological diversity discussed at all political levels. Species decline has long been a key issue for those citizens who are, for the most part, voluntarily involved in efforts to protect species and the environment. The continuing decline of biodiversity has only gained greater attention in society and the media since the end of 2017 with the publication of the Krefeld study. From then on, public awareness has noticeably grown around the issue of insect decline in many areas of Germany, including nature reserves. The public have also gained a greater understanding of the many consequences that this decline entails for agricultural ecology and our way of life. A public petition in Bavaria calling for action to "save the bees" garnered around 1.8 million signatures, impressively demonstrating the increased level of attention that such issues are receiving from citizens. This and similar initiatives aim to create a biotope network, reduce the use of plant protection products, expand organic farming and improve protection to riverbanks, among other goals. A further aim is to have issues such as the declines in insect populations and species richness included in future agricultural training curricula.[205]

202 Holland et al. (2016).

203 UBA (2018c).

204 Peschel et al. (2016).

205 Deutsches Bienenjournal [German Bee Journal] (2019).

Increasing demand for organic products

Society's interest is also reflected in an increasing demand for organic products, whereby – for varying reasons – consumers accept paying a higher price for such products. Organic products distributed through various channels grossed EUR 10.91 billion on the market in 2018. The largest contributors to this figure were food retailers and discount retailers, accounting for 59% of sales, followed by wholefood shops and farm shops with 27%. Other distribution channels, such as bakeries, butchers, weekly markets, direct sales from producers, subscription boxes and health food shops, account for the final 14%.[206] The fact that consumers are buying more locally and organically farmed produce can certainly be considered an effort on the part of society to counter the loss of biodiversity. Organic food is more expensive, as clearly shown by the sales figures, with organic wheat costing around 150% more on average compared to non-organic varieties,[207] and organic milk costing around 50% more.[208] Studies on consumer preferences reveal that shoppers buying organic produce all have different motives. Environmental benefits are just one of the main reasons besides health, taste, shopping experience and lifestyle.[209] Consumers who buy organic produce often expect other ethical criteria to be met, such as ensuring animal welfare, setting fair prices, being locally produced and even preserving and promoting biodiversity.[210]

However, different social groups have markedly different levels of awareness about biodiversity.[211] For example, social groups with advanced educational attainment (incl. students) and a net monthly household income of EUR 3,500 or more have a greater awareness of this topic.[212]

5.6 Role of science

For decades, scientific studies have highlighted the risks to biodiversity from exploiting agricultural landscapes and have emphasised the need for protective measures to be developed. They have documented long-term shifts in the populations of species living in agricultural landscape and the causes of decline of specific species or species groups (chapter 4). There have been interdisciplinary and transdisciplinary projects that have developed, implemented and monitored biodiversity-supporting measures and then assessed their effectiveness.[213] We therefore have enough reliable research on the overall plight of agricultural biodiversity. However, there continues to be a disappointing lack of influence from these studies that would give the issue a greater profile in society,

206 BÖLW (2019).

207 EUR 170 vs 410 per tonne on average 2007–2018, cf. AMI (2019). It should be noted, however, that prices and the price ratio are subject to considerable fluctuations, see also Würriehausen et al. (2015).

208 The average price of milk is EUR 0.30 per kg for conventional milk and EUR 0.45 per kg for organic milk. However, these prices and the price ratio are also subject to considerable fluctuations (cf. AMI 2019).

209 Bruhn (2001); Hasselbach and Roosen (2015).

210 Zander and Hamm (2010); Stein-Bachinger and Gottwald (2016); Risius and Hamm (2017).

211 BMU and BfN (2015).

212 BMU and BfN (2015).

213 Examples of interdisciplinary projects: German Research Foundation (DFG) Collaborative Research Centre 299: land use options for peripheral regions; project funded by the German Federal Ministry of Education and Research (BMBF) – Bioplex: biodiversity and spatial complexity in agricultural landscapes under global change; joint project between the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety and the Federal Ministry of Food and Agriculture – F.R.A.N.Z. Transdisciplinary projects: Horizon 2020: Shared innovation space for sustainable productivity of grasslands in Europe Inno4Grass; DiverIMPACTS – Diversification through Rotation, Intercropping, Multiple Cropping, Promoted with Actors and value-Chains towards Sustainability; BMBF programme on agricultural systems of the future: innovative use of diverse grassland for a sustainable intensification of farming at the landscape scale, GreenGrass.

politics and agricultural practice. A key question then is: how can science have a more powerful impact in the public and political spheres?

Requirement for research into biodiversity losses and their reciprocal effects
There continue to be several gaps in knowledge about local trends in species richness and the consequences and specific causes of the decline in biodiversity, particularly regarding the complex interactions between crops, pesticides, fertilisation and structural diversity of agricultural landscapes. There is also a greater demand for more in-depth interdisciplinary and transdisciplinary research that develops, implements, monitors and evaluates measures to support biodiversity. There is a gap between research and practice when developing these measures, including the future scenarios that draw on current practice. This applies to both conservation and agriculture.[214]

Downsides to the increase in scientific specialisation
The failure to sufficiently translate research into practice is, on the one hand, due to structures beyond academia that prevent recommended actions from being adopted (wrong incentive schemes, power struggles, lack of resources, etc.). At the same time, though, academic structures themselves can be a contributing factor. As a result of increasingly specialised academic research, the range of disciplines in universities is changing, which is why professorships for biological systematics and taxonomy or for agricultural and forest ecology are disappearing.[215] In addition, local research institutes are closing. Consequently, there is often a lack of systematic research approaches and well-founded, application-oriented research within and outside of higher education institutions. For example, there have been extraordinarily few studies so far to investigate biodiversity and agricultural productivity at the same location in one consistent experiment.[216] The German Research Foundation (DFG) Senate Commission on Agroecosystem Research has suggested setting up a network of agronomic testing facilities to enable researchers to investigate productivity, resilience and resource efficiency in specific landscapes as part of an interdisciplinary approach.[217] This much-needed network of test fields would also have to take into account landscape structure and avoid focusing solely on measures to be implemented directly on farmland.

Practical agroecological research
Moreover, there is still a need for comprehensive, interdisciplinary and practical agricultural research on sustainable farming methods that is designed to be participatory and aims to further develop organic farming as well as sustainable concepts for integrated farming. This kind of agroecological research exists in the USA and now in France too, aiming to translate agroecological knowledge from scientific theory into practice so that conventional and integrated farming systems can be made more sustainable.[218] Germany in particular is lacking transdisciplinary research involving groups of stakeholders, farming decision-makers, local policy-makers and civil society.

There also still exists, or once again can be seen, a lack of exchange between academic research and teaching and practical training. That is to say, the latest research is not integrated into courses at universities of applied sciences or agricultural technical

214 e.g. Braunisch et al. (2012).
215 German National Academy of Sciences Leopoldina (2014).
216 1% of all studies synthesised in the meta-analysis by Beckmann et al. (2019).
217 Stützel et al. (2014).
218 Wezel (2017); FAO (2019).

schools, for example, and as a result, it is not integrated into official administrative practice (e.g. local conservation agencies or chambers of agriculture). This would in turn provide advisory services for farms or development measures and management plans for Natura 2000. Last but not least, higher education and research institutes as well as the public sector need more staff and financial support; their lack of resources indicates that there is still a failure to take the issue into consideration in politics and society.

6. Courses of action

6.1 Guiding principles and main courses of action

The possible courses of action described below clarify the role of the state in protecting basic natural resources out of a responsibility to future generations (Article 20a Basic Law for the Federal Republic of Germany, GG). European Union (EU) legislation also stipulates a similar obligation (Article 37 of the EU Charter of Fundamental Rights, CFR)[219]. The guiding principles of this statement are based on the goals of the Convention on Biological Diversity (CBD), the German Federal Nature Conservation Act (BNatSchG), the EU Biodiversity Strategy, the National Biodiversity Strategy (NBS) adopted by the German Federal Cabinet in 2007, Germany's 2018 National Sustainable Development Strategy and the 2020 conservation campaign run by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). All these legal frameworks and initiatives stipulate that the decline in agricultural biodiversity (including species populations and biomass) needs to be stopped with a reversal of current trends. The purpose of this statement is, therefore, to highlight courses of action that could be taken to preserve and promote agricultural biodiversity. This applies to both biodiversity on farmland and within the wider agricultural landscape (including structural features such as hedgerows, field margins and fallow land). However, no recommended actions for specific species, species communities and frequencies have been given, as such detailed objectives would need to be drawn up locally.

Urgent need for action
The decline in agricultural biodiversity is so dramatic that researchers predict serious knock-on effects for the functionality of agricultural ecosystems and for human well-being in the future. Immediate and effective action is therefore required.

We need multiple solutions
There are numerous possible measures that can be taken to preserve and promote agricultural biodiversity. However, biodiversity can only be sustainably protected if there is a fundamental societal change, which is why measures should not just involve farms and look at agricultural and environmental policies and legislation. Instead they need to consider education, values, trade, markets, consumer behaviour and academia as well. Since the causes and consequences of biodiversity loss are complex and affect many different levels of decision-making and action, it is necessary to take many different measures and implement them in parallel. It would be neither sufficient, feasible or fair to demand change solely from farmers. Instead, given the scale of the current challenges and the need to act quickly, a change at every level is required. This means that both agricultural and environmental policies and legislation should be updated as soon as possible, and that

219 Art. 37 of the CFR states: "A high level of environmental protection and the improvement of the quality of the environment must be integrated into the policies of the European Union and ensured in accordance with the principle of sustainable development".

farms, the education system, trade, markets, consumer behaviour and academia, as well as general understanding, and thus values, need to adapt in line with a sustainable biodiversity strategy. With a combination of the measures suggested, it is possible to halt and reverse the decline in agricultural biodiversity. Many populations can recover and species which have vanished at a local or regional level can return from neighbouring areas.

6.2 Agricultural and environmental protection policies at German and European level

Biodiversity-friendly farming can and must also be economically viable. This urgently requires the EU Common Agricultural Policy (CAP) to be reformed fundamentally so that effective measures to protect biodiversity can be fully funded. The pending 2020 CAP reform to cover the period 2021–2027 presents an opportunity to achieve this.[220] An environment-oriented CAP should make greater use of financial instruments to reward farms for their efforts to preserve biodiversity with adequate payments.[221] Such instruments would require more specific quantitative criteria that ensure improvements to species richness and regular biodiversity monitoring. The opportunities to shape policy at national level and as part of the CAP[222] present the most effective tools to support agricultural biodiversity regarding both the extent of the areas affected and the scale of the impacts. We therefore recommend taking the following measures – which have not yet been considered in the European Commission's draft for a reform of the CAP in this form [223] – as a matter of priority.

Coupling support with benefits for biodiversity and coupling funding in the first pillar of the CAP with impacts on biodiversity and the environment

As part of the 2020 proposed CAP reform, direct payments within the first pillar should be directly coupled with the benefits of land use for biodiversity and the environment. Tiered basic funding focused on the services provided by farms for the common good (e.g. as part of eco-schemes[224]) would be particularly suitable in this context as it could create incentives for more effective measures to protect biodiversity and promote a more varied landscape structure.[225]

Gradually phasing out decoupled direct payments

Over the next few years and decades, several environmental objectives (e.g. stemming biodiversity loss) may create considerable demand for more financial support as part

220 Pe'er et al. (2017, 2019); WBAE (2018a).

221 Pe'er et al. (2019).

222 Whether Article 43(2) TFEU can still underpin the kind of paradigm shift called for here, i.e. transforming the CAP into a new form of climate and environmental policy for the agricultural sector, still needs to be examined, according to Mögele (2019). Article 11 TFEU does, however, support this, stipulating that the CAP must fulfil environmental objectives alongside its agriculture-related requirements and that Article 39 TFEU is to be understood as an indirect legal framework for environmental policy, Kahl/Gärditz (2019).

223 Proposal for a Regulation of the European Parliament and of the Council, establishing rules on support for strategic plans to be drawn up by Member States under the Common agricultural policy (CAP Strategic Plans), COM (2018), 392 final, available at: https://ec.europa.eu/transparency/regdoc/rep/1/2018/DE/COM-2018-392-F1-DE-MAIN-PART-1.PDF; Proposal for a Regulation of the European Parliament and of the Council on the financing, management and monitoring of the common agricultural policy, COM (2018), 393 final, available at: https://ec.europa.eu/transparency/regdoc/rep/1/2018/DE/COM-2018-393-F1-DE-MAIN-PART-1.PDF; Proposal for a Regulation of the European Parliament and of the Council establishing a common organisation of the markets in agricultural products (Single CMO Regulation), COM (2018), 394 final/2, available at: https://ec.europa.eu/transparency/regdoc/rep/1/2018/DE/COM-2018-394-F2-DE-MAIN-PART-1.PDF.

224 Dupraz and Guyomard (2019); European Commission (2019).

225 Neumann et al. (2017).

of agricultural funding. By contrast, current decoupled direct payments are difficult to justify based on science or policy objectives.[226] Moreover, they only partly fulfil their purpose as they only fund land rents and not farming, having negative knock-on effects, such as distorting land markets.[227] Gradually phasing out the direct payments system is necessary for suitable biodiversity preservation programmes to be funded. It is vital that in doing so, political stakeholders quickly initiate a public dialogue on the objectives of agricultural policy and demonstrate to farms that there would be a secure planning horizon for when the direct payments expire.

Expanding and fleshing out agri-environment-climate measures
Agri-environment-climate measures from the second pillar of the CAP, which scientists recommend restructuring and expanding,[228] also provide multiple starting points for developing effective action to protect biodiversity. One particularly strong recommendation is to run agri-environmental programmes as promising regional portfolios, focusing on local models and objectives for agricultural habitats and (indicator) species, unlike the largely arbitrary nature of the schemes to date. Connecting regions is key to developing and implementing such programmes (chapters 5.5 and 5.6).

Developing in-depth ("dark green") agri-environment-climate measures
In the context of agri-environmental schemes, a distinction is made between simple ("light green") measures, which usually reap small rewards, and targeted ("dark green") measures that are geared towards specific objectives, set high standards for farms and have high returns. Many studies have shown that dark green measures are the most effective in meeting biodiversity objectives.[229]

Adapting agri-environmental measures to align with EU habitat conservation (Natura 2000)
The European Commission infringement proceedings introduced at the start of 2020 against Germany for insufficiently following the FFH requirements highlight the need for action in the space where environmental protection and agricultural policies meet. The shortcomings that were raised could be addressed using agricultural policy mechanisms. To this end, agri-environmental-climate measures could be more closely aligned with the requirements of the Natura 2000 strategy and the real-world application of the Habitats Directive and the Birds Directive.[230] Aspects of the contract-based conservation programme ("Vertragsnaturschutzprogramm") are ideal for this, including a modular set-up that is flexible and enables stakeholders to develop extra targeted measures that complement its basic provisions. Moreover, an effective conservation policy needs to focus on voluntary participation, dialogue and targeted incentives as much as possible, only relying on legal mechanisms in reasonable and exceptional circumstances.

Developing and supporting organic farming
Measures supporting organic farming play a specific role in agri-environmental schemes as actions that apply to the entirety of an agricultural enterprise. Organic farms also have

226 Pe'er et al. (2019).
227 WBAE (2010, 2018b); Pe'er et al. (2019).
228 WBAE (2018b, 2019); Lakner et al. (2012); Pe'er et al. (2019).
229 Armsworth et al. (2012); Batáry et al. (2015); Oppermann et al. (2016).
230 Lakner and Kleinknecht (2013); Lakner et al. (2020).

extra potential to more intensively foster species richness. The continued development of existing integrated and organic farming concepts should be encouraged, meaning that there needs to be support for these kinds of farms that promote biodiversity. Such farms should be allowed to participate in "dark green" agri-environmental programmes with a greater degree of flexibility than at present. Furthermore, the market for organically grown produce, where farms can obtain a higher price on account of the farming method's environmental benefits, should be more effectively developed.[231] Support for organic farming therefore needs to be accompanied by schemes for artisanal food producers and the sale of organic products, such as in the catering industry. At the forefront of these actions is Bavaria's BioRegio Bayern 2020 programme, featuring its own model regions for organic farming.[232] Beyond organic farming, there should be more measures to support biodiversity in farms using integrated pest management, and these measures should be used to transform and further develop conventional cropping systems so that ecosystem services can be used in a targeted way as part of farming systems.[233]

Developing innovative funding schemes[234]
Innovative auction models,[235] result-oriented agri-environmental schemes[236] and collaborative approaches between hunters, beekeepers and municipalities may encourage farms to become more self-motivated to act and enable the funds that have been invested to be used more effectively.

Improving institutional cooperation on agricultural and environmental policies
Protecting biodiversity, and by extension the environment, is a cross-cutting issue that involves both agricultural and environmental policies. Previous experience has shown that there is a lack of cooperation between stakeholders in farming and those involved in environmental matters, as well as within government departments and the public sector, hindering the progress of efforts to preserve biodiversity. All these parties therefore need to cooperate more closely in the future, and agricultural and environmental policies need to be fully integrated to continue supporting biodiversity.

6.3 Agricultural and environmental legislation and its application

Adopting agricultural legislation and reinforcing regulatory instruments
In addition to using CAP funding as a means of indirectly regulating farming practices, the agricultural sector needs a new legal framework, namely an agriculture law. Drafting specific standards could ensure that even without subsidies, authorities are able to enforce and monitor environmental and conservation standards.[237] Care should be taken to ensure that the legislation has a manageable number of clearly written requirements so it is easy for farms to observe them. Legislators could consider laying down an obligation for farms to operate in an eco-friendly manner[238], which could replace the agricultural best practices obligation in soil protection and nature conservation legis-

231 Zander and Hamm (2010).
232 Sadler et al. (2018).
233 Poux and Aubert (2018).
234 WBAE (2019); Pe'er et al. (2019).
235 Schilizzi and Latacz-Lohmann (2012); Iftekhar and Latacz-Lohmann (2017).
236 Lakner and Kleinknecht (2013); Lakner et al. (2013).
237 Möckel et al. (2014); Köck (2018).
238 Leipzig declaration by the Deutscher Naturschutzrechtstag e.V. [German alliance on nature conservation law] (2018).

lation as it is largely ignored and consequently ineffective. The legislation should also include a location-specific limit to the stocking density of animals per hectare and an obligation to seek advice from public authorities on how to operate in an eco-friendly manner[239]. This could include powers to ban certain agricultural activities (reserving the option to grant permission) so as to help preserve permanent grassland.[240]

Neither Germany nor the EU currently has an agricultural act of this kind. Both the fact that no EU-wide majority would be required to make reforms to the German agricultural policy – which remains largely unchanged since its inception in 1955 when its aim was food security – and the fact that German legislators could use CAP aid to draw up more stringent requirements for agri-environmental-climateschemes, work in favour of carrying out a root-and-branch reform of said agricultural legislation. However, further investigation is needed to determine whether German legislators can use concurrent legislative powers (Article 74(1) points 17 and 20 GG) as a basis for all the measures detailed above.[241]

EU-wide legislation for a more advanced regulatory climate and environmental policy in the agricultural sector, linking to farms where applicable, would harmonise regulations, thereby preventing any competitive disadvantages for German farms or unfair competition on the EU agricultural market. There also needs to be clarification regarding EU legislative powers in this domain.[242]

Considering the impact of plant protection products on biodiversity when approving their use

Approval processes for plant protection products need to test how a commercial product's active substances, their by-products, and other chemicals in its formula interact with other products (combination effect) and how this impacts the life, behaviour and fertility of non-target organisms, examining the risks to the food chain and the risk of the substances leaching into neighbouring land or waters.[243] The process should also check whether plant protection products can be used in such a way that damage to the environment is limited as much as possible.

Protecting conservation areas more effectively and giving more consideration to lateral effects of farming on conservation areas

Based on our current knowledge of pesticides, spreading plant protection products – even using best agricultural practice – can have numerous indirect and sublethal effects on insects, conflicting with the aim of protecting biodiversity. Feasible plans need to be made to gradually reduce the use of pesticides in conservation areas or ban their use altogether. Specific chemical plant protection products and fertilisers may only then be used if they are vital to protecting conservation areas. In exchange, farms operating in conservation areas should receive long-term, sustainable compensation to make up for the loss of yields caused by the change in growing conditions, enabling them to continue as going concerns.

239 Möckel et al. (2014).

240 Köck (2019).

241 Rehbinder (2019) considers Article 20(1) points 17 and 20 GG adequate to use as a basis for major measures.

242 It is unlikely that Article 43(2) TFEU will be sufficient; such legal provisions need to be based on environmental policy procedures of the EU in Article 192(1) TFEU.

243 For more details, see German National Academy of Sciences Leopoldina (2018) and the Scientific Advisory Board of the National Action Plan (2019).

Since spreading plant protection and fertiliser products can impact neighbouring areas, adequately sized buffer zones need to be established and the use of products next to conservation areas regulated to ensure biodiversity in such areas is not harmed. Achieving this requires a uniform set of rules on land use within conservation areas and surrounding land together with the creation of buffer zones and corridors for biotope networks around conservation areas.

Successfully eliminating gaps in the enforcement of environmental regulations
Protecting biodiversity, e.g. by preventing lateral effects on conservation areas, is consistent with agricultural best practices as enshrined in soil protection and nature conservation legislation. However, these legislative acts do not sufficiently define what agricultural best practices are in robust terms. Fleshing out these concepts would make the subsequent obligations for farms clearer, enabling supervisory authorities to monitor compliance and sanction any breaches. An example of inadequate enforcement of regulations at municipal and rural district level is when farms frequently and illegally repurpose public strips of grassland along paths or bodies of water for agricultural use (see the "'Eh da' initiative" box), and authorities do not sanction them.[244] Even though fertilisation and plant protection legislation contain more specific definitions of best agricultural practices, authorities are still failing to enforce them. As a result, there are very few sanctions for violating the Fertiliser Ordinance and Plant Protection Act. These gaps in enforcement stem from the size of the farms and their fields, the authorities' lack of capacity and the transfer of auditing responsibilities to chambers of agriculture, who are not sufficiently independent from the farms that they are meant to monitor.[245]

A combination of different measures can eliminate these deficiencies. Firstly, more specific quantitative criteria for improving species richness are required, as well as regular inspections to monitor such richness (chapter 6.9). Secondly, independent supervisory authorities need more staff and financial resources together with targeted, risk-based audits. EU agricultural aid could provide the funding for this.

6.4 Landscape planning

Landscape planning methods and tools should be used more for agricultural landscapes and integrated into technical agricultural planning, encouraging collaboration and creating synergies
Action taken at landscape level can focus on measures that play a key role in supporting biodiversity in the landscape, such as preserving and supporting structural features (e.g. hedgerows, copses and ponds). Two good examples of tools that help achieve these objectives are: landscape development concepts at regional level[246], taking into account the different protected species and habitats and their recovery; and a programme to protect species and biotopes[247] at rural district level. Action plans for target species and agricultural landscapes can be developed from existing data, tools and findings from conservation-based landscape plans. They should then be expanded to encompass ag-

244 Rennebaum (2015).
245 Möckel et al. (2014).
246 Bayerisches Landesamt für Umweltschutz [Bavarian State Office for Environmental Protection] (2003).
247 Bayerisches Landesamt für Umwelt [Bavarian State Office for the Environment] (2018).

ricultural landscapes, broadening the scope from indicator species to biodiversity as a whole while synchronously factoring in farming interests.

The work of voluntary organisations to support species richness should receive public backing

It is crucial that regional stakeholders take joint responsibility to achieve the goals of conserving agricultural environments. Countryside management associations play a central role in balancing the interests of different parties and implementing measures to support biodiversity on site in a practical way. What makes them successful is that conservation associations, farms and local politicians all sit on their boards with equal representation. This helps create mutual trust and understanding, which makes implementing the measures effective. Similarly, agricultural and non-agricultural stakeholders also work together in municipal associations, communal associations ("Realverband"), countryside interest groups and on water boards.

With a tailored regional, collective approach, species diversity in agricultural landscapes can be extensively, reliably and efficiently stabilised and can increase again.

6.5 Municipalities

Municipalities should take more advantage of the options available to preserve species richness

There are possible courses of action to take at municipal level, such as using communally owned land to protect and support biodiversity (see the "'Eh da' initiative" box). Many municipalities are already taking the lead in protecting and supporting species richness, and they are linking up with one another so that they can share their experiences, for example the "Kommunen für die biologische Vielfalt"[248] alliance (municipalities for biodiversity). They also include "pesticide-free municipalities"[249] that manage their green spaces without using chemical plant protection products and reduce the amount of times that green spaces and grass verges are mowed. Although there are relatively limited opportunities for municipalities to impact biodiversity on their land, they play an extremely important role as opinion-makers, helping to change values and communicate and educate others about the actions they are taking. There are also a multitude of ways that municipalities can help support urban green spaces, especially in towns and cities where such spaces are the only places people can experience nature on a daily basis. Setting biodiversity standards in urban and rural areas, for example by banning crop or plant protection products in public and private spaces, could raise more awareness about the significance of biodiversity among citizens over time.

248 Kommunen für biologische Vielfalt e.V. [municipalities for biodiversity] (2019).
249 BUND (2019).

"Eh da" initiative

The "Eh da" initiative was created in 2012 to organise actions in spaces that were "already there" ("eh da" in German). The project focuses on open spaces in agricultural landscapes and built-up areas that are neither farmed nor maintained for conservation purposes.[250] These spaces are usually strips of land alongside roads, farmland and bodies of water, containing unused grass verges, fallow land and urban greenery, or more broadly, land which belongs to the municipality and is designated as "wasteland" on current maps. Around 2–6% of the agricultural landscape are "eh da" spaces, most of which are strips of grassland.[251] They are easy to identify using geospatial data queries and can help support biotope networks. The project relies on volunteers from local communities, and it gained recognition from the United Nations in 2018.[252] Local stakeholders can meet their community responsibility on "eh da" land, and at the same time it gives them a valuable tool for communicating and organising citizens' initiatives. Rhineland-Palatinate adopted the "eh da" spaces concept in 2015 as part of its biodiversity strategy.[253]

6.6 Trade, markets and consumers

Information about producing agricultural goods and how this impacts biodiversity needs to be made available to consumers so that they can make biodiversity-conscious purchase decisions

The market price of agricultural products should ideally reflect the external costs of production in relation to biodiversity (see the "Externalities and biodiversity" box in chapter 5.4). However, this assumes that such vague effects, which are largely difficult to quantify, can be given a monetary value, and there are few examples of this in practice at present. A more effective approach is therefore to provide consumers with information about how the product has been produced. This could include details about ingredients, a traffic light labelling system or labels of certification (e.g. the Bioland German organic food association, EU-certified organic label, etc.). The box on the "Farming for biodiversity" project details a good example of agricultural products that have been grown in biodiversity-friendly conditions and have been effectively certified and marketed as such. Measures to inform consumers benefit biodiversity indirectly, making it difficult to quantify exactly how effective they are. However, such measures are recommended as a matter of urgency since positive effects can at least be verified in principle, and these measures have considerable potential to be effective and highly sustainable.

250 Künast et al. (2019).

251 Künast et al. (2019).

252 United Nations Decade on Biodiversity (2018).

253 Minsterium für Umwelt Energie Ernährung und Forsten Rheinland-Pfalz [Rhineland-Palatinate Ministry for the Environment, Energy, Nutrition and Forestry] (2018).

Project: Farming for biodiversity

The “Farming for biodiversity” project has been testing a system for certifying conservation initiatives at organic farms in Brandenburg and Mecklenburg-Western Pomerania since 2016. The project aims to link conservation efforts to the market and was launched by several organisations in collaboration: the supermarket chain Edeka Nord, WWF Germany and the organic association Biopark. The project collects information about these initiatives and uses a label to publicise them for the benefit of supermarket shoppers. The project involves 62 Biopark farms in north-east Germany, covering a total of 40,000 hectares. Their conservation efforts are evaluated with a points-based system. Edeka Nord marks their products with the project’s label “Landwirtschaft für Artenvielfalt” (farming for biodiversity) and sells them at a higher price.[254] A scientific study accompanying the project found that species richness had improved on several farms as a consequence of the certification system.[255]

6.7 Agricultural practices

Farms should be given support with training and further education to learn how to move to a more nature-oriented farming model and reduce the use of plant protection products

Farms can receive specific guidance to help them preserve and support biodiversity on farmland and within the agricultural landscape (e.g. taking into account neighbouring conversation areas). There are currently a multitude of regional services providing individual farms with guidance on conservation and biodiversity, including guiding principles for such services,[256] and this guidance should be rolled out nationwide. Farms should acquire expertise in biodiversity matters as part of the procedure for obtaining the existing certificate of competence in plant protection. . It is also useful for everyone working in farming to obtain a specific biodiversity certificate, which could be integrated into the CAP cross-compliance rules.

Farms should receive support to convert to organic farming, or support to continue organic farming, since it has many environmental benefits. Even introducing an explicit extensification process as part of conventional farming methods (e.g. using specific “dark-green” agri-environment-climate schemes on arable land and grassland) can make a key contribution to protecting endangered species or biotopes in a targeted way. Species-rich and low-intensity grassland is particularly crucial to preserving biodiversity, which is why low-intensity livestock farming, including extensive grazing, plays a significant role in protecting the environment.

At the same time, the legal standard for integrated pest management (IPM) urgently needs to be put into practice nationwide. Biodiversity-friendly measures taken as part of IPM support beneficial organisms; both pests and beneficial organisms are recorded, and only after careful data collection and assessment are countermeasures then introduced. Although IPM has been enshrined in the Plant Protection Act since 1986,

254 Wolter (2017).
255 Gottwald and Stein-Bachinger (2018).
256 DVL (2018).

making it legally binding, it has not been fully established in farming practices and crop growing. The German National Action Plan on the Sustainable Use of Plant Protection Products needs to adopt measures to reduce the use of pesticides and make them legally binding. This should be accompanied by efforts to develop and test even more production methods for arable farming, horticulture and perennial agriculture that enable farmers to use fewer pesticides. These methods then need to be taught as part of training for farm workers.

Structural landscape features, such as hedgerows, dry stone walls and strips of nutrient-poor grasses and flowers, play a major role in supporting agricultural biodiversity at the landscape level. Farms, together with other stakeholders, can help protect these structural features, especially if community action involving these stakeholders is facilitated through municipal or communal associations, countryside interest groups or water boards.

Many farms have been committed to preserving biodiversity for several years, either through contractual nature conservation and countryside management or independently of established programmes on their land. This commitment calls for greater public awareness and recognition. Good examples of this are the "conservation partner in farming" competition (Naturschutzpartner Landwirt)[257] and the "Bavarian meadow management championships" (Bayerische Wiesenmeisterschaften).[258] These achievements and successful models ought to be communicated more to the public.

Overall, farms can make the biggest and most crucial contribution to promoting agricultural biodiversity, especially when working with other local stakeholders in the community. However, it is essential that policies and legislation, as well as markets and civil society, establish suitable frameworks to make it economically viable for farms to protect and promote biodiversity and make such measures workable in practice. Despite all the legal frameworks, each farm is an independent stakeholder that can play an important role in preserving biodiversity regardless of government guidelines and incentives.

6.8 Public awareness and appreciation of the issues

Biodiversity can only be protected in the long term if its significance for humans is understood throughout society and the responsibility for preserving and promoting biodiversity is accepted by society as a whole

Greater public awareness is required about the various benefits of biodiversity since people protect what they know and appreciate. There should be better communication about the complex relationships between intensive land use and low species diversity, on the one hand, and quality, food prices and consumer behaviour, on the other, while members of the public need to change their purchasing behaviour to help preserve and promote agricultural biodiversity. Top priorities in this respect should be consuming less meat (by foregoing intensively farmed livestock products), buying more food products that have been grown in biodiversity-friendly conditions and reducing food waste

257 Bayerische Akademie für Naturschutz und Landschaftspflege [The Bavarian Academy for Nature Conservation and Landscape Management].

258 Bayerische Landesanstalt für Landwirtschaft [Bavarian State Research Centre for Agriculture] (2016).

at home and in retail. It is only through making these changes that farming can become economically viable and biodiversity-friendly farmland can be developed and expanded (in response to the reduced productivity of such farmland).

Traditional methods and tools of science communication are one suitable way for helping put these recommendations into action. Showing the public how scientific research works through documentaries, open days and exhibitions in museums or public spaces, such as educational gardens, has proved successful in raising the profile of research. Specialists in research institutions could also receive media skills training. Journalists can access grants and writer-in-residence programmes for longer investigative trips to research institutes. There is also a demand for academic projects to research the discourse around biodiversity, which could be used to develop future communications strategies (e.g. meaningful stories, or narratives, to share).

Secondly, formats that encourage people to experience biodiversity directly are particularly important for getting the message across, for example excursions or joint experiments organised and led by farms and schools in demonstration gardens or on model farms. New participatory formats are especially important here, ranging from citizen science to communal actions to improve species richness in urban and agricultural landscapes. The successful "butterfly meadows" project in Saxony is a good example of this. This project was born out of a collaboration between academia, conservation associations, municipalities and civil society and involves citizens in helping to create and maintain meadows filled with different flower and insect species.[259] Other successful projects include initiatives to set up urban apiaries and gardens worked on jointly by citizens, conservation organisations and academic institutes.[260]

Many different ideas have come to fruition in universities, museums, schools and at academies for nature conservation, including participatory research formats (see the "Research as collaboration between scientists and farming experts" box). Nevertheless, these kinds of actions and efforts by teachers, practitioners, journalists and citizens need to be linked up even more closely than they already have been. Public and private educational establishments are called upon to devise these new formats and organise the necessary resources to implement them, with joint funding from the Federal Government, federal states, municipalities and private institutes or foundations. Ultimately it requires school and training curricula to include hands-on activities around wildlife conservation and horticultural issues so that young people can learn about how species conservation and food production interact, embedding an appreciation for biodiversity-friendly farming in society from an early age.

Considered as a whole, these initiatives to support agricultural biodiversity have a relatively indirect impact and need time to come to fruition. Nevertheless, they target deep leverage points in the agricultural system,[261] i.e. if they take expertise, knowledge, values, attitudes and behaviours as starting points, they can bring about fundamental change and thus make a major contribution to sustainable transformation in society. The measures presented here are ultimately connected to an overarching debate in so-

259 Sächsische Landesstiftung Natur und Umwelt [Saxony State Foundation for Nature and the Environment] et al. (2014).

260 Hemmer and Hölzer (2013).

261 Fischer and Riechers (2019).

ciety about values – for example, a debate on living well or on sufficiency in terms of what do we really need?[262]

6.9 Monitoring and research

We urgently require long-term, nationwide and standardised monitoring of biodiversity to be able to document changes for a broad and representative range of species and habitats. Furthermore, we need to have the ability to monitor the effectiveness of measures for protecting biodiversity[263]

Monitoring schemes that collect data on biodiversity need to set clear objectives. As with bird and high nature value farmland monitoring schemes, extra components within such schemes should be designed in such a way that they produce reliable statistics that can be used to draw conclusions about population trends for individual species and changes within particular habitats. Monitoring biodiversity should also help produce sound preliminary evidence for the causes of these trends. Furthermore, in-depth root cause analyses and specific performance monitoring schemes are required to evaluate measures and funding programmes. However, since reliable data cannot be obtained through nationwide, sample-based monitoring for many rare or cryptic species, or species that only appear in specific areas, other initiatives to record and evaluate data on biodiversity need to continue and be further developed, such as the Red Lists and species-specific monitoring programmes.

Research as collaboration between scientists and farming experts

The last 20 years has seen an increasing number of cooperative and participatory formats used in scientific research.[264] This approach applies the findings from new knowledge research which states that producing relevant knowledge is not the sole preserve of academia; instead this knowledge is generated collectively in different areas of society.

The theoretical and practical expertise of different people working in the field[265] proves to be extremely pertinent, especially with regard to protecting biodiversity. Researchers in cultural studies, social sciences, agricultural sciences and natural sciences are encouraged to establish innovative interdisciplinary and participatory research projects with these non-academic stakeholders. This not only incorporates social needs into the research from the start, but it also makes the research more practice-oriented and sustainable.

262 Meisch et al. (2018); Pissarskoi et al. (2018).
263 Geschke et al. (2019).
264 Criado and Estalella (2018).
265 Polanyi (1966); Barth (2002); Collins (2010).

The main issues are:

- Taking into account species or species groups representing a broad spectrum of biodiversity and ecological functions, including groups where little is currently known about population trends or groups that play a significant role in how ecosystems function (e.g. soil organisms).

- Collecting data about ecological functions so that the decline in species or species groups can be linked to their ecological functions.

- Habitat monitoring should collect representative, qualitative and quantitative habitat data; the high nature value farmland monitoring method is a good model for this.[266]

- Adaptability when accounting for new issues and influencing factors that may impact biodiversity (e.g. using genetically modified organisms, adapting to change in land use and changing the focus of the CAP). To be agile, programmes monitoring general trends need to be supplemented with other approaches that focus on specific issues.

- Expanding monitoring programmes with extra components to continue the current range of monitoring activities and involve various associations, professional organisations and citizens in these activities. This enables systematic core monitoring to be extended to cover more taxa and whole areas in shorter time periods.

- Recording data on the main causes (e.g. pesticides, fertilisers, land use and landscape structure) using the same spatial and chronological scales as when monitoring biodiversity.

- Adding targeted, experimental tests and studies on single or multiple factors and their impacts on biodiversity (e.g. fertilisation) on different scales: laboratory, field test and, where possible, the whole landscape.

- Adding targeted and customised performance monitoring activities when implementing measures to increase biodiversity (e.g. flower strips).

- There is also enormous potential for gathering, reviewing, digitising and analysing existing data on past biodiversity trends from varied data sources (retrospective data analysis).

- It should be ensured that all aspects of biodiversity monitoring are devised based on sound science and that data collection and evaluation are subject to quality assurance controls.

- Various academic institutions, relevant government departments (including the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, the Federal Ministry of Food and Agriculture and the Federal Ministry of Education and Research) and competent state authorities need to work together closely to ensure that biodiversity monitoring programmes are successfully set up and run.

266 Benzler (2009); Benzler et al. (2015).

- The federal states' monitoring data on biodiversity should be made widely available to everyone. This requires legislative changes.

Research: in view of the complex connections between humans, land use and agricultural biodiversity, sustainable development research needs to harness interdisciplinary and transdisciplinary collaboration, take into account any local particularities and make use of the knowledge of those working in the field.

At present, the urgent research questions appear to be:

- **What are the consequences of losing biodiversity for agricultural ecosystems and humans?** Although there is already a great deal of evidence in this area, research is still needed to examine the role of biodiversity in the function of agricultural ecosystems, particularly with regard to species groups where there has been little investigation, such as soil organisms. As agricultural biodiversity is given values in relation to humans, research needs to focus in particular on the relational and intrinsic values of biodiversity.

- **How do the specific causes of agricultural biodiversity loss work together** (e.g. loss of structural diversity in the landscape; use of plant protection products; use of fertilisers; use of chemical and/or organic pest management methods) **and how do they interact?** How do specific causes affect specific species groups? To answer this question, we need a better understanding of the system at the agricultural landscape level.

- **How do the different components of biodiversity and their ecosystem services interact with one another in the first instance, and how do they interact with specific land use and the needs and values of different social groups?** To answer this question, we need to develop systematic and interdisciplinary research approaches, including interdisciplinary cooperation between ecology, agricultural science, social sciences and cultural studies.

- **How can trade, markets, civil society and conservation and agricultural policies help stem the loss of agricultural biodiversity and reverse the trend, supporting biodiversity in agricultural landscapes?** These questions examine the macrosocial contexts of farming and look at the possible courses of action to take at federal and state level; as yet, they have not been sufficiently explored. Here too, systematic, interdisciplinary and transdisciplinary research approaches are required, for example to consider the interaction between economic and regulatory incentives and psychological factors.

- **How can biodiversity issues be sustainably linked to digitalisation?** Digitalisation in farming offers enormous potential to help preserve and support biodiversity (e.g. in growing crops, pest management and marketing). To make this sustainable, farms need to consider technological capabilities, economic impacts and social acceptance.

- **What future farming scenarios can we envisage and which of these are feasible?** How willing are various social groups to make the necessary organisational and financial changes to bring these scenarios to fruition? Future farming scenarios need to be developed using interdisciplinary and transdisciplinary methods, allowing political and social decisions to be made on the basis of these scenarios. These scenarios should focus on the pros and cons of the different "futures" and show how they can be achieved in practice. This requires researchers to forecast the different scenarios (if-then analyses), such as simulating the different impacts of climate change and land use changes (e.g. as a result of new CAP programmes) and then predicting their consequences.

- **How can we develop feasible biodiversity-friendly measures to be implemented in agricultural practices?** This requires developing application-oriented, transdisciplinary research methods with a solid scientific grounding that can help devise, implement, monitor and evaluate various measures to support and harness agricultural biodiversity. It is particularly crucial to involve decision-makers from farming, municipalities and civil society (e.g. what is the scope for action at an operational level, and how can local knowledge bases be incorporated?).

- **Does implementing different measures increase agricultural biodiversity, and if so, how?** This requires performance monitoring to examine the effectiveness and sustainability of the measures devised (including CAP-related measures).

Members of the working group

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Bibliography

Alons, G. 2017. Environmental policy integration in the EU's common agricultural policy: Greening or greenwashing? *Journal of European Public Policy*, *24*, 1604 – 1622.

AMI (Agrarmarkt Informations-Gesellschaft). 2019. [Datenbank für verschiedene biologische und konventionelle Agrarprodukte]. Bonn: Agrarmarkt Informations-Gesellschaft.

Armsworth, P. R. et al. 2012. The cost of policy simplification in conservation incentive programs. *Ecology Letters*, *15*, 406 – 414.

Badgley, C., Moghtader, J., Quintero, E. et al. 2007. Organic agriculture and the global food supply. *Renewable Agriculture and Food Systems*, *22*, 86 – 108.

Ball, D., Ross, P., English, D. et al. 2015. Robotics for sustainable broad-acre agriculture. In: L. Mejias, P. Corke & J. Roberts (Hrsg.), *Field and service robotics* (S. 439 – 453). Cham: Springer.

Balmford, A., Amano, T., Bartlett, H. et al. 2018. The environmental costs and benefits of high-yield farming. *Nature Sustainability*, *1,* 477 – 485.

Barth, F. 2002. An anthropology of knowledge. *Current Anthropology*, *43*, 1 – 18.

Batáry, P., Báldi, A., Kleijn, D. & Tscharntke, T. 2011. Landscape-moderated biodiversity effects of agri-environmental management: A meta-analysis. *Proceedings of the Royal Society B*: *Biological Sciences*, *278*, 1894 – 1902.

Batáry, P., Dicks, L. V., Kleijn, D. & Sutherland, W. J. 2015. The role of agri-environment schemes in conservation and environmental management. *Conservation Biology*, *29*, 1006 – 1016.

Batáry, P., Gallé, R., Riesch, F. et al. 2017. The former Iron Curtain still drives biodiversity-profit trade-offs in German agriculture. *Nature Ecology and Evolution*, *1*, 1279 – 1284.

Bayerische Akademie für Naturschutz und Landschaftspflege. [O. J.]. *Der Wettbewerb Naturschutzpartner Landwirt 2018*. Abgerufen von https://www.anl.bayern.de/projekte/naturschutzpartner_landwirt/index.htm

Bayerisches Landesamt für Umwelt. 2018. *Arten- und Biotopschutzprogramm: Einführung und Bearbeitungsstand*. Abgerufen von https://www.lfu.bayern.de/natur/absp_einfuehrung/index.htm

Bayerisches Landesamt für Umweltschutz. 2003. *Regionale Landschaftsentwicklungskonzepte in Bayern*. Abgerufen von https://regierung.niederbayern.bayern.de/media/aufgabenbereiche/5u/naturschutz/landschaftsentwicklungskonzept_infoblatt_bayern.pdf

Bayerische Landesanstalt für Landwirtschaft. 2016. *Bayerische Wiesenmeisterschaften: Naturschutz und Landwirtschaft Hand in Hand* [LfL-Information]. Abgerufen von https://www.lfl.bayern.de/mam/cms07/publikationen/daten/informationen/bayerische-wiesenmeisterschaft_lfl-information.pdf

Beckmann, M., Gerstner, K., Akin-Fajiye, M. et al. 2019. Conventional land-use intensification reduces species richness and increases production: A global meta-analysis. *Global Change Biology*, *25*, 1941 – 1956.

Benton, T. G., Vickery, J. A. & Wilson, J. D. 2003. Farmland biodiversity: Is habitat heterogeneity the key? *Trends in Ecology and Evolution*, *18*, 182 – 188.

Benzler, A. 2009. The implementation of the HNV farmland indicator in Germany. *Rural Evaluation News*, *2*, 4 – 5.

Benzler, A., Fuchs, D. & Hünig, C. 2015. Methodik und erste Ergebnisse des Monitorings der Landwirtschaftsflächen mit hohem Naturwert in Deutschland. *Natur und Landschaft*, *90*, 309 – 316.

BfN (Bundesamt für Naturschutz). 2009 – 2018. *Rote Liste gefährdeter Tiere, Pflanzen und Pilze Deutschlands* [Bde 1 – 8]. Münster: Landwirtschaftsverlag Münster.

BfN (Bundesamt für Naturschutz). 2014. *Grünland-Report: Alles im Grünen Bereich?* Bonn: Bundesamt für Naturschutz.

Blüthgen, N. & Klein, A. M. 2011. Functional complementarity and specialisation: The role of biodiversity in plant-pollinator interactions. *Basic and Applied Ecology*, *12*, 282 – 291.

BMEL (Bundesministerium für Ernährung und Landwirtschaft). 1992. Statistisches Jahrbuch über Ernährung, Landwirtschaft und Forsten 1992. Bundesanstalt für Landwirtschaft und Ernährung. Münster: Landwirtschaftsverlag Münster-Hiltrup.

BMEL (Bundesministerium für Ernährung und Landwirtschaft) . 2005. Statistisches Jahrbuch über Ernährung, Landwirtschaft und Forsten 2005. Bonn.

BMEL (Bundesministerium für Ernährung und Landwirtschaft). 2015. Agrarpolitischer Bericht der Bundesregierung 2015. 1 – 48.

BMEL (Bundesministerium für Ernährung und Landwirtschaft) . 2012. Statistisches Jahrbuch über Ernährung, Landwirtschaft und Forsten 2012. Bonn.

BMEL (Bundesministerium für Ernährung und Landwirtschaft) . 2017. Statistisches Jahrbuch über Ernährung, Landwirtschaft und Forsten 2017. Bonn.

BMEL (Bundesministerium für Ernährung und Landwirtschaft). 2019. Statistisches Jahrbuch über Ernährung, Landwirtschaft und Forsten 2019.

BMU (Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit. 2019. *Aktionsprogramm Insektenschutz der Bundesregierung: Gemeinsam wirksam gegen das Insektensterben*. Berlin: Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit.

BMU & BfN (Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit & Bundesamt für Naturschutz). 2016. *Naturbewusstsein 2015: Bevölkerungsumfrage zu Natur und biologischer Vielfalt*. Berlin: Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit & Bundesamt für Naturschutz. Abgerufen von https://www.bfn.de/fileadmin/BfN/gesellschaft/Dokumente/Naturbewusstsein-2015_barrierefrei.pdf

BMU & BfN (Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit & Bundesamt für Naturschutz). 2018. *Naturbewusstsein 2017: Bevölkerungsumfrage zu Natur und biologischer Vielfalt*. Berlin: Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit & Bundesamt für Naturschutz. Abgerufen von https://www.bmu.de/fileadmin/Daten_BMU/Pools/Broschueren/naturbewusstseinsstudie_2017_de_bf.pdf

BÖLW (Bund Ökologische Lebensmittelwirtschaft). 2019. *Zahlen, Daten, Fakten*: *Die Bio-Branche 2019*. Abgerufen von https://bit.ly/2Hj1TVY

Boncinelli, F., Bartolini, F., Brunori, G. & Casini, L. 2016. Spatial analysis of the participation in agri-environment measures for organic farming. *Renewable Agriculture and Food Systems*, *31*, 375 – 386.

Bourguet, D. & Guillemaud, T. 2016. The hidden and external costs of pesticide use. *Sustainable Agriculture Reviews*, *19*, 35 – 120.

Bowler, D. E., Heldbjerg, H., Fox, A. D. et al. 2019. Long-term declines of European insectivorous bird populations and potential causes. *Conservation Biology*, *33*, 1120 – 1130.

Brandt, K. & Glemnitz, M. 2014. Assessing the regional impacts of increased energy maize cultivation on farmland birds. *Environmental Monitoring and Assessment*, *186*, 679 – 697.

Braunisch, V., Home, R., Pellet, J. & Arlettaz, R. 2012. Conservation science relevant to action: A research agenda identified and prioritized by practitioners. *Biological Conservation*, *153*, 201 – 210.

Brittain, C., Kremen, C., Garbers, A. & Klein, A. M. 2014. Pollination and plant resources change the nutritional quality of almonds for human health. *PLOS ONE, 9,* e90082. doi: 10.1371/journal.pone.0090082

Brittain, C., Kremen, C. & Klein, A.-M. 2013a. Biodiversity buffers pollination from changes in environmental conditions. *Global Change Biology*, *19*, 540 – 547.

Brittain, C., Williams, N., Kremen, C. & Klein, A.-M. 2013b. Synergistic effects of non-Apis bees and honey bees for pollination services. *Proceedings of the Royal Society B: Biological Sciences*, *280*, 1 – 7.

Brooks, D. R., Bater, J. E., Clark, S. J. et al. 2012. Large carabid beetle declines in a United Kingdom monitoring network increases evidence for a widespread loss in insect biodiversity. *Journal of Applied Ecology*, *49*, 1009 – 1019.

Bruelheide, H., Jansen, F., Jandt, U. et al. 2020. Using incomplete floristic monitoring data from habitat mapping programmes to detect species trends. *Diversity and Distributions*, *26*, 782 – 794.

Brühl, C. 2018. Pestizide und ihre Auswirkungen auf die terrestrische Fauna und Flora. In: M. Vischer-Leopold et al. *Natura 2000 und Artenschutz in der Agrarlandschaft*. Münster: Landwirtschaftsverlag.

Bruhn, M. 2001. *Verbrauchereinstellungen zu Bioprodukten: Der Einfluß der BSE-Krise 2000/2001* [Arbeitsberichte des Instituts für Agrarökonomie der Universität Kiel, Bd. 20]. Kiel: Institut für Agrarökonomie der Universität Kiel.

BUND (Bund für Umwelt und Naturschutz Deutschland). 2019. *Pestizidfreie Kommunen: Es tut sich was*. Abgerufen von https://www.bund.net/umweltgifte/pestizide/pestizidfreie-kommune/

Buse, J., Boch, S., Hilgers, J. & Griebeler, E. M. 2015. Conservation of threatened habitat types under future climate change: Lessons from plant-distribution models and current extinction trends in southern Germany. *Journal for Nature Conservation*, *27*, 18 – 25.

Burton, R. J. F. & Schwarz, G. 2013. Result-oriented agri-environmental schemes in Europe and their potential for promoting behavioural change. *Land Use Policy*, *30*, 628 – 641.

Busch, M., Katzenberger, J., Trautmann, S. et al. 2020. Drivers of population change in common farmland birds in Germany. *Bird Conservation International*, doi:10.1017/S0959270919000480

BUWAL & BFS (Bundesamt für Umwelt, Wald und Landschaft & Bundesamt für Statistik). 1997. *Umwelt in der Schweiz 1997*. Bern: Bundesamt für Umwelt, Wald und Landschaft.

Castle, D., Grass, I. & Westphal, C. 2019. Fruit quantity and quality of strawberries benefit from enhanced pollinator abundance at hedgerows in agricultural landscapes. *Agriculture, Ecosystems & Environment*, *275*, 14 – 22.

Civitello, D. J., Cohen, J., Fatima, H. et al. 2015. Biodiversity inhibits parasites: Broad evidence for the dilution effect. *Proceedings of the National Academy of Sciences*, *112*, 8667 – 8671.

Collins, H. M. 2010. *Tacit and explicit knowledge*. Chicago/London: The University of Chicago Press.

Conrad, K. F., Warren, M. S., Fox, R. et al. 2006. Rapid declines of common, widespread British moths provide evidence of an insect biodiversity crisis. *Biological Conservation*, *132*, 279 – 291.

Cox, D. T. C., Shanahan, D. F., Hudson, H. L. et al. 2017. Doses of neighborhood nature: The benefits for mental health of living with nature. *BioScience*, *67*, 147 – 155.

Criado, T. S. & Estalella, A. 2018. *Experimental collaborations: Ethnography through fieldwork devices*. New York/Oxford: Berghahn Books.

Dainese, M., Martin, E. A., Aizen, M. A. et al. 2019. A global synthesis reveals biodiversity-mediated benefits for crop production. *Science Advances*, *5*, eaax0121.

Dakos, V., Matthews, B., Hendry, A. P. et al. 2019. Ecosystem tipping points in an evolving world. *Nature Ecology and Evolution*, *3*, 335 – 362.

Dallimer, M., Irvine, K. N., Skinner, A. M. J et al. 2012. Biodiversity and the feel-good factor: Understanding associations between self-reported human well-being and species richness. *BioScience*, *62*, 47 – 55.

Damos, P. 2015. Modular structure of web-based decision support systems for integrated pest management: A review. *Agronomy for Sustainable Development*, *35*, 1347 – 1372.

Desender, K. & Turin, H. 1989. Loss of habitats and changes in the composition of the ground and tiger beetle fauna in four West European countries since 1950 (Coleoptera: Carabidae, Cicindelidae). *Biological Conservation*, *48*, 277 – 294.

Destatis (Statistisches Bundesamt). 2011. *Land- und Forstwirtschaft, Fischerei: Wirtschaftsdünger, Stallhaltung, Weidehaltung, Landwirtschaftszählung/Agrarstrukturerhebung 2010* [Fachserie 3, Heft 6]. Wiesbaden: Statistisches Bundesamt.

Destatis (Statistisches Bundesamt). 2019a. Gehaltene Tiere seit 1950; Allgemeine und repräsentative Erhebung über die Viehbestände; Statistisches Bundesamt (Destatis); Wiesbaden. Online Datenbank; url: https://www-genesis.destatis.de

Destatis (Statistisches Bundesamt). 2019b. Landwirtschaftliche Betriebe und ihre Flächen nach Größenklassen. *BMELV* **425**.

Destatis (Statistisches Bundesamt). 2019c. *Land- und Forstwirtschaft, Fischerei: Bodennutzung der Betriebe, landwirtschaftlich genutzte Flächen* [Fachserie 3, Reihe 3.1.2]. Wiesbaden: Statistisches Bundesamt. 1 – 39.

Destatis (Statistisches Bundesamt). 2019d. *Land- und Forstwirtschaft, Fischerei: Viehbestand* [Fachserie 3, Reihe 4.1]. Wiesbaden: Statistisches Bundesamt. 1 – 46.

Deutsches Bienenjournal. 2019. *Insektenschutz: Weitere Bundesländer planen Volksbegehren. Aktuelles am 18.02.2019*. Abgerufen von https://www.bienenjournal.de/aktuelles/meldungen/insektenschutz-weitere-bundeslaender-planen-volksbegehren/

Díaz, S., Demissew, S., Carabias, J. et al. 2015. The IPBES Conceptual Framework: Connecting nature and people. *Current Opinion in Environmental Sustainability*, *14*, 1 – 16.

Dupraz, P. & Guyomard, H. 2019. Environment and climate in the Common Agricultural Policy. *EuroChoices*, *18*, 18 – 25.

Duprè, C., Stevens, C. J., Ranke, T. et al. 2010. Changes in species richness and composition in European acidic grasslands over the past 70 years: The contribution of cumulative atmospheric nitrogen deposition. *Global Change Biology*, *16*, 334 – 357.

DVL (Deutscher Verband für Landschaftspflege). 2018. Leitfaden für die einzelbetriebliche Biodiversitätsberatung [DVL-Schriftenreihe „Landschaft als Lebensraum“, Nr. 24]. Ansbach: Deutscher Verband für Landschaftspflege.

Dyck, H. v., Strien, A. J. v., Maes, D. & Swaay, C. A. v. 2009. Declines in common, widespread butterflies in a landscape under intense human use. *Conservation Biology*, *23*, 957 – 965.

Eilers, E. J., Kremen, C., Smith Greenleaf, S. et al. 2011. Contribution of pollinator-mediated crops to nutrients in the human food supply. *PLoS ONE*, *6*, e21363.

EBCC (European Bird Census Council). 2019. *Common bird indicator*. Abgerufen von https://pecbms.info/trends-and-indicators/indicators/

European Commission. 2019. *The Post-2020 Common Agricultural Policy: Environmental benefits and simplification*. Brüssel: European Union.

EEA (European Environment Agency). 2013. *The European grassland butterfly indicator: 1990 – 2011* [EEA Technical Report, Nr. 11/2013]. Luxemburg: European Environment Agency.

EEA (European Environment Agency). 2015. *State of nature in the EU: Results from reporting under the nature directives 2007 – 2012* [Technical Report, Bd. 2/2015]. Luxemburg: European Environment Agency.

Fahrig, L., Girard, J., Duro, D. et al. 2015. Farmlands with smaller crop fields have higher within-field biodiversity. *Agriculture, Ecosystems & Environment*, *200*, 219 – 234.

FAO (Food and Agriculture Organization of the United Nations). 2019. *Agroecology knowledge hub*. Abgerufen von http://www.fao.org/agroecology/home/en/

Farm Accountancy Data Network 2020. Abgerufen von https://ec.europa.eu/agriculture/rica/

Firbank, L. G., Petit, S., Smart, S. et al. 2008. Assessing the impacts of agricultural intensification on biodiversity: A British perspective. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *363*, 777 – 787.

Firbank, L. G., Smart, S. M., Crabb, J. et al. 2003. Agronomic and ecological costs and benefits of set-aside in England. *Agriculture, Ecosystems & Environment*, *95*, 73 – 85.

Fischer, J. & Riechers, M. 2019. A leverage points perspective on sustainability. *People and Nature*, *1*, 115 – 120.

Freemark, K. & Boutin, C. 1995. Impacts of agricultural herbicide use on terrestrial wildlife in temperate landscapes: A review with special reference to North America. *Agriculture, Ecosystems & Environment*, *52*, 67 – 91.

Friege, H. & Claus, F. 1988. *Chemie für wen? Chemiepolitik statt Chemieskandale*. Reinbeck: Rowohlt.

Fuller, R. A., Irvine, K. N., Devine-Wright, P. et al. 2007. Psychological benefits of greenspace increase with biodiversity. *Biology Letters*, *3*, 390 – 394.

Galaz, V., Crona, B., Dauriach, A. et al. 2018. Tax havens and global environmental degradation. *Nature Ecology & Evolution*, *2*, 1352 – 1357.

Gallai, N., Salles, J. M., Settele, J. & Vaissière, B. E. 2009. Economic valuation of the vulnerability of world agriculture confronted with pollinator decline. *Ecological Economics*, *68*, 810 – 821.

Garibaldi, L.A., Carvalheiro, L.G., Leonhardt, et al. 2014. From research to action: practices to enhance crop yield through wild pollinators. *Frontiers in Ecology and the Environment*, *12*, 439 – 447.

Garratt, M. P. D., Breeze, T. D., Jenner, N. et al. 2014. Avoiding a bad apple: Insect pollination enhances fruit quality and economic value. *Agriculture, Ecosystems & Environment*, *184*, 34 – 40.

Geiger, F., Bengtsson, J., Berendse, F. et al. 2010. Persistent negative effects of pesticides on biodiversity and biological control potential on European farmland. *Basic and Applied Ecology*, *11*, 97 – 105.

Gellermann, M. 2019. Bundesnaturschutzgesetz: Paragraph 14. In: R. v. Landmann & G. Rohmer (Hrsg.), Umweltrecht II (§ 14, Rn. 22). München: C. H. Beck.

Geschke, J., Vohland, K., Bonn, A. et al. 2019. Biodiversitätsmonitoring in Deutschland: Wie Wissenschaft, Politik und Zivilgesellschaft ein nationales Monitoring unterstützen können. *GAiA*, *28*, 265 – 270.

Gilhaus, K., Boch, S., Fischer, M. et al. 2017. Grassland management in Germany: Effects on plant diversity and vegetation composition. *Tuexenia*, *37*, 379 – 397.

Gottwald, F. & Stein-Bachinger, K. 2018. „Farming for biodiversity“: A new model for integrating nature conservation achievements on organic farms in north-eastern Germany. *Organic Agriculture*, *8*, 79 – 86.

Goulson, D., Hanley, M. E., Darvill, B. et al. 2005. Causes of rarity in bumblebees. *Biological Conservation*, *122*, 1 – 8.

Habel, J. C., Segerer, A., Ulrich, W. et al. 2016. Butterfly community shifts over two centuries. *Conservation Biology*, *30*, 754 – 762.

Haber, W. 2014. *Landwirtschaft und Naturschutz*. Weinheim: Wiley-VDH.

Haller, L., Moake, S., Niggli, U. et al. 2020. *Entwicklungsperspektiven der ökologischen Landwirtschaft in Deutschland* [Umweltbundesamt Texte, Nr. 32/2020]. Dessau-Roßlau: Umweltbundesamt.

Hallmann, C. A., Sorg, M., Jongejans, E. et al. 2017. More than 75 percent decline over 27 years in total flying insect biomass in protected areas. *PLOS ONE*, *12*, e0185809.

Hallmann, C., Zeegers, T., Klink, R. v. et al. 2018. *Analysis of insect monitoring data from De Kaaistoep and Drenthe*. Nijmegen: Radboud University.

Hampicke, U. 2018. *Kulturlandschaft: Äcker, Wiesen, Wälder und ihre Produkte*. Berlin/Heidelberg: Springer.

Harris, J. E., Rodenhouse, N. L. & Holmes, R. T. 2019. Decline in beetle abundance and diversity in an intact temperate forest linked to climate warming. *Biological Conservation*, *240*, 108219.

Hart, L. 2015. The fate of green direct payments in the CAP reform negotiations. In: J. Swinnen (Hrsg.). *The political economy of the 2014 – 2020 Common Agricultural Policy: An imperfect storm* (S. 245 – 276). London: Rowman & Littlefield.

Hasselbach, J. L. & Roosen, J. 2015. Motivations behind preferences for local or organic food. *Journal of International Consumer Marketing*, *27*, 295 – 306.

Hawkins, B. A., Field, R., Cornell, H. V. et al. 2003. Energy, water, and broad-scale geographic patterns of species richness. *Ecology*, *84*, 3105 – 3117.

Hedblom, M., Heyman, E., Antonsson, H. & Gunnarsson, B. 2014. Bird song diversity influences young people's appreciation of urban landscapes. *Urban Forestry & Urban Greening*, *13*, 469 – 474.

Heimbach, U. 1988. Nebenwirkungen einiger Fungizide auf Insekten. *Nachrichtenblatt des Deutschen Pflanzenschutzdienstes*, *40*, 180 – 183.

Heinrich, B., Würriehausen, N., Hernández Villafuerte, K. et al. 2013. Ökologische Landwirtschaft als ein Baustein zur -Sicherung der Welternährung? Eine kritische Bestandsaufnahme und ökonometrische Analyse. In: Rentenbank (Hrsg.), *Sicherung der Welternährung bei knappen Ressourcen*, (S. 137 – 177), Frankfurt a.M.

Hemmer, C. & Hölzer, C. 2013. *Wir tun was für Bienen: Wildbienengarten, Insektenhotel und Stadtimkerei*. Stuttgart: Kosmos.

Henderson, I. G., Cooper, J., Fuller, R. J. & Vickery, J. 2000. The relative abundance of birds on set-aside and neighbouring fields in summer. *Journal of Applied Ecology*, *37*, 335 – 347.

Herlitzius, T., Grosa, A. & Bögel, T. 2018. Bodenbearbeitungstechnik. *Jahrbuch Agrartechnik*, *30*, 92 – 102.

Hole, D. G., Perkins, A. J., Wilson, J. D. et al. 2005. Does organic farming benefit biodiversity? *Biological Conservation*, *122*, 113 – 130.

Holland, J. M., Bianchi, F. J., Entling, M. H. et al. 2016. Structure, function and management of semi-natural habitats for conservation biological control: A review of European studies. *Pest Management Science*, *72*, 1638 – 1651.

Homburg, K., Drees, C., Boutaud, E. et al. 2019. Where have all the beetles gone? Long-term study reveals carabid species decline in a nature reserve in Northern Germany. *Insect Conservation and Diversity*, *12*, 268 – 277.

Iftekhar, M. S. & Latacz-Lohmann, U. 2017. How well do conservation auctions perform in achieving landscape-level outcomes? A comparison of auction formats and bid selection criteria. *Australian Journal of Agricultural and Resource Economics*, *61*, 557 – 575.

IPBES (Intergovernmental Platform on Biodiversity and Ecosystem Services). 2015. *Conceptual Framework: Rationale for a conceptual framework for the platform*. Abgerufen von https://www.ipbes.net/conceptual-framework

IPBES (Intergovernmental Platform on Biodiversity and Ecosystem Services). 2016. *Summary for policymakers of the assessment report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services on pollinators, pollination and food production*. Abgerufen von https://ipbes.net/sites/default/files/spm_deliverable_3a_pollination_20170222.pdf

IPBES (Intergovernmental Platform on Biodiversity and Ecosystem Services). 2018. *Summary for policymakers of the regional assessment report on biodiversity and ecosystem services for Europe and Central Asia of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. Abgerufen von https://ipbes.net/sites/default/files/ipbes_6_15_add.4_eca_english.pdf

IPBES (Intergovernmental Platform on Biodiversity and Ecosystem Services). 2019. *Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. Abgerufen von https://ipbes.net/sites/default/files/2020-02/ipbes_global_assessment_report_summary_for_policymakers_en.pdf

Isselstein, J., Jeangros, B. & Pavlu, V. 2005. Agronomic aspects of biodiversity targeted management of temperate grasslands in Europe: A review. *Agronomy Research*, *3*, 139 – 151.

Jänsch, S. & Römbke, J. 2009. *Einsatz von Kupfer als Pflanzenschutzmittel-Wirkstoff: Ökologische Auswirkungen der Akkumulation von Kupfer im Boden* [Umweltbundesamt Texte, Nr. 10/2009]. Dessau-Roßlau: Umweltbundesamt.

Jansen, F., Bonn, A., Bowler, D. et al. 2019. Moderately common plants show highest relative losses. *Conservation Letters*, *13*, e12674.

Jeliazkov, A., Mimet, A., Chargé, R. et al. 2016. Impacts of agricultural intensification on bird communities: New insights from a multi-level and multi-facet approach of biodiversity. *Agriculture, Ecosystems & Environment*, *216*, 9 – 22.

Kahl, W. & Gärditz, K. F. 2019. *Umweltrecht* [11. Auflage]. München: C. H. Beck.

Kleijn, D., Baquero, R. A., Clough, Y. et al. 2006. Mixed biodiversity benefits of agri-environment schemes in five European countries. *Ecology Letters*, *9*, 243 – 254.

Kleijn, D., Rundlöf, M., Scheper, J. et al. 2011. Does conservation on farmland contribute to halting the biodiversity decline? *Trends in Ecology & Evolution*, *26*, 474 – 481.

Kleijn, D. & Sutherland, W. J. 2003. How effective are European agri-environment schemes in conserving and promoting biodiversity? *Journal of Applied Ecology*, *40*, 947 – 969.

Kleijn, D., Winfree, R., Bartomeus, I. et al. 2015. Delivery of crop pollination services is an insufficient argument for wild pollinator conservation. *Nature Communications*, *6*, 7414.

Klein, A.-M., Vaissière, B. E., Cane, J. H. et al. 2007. Importance of pollinators in changing landscapes for world crops. *Proceedings of the Royal Society B: Biological Sciences*, *274*, 303 – 313.

Klink, R. v., Bowler, D. E., Gongalsky, K. B. et al. 2020. Meta-analysis reveals declines in terrestrial but increases in freshwater insect abundances. *Science*, *368*, 417 – 420.

Knapp, S. & Heijden, M. G. A. v. d. 2018. A global meta-analysis of yield stability in organic and conservation agriculture. *Nature Communications*, *9*, 3632.

Köck, W. 2018. Für ein umweltgerechtes Agrarrecht. *Zeitschrift für Umweltrecht*, *29*, 449 – 450.

Köck, W. 2019. Naturschutz und Landwirtschaft: Regelungsmöglichkeiten und grenzen im BNatSchG im Verhältnis zum (Umwelt- und Agrar-)Fachrecht. In: D. Czybulka & W. Köck (Hrsg.), *Landwirtschaft und Naturschutzrecht* (S. 189 – 208). Baden-Baden: Nomos.

Koester, U. 2016. *Grundzüge der landwirtschaftlichen Marktlehre*. München: Vahlen.

Kommunen für biologische Vielfalt. 2019. [Website]. Abgerufen von https://www.kommbio.de

Korkeamäki, E. & Suhonen, J. 2002. Distribution and habitat specialization of species affect local extinction in dragonfly Odonata populations. *Ecography*, *25*, 459 – 465.

Kremen, C., Iles, A. & Bacon, C. 2012. Diversified farming systems: An agroecological, systems-based alternative to modern industrial agriculture. *Ecology and Society*, *17*, art44.

Kromp, B. 1999. Carabid beetles in sustainable agriculture: A review on pest control efficacy, cultivation impacts and enhancement. *Agriculture, Ecosystems & Environment*, *74*, 187 – 228.

Künast, C., Deubert, M., Künast, R. & Trapp, M. 2019. Die Eh da-Initiative: Mehr Platz für biologische Vielfalt in Kulturlandschaften. *Biologie in unserer Zeit*, *49*, 28 – 38.

Lakner, S. & Breustedt, G. 2017. Efficiency analysis of organic farming systems: A review of concepts, topics, results and conclusions. *German Journal of Agricultural Economics*, *66*, 85 – 108.

Lakner, S., Brümmer, B., Cramon-Taubadel, S. v. et al. 2012. *Der Kommissionsvorschlag zur GAP-Reform 2013: Aus Sicht von Göttinger und Witzenhäuser Agrarwissenschaftler(inne)n* [Diskussionsbeitrag, Nr. 1208, Georg-August-Universität Göttingen, Department für Agrarökonomie und Rurale Entwicklung]. Göttingen: Department für Agrarökonomie und Rurale Entwicklung der Georg-August-Universität Göttingen.

Lakner, S. & Kleinknecht, U. 2013. Naturschutzfachliche Optimierung von Grünland mit Hilfe der FFH-Managementplanung in Sachsen. *Schriften der Gesellschaft für Wirtschafts- und Sozialwissenschaften des Landbaues*, *48*, 85 – 96.

Lakner, S., Zinngrebe, Y. & Koemle, D. 2020. Combining management plans and payment schemes for targeted grassland conservation within the Habitats Directive in Saxony, Eastern Germany. *Land Use Policy*, *97*, 104642.

Lautenbach, S., Seppelt, R., Liebscher J. & Dormann, C. F. 2012. Spatial and temporal trends of global pollination benefit. *PLoS ONE*, *7*, e35954.

Lavelle, P., Decaëns, T., Aubert, M. et al. 2006. Soil invertebrates and ecosystem services. *European Journal of Soil Biology*, *42*(Suppl. 1), S3–S15.

Leipziger Erklärung des Deutschen Naturschutzrechtstages. 2018. *Zeitschrift für Umweltrecht*, *29*, 469 – 470.

Lemoine, N., Bauer, H.-G., Peintinger, M. & Böhning-Gaese, K. 2007. Effects of climate and land-use change on species abundance in a Central European bird community. *Conservation Biology*, *21*, 495 – 503.

Lenz, N. & Schulten, D. 2005. Tagfalter (Lep., Hesperioidea et Papilionoidea) im Gebiet der Landeshauptstadt Düsseldorf um 1900 und um 2000: Ein Beispiel für alarmierende Artenverarmung im 20. Jahrhundert. *Melanargia*, *17*, 19 – 29.

Leonhardt, S. D., Gallai, N., Garibaldi, L. A. et al. 2013. Economic gain, stability of pollination and bee diversity decrease from southern to northern Europe. *Basic and Applied Ecology*, *14*, 461 – 471.

Leuschner, C., Krause, B., Meyer, S. & Bartels, M. 2014. Strukturwandel im Acker- und Grünland Niedersachsens und Schleswig-Holsteins seit 1950. *Natur und Landschaft*, *89*, 386 – 391.

Liu, T., Bruins, R. & Heberling, M. 2018. Factors influencing farmers' adoption of best management practices: A review and synthesis. *Sustainability*, *10*, 432.

Lobo, J. M. 2001. Decline of roller dung beetle (Scarabaeinae) populations in the Iberian peninsula during the 20th century. *Biological Conservation*, *97*, 43 – 50.

Lüscher, G., Jeanneret, P., Schneider, M. K. et al. 2014. Responses of plants, earthworms, spiders and bees to geographic location, agricultural management and surrounding landscape in European arable fields. *Agriculture, Ecosystems & Environment*, *186*, 124 – 134.

Madureira, L., Rambonilaza, T. & Karpinski, I. 2007. Review of methods and evidence for economic valuation of agricultural non-commodity outputs and suggestions to facilitate its application to broader decisional contexts. *Agriculture, Ecosystems & Environment*, *120*, 5 – 20.

Maes, D., Dyck, H. v. 2001. Butterfly diversity loss in Flanders (north Belgium): Europe's worst case scenario? *Biological Conservation*, *99*, 263 – 276.

Marques, A., Martins, I. S., Kastner, T. et al. 2019. Increasing impacts of land use on biodiversity and carbon sequestration driven by population and economic growth. *Nature Ecology & Evolution*, *3*, 628 – 637.

Martin, E. A., Dainese, M., Clough, Y. et al. 2019. The interplay of landscape composition and configuration: New pathways to manage functional biodiversity and agroecosystem services across Europe. *Ecology Letters*, *22*, 1083 – 1094.

Meemken, E. M. & Qaim, M. 2018. Organic Agriculture, Food Security, and the Environment. *Annual Review of Resource Economics*, *10*, 39 – 63.

Meisch, S., Kerr, M. & Potthast, T. 2018. *Mengenproblematik: Wenn individuelle Entscheidungsfreiheit (scheinbar) mit der Nachhaltigkeit in Konflikt gerät* [Umweltbundesamt Texte, Nr. 113/2018]. Abgerufen von https://www.umweltbundesamt.de/publikationen/mengenproblematik-wenn-individuelle/

Meyer, M., Ott, D., Götze, P. et al. 2019. Crop identity and memory effects on aboveground arthropods in a long-term crop rotation experiment. *Ecology and Evolution*, *9*, 7307 – 7323.

Meyer, S., Wesche, K., Krause, B. et al. 2014. Diversitätsverluste und floristischer Wandel im Ackerland seit 1950. *Natur und Landschaft*, *89*, 392 – 398.

Meyer, S., Wesche, K., Krause, B. & Leuschner, C. 2013. Dramatic losses of specialist arable plants in Central Germany since the 1950s/60s: A cross-regional analysis. *Diversity and Distributions*, *19*, 1175 – 1187.

Milchtrends.de. 2019. *Regionale Unterschiede in der Herdengrößenstruktur: Anteil der Betriebe >100 Milchkühe in % (2018)*. Abgerufen von https://www.milchtrends.de/daten/milchproduktion/herdengroessenstrukturen/

Ministerium für Umwelt, Energie, Ernährung und Forsten Rheinland-Pfalz. 2018. *Die Vielfalt der Natur bewahren: Biodiversitätsstrategie für Rheinland-Pfalz*. Abgerufen von https://mueef.rlp.de/fileadmin/mulewf/Publikationen/Die_Vielfalt_der_Natur_bewahren_2018.pdf

Möckel, S. 2014. Verbesserte Anforderungen an die gute fachliche Praxis der Landwirtschaft. *Zeitschrift für Umweltrecht*, *25*, 14 – 23.

Möckel, S. 2015. Agrarumweltrecht heute und morgen. *Zeitschrift für Umweltrecht*, *26*, 131 – 139.

Möckel, S., Köck, W., Rutz, C. & Schramek, J. 2014. *Rechtliche und andere Instrumente für vermehrten Umweltschutz in der Landwirtschaft* [Umweltbundesamt Texte, Nr. 42/2014]. Abgerufen von https://www.umweltbundesamt.de/sites/default/files/medien/378/publikationen/texte_42_2014_rechtliche_und_andere_instrumente.pdf

Mögele, R. 2019. Gemeinsame Agrarpolitik und Umwelt- und Klimaschutz: Die Vorschläge der Kommission für die Zeit nach 2020. In: D. Czybulka & W. Köck (Hrsg.), *Landwirtschaft und Naturschutz* (S. 173 – 188). Baden-Baden: Nomos.

Moss, C., Lukac, M., Harris, F. et al. 2019. The effects of crop diversity and crop species on biological diversity in agricultural landscapes. A systematic review protocol. *Wellcome Open Research*, *4*, 101.

Muller, A., Schader, C., El-Hage Scialabba, N. et al. 2017. Strategies for feeding the world more sustainably with organic agriculture. *Nature Communications*, *8*, 1290.

NABU. 2019. *Fairpachten: Gut beraten. Hand in Hand für die Natur*. Abgerufen von https://naturerbe.nabu.de/aktiv/aktionen-und-projekte/24441.html

Nationale Akademie der Wissenschaften Leopoldina. 2014. *Herausforderungen und Chancen der integrativen Taxonomie für Forschung und Gesellschaft: Taxonomische Forschung im Zeitalter der OMICS-Technologien*. Halle (Saale): Deutsche Akademie der Naturforscher Leopoldina – Nationale Akademie der Wissenschaften.

Nationale Akademie der Wissenschaften Leopoldina. 2018. *Der stumme Frühling: Zur Notwendigkeit eines umweltverträglichen Pflanzenschutzes*. Halle (Saale): Deutsche Akademie der Naturforscher Leopoldina – Nationale Akademie der Wissenschaften.

Neumann, H., Dierking, U. & Taube, F. 2017. Erprobung und Evaluierung eines neuen Verfahrens für die Bewertung und finanzielle Honorierung der Biodiversitäts-, Klima- und Wasserschutzleistungen landwirtschaftlicher Betriebe („Gemeinwohlprämie“). *Berichte über Landwirtschaft*, *95*(3), 1 – 37.

Oppermann, R., Fried, A., Lepp, N. et al. 2016. *Fit, fair und nachhaltig: Vorschläge für eine neue EU-Agrarpolitik* [Studie im Auftrag des NABU-Bundesverbands]. Abgerufen von https://www.nabu.de/imperia/md/content/nabude/landwirtschaft/agrarreform/161104-studie-neueeuagrarpolitik-langfassung.pdf

Oppermann, R., Gelhausen, J., Matzdorf, B. et al. 2012. *Gemeinsame Agrarpolitik ab 2014: Perspektiven für mehr Biodiversitäts- und Umweltleistungen der Landwirtschaft?* Abgerufen von http://www.ifab-mannheim.de/GAP+Umwelt-F+E-Ergebnisse-nov2012-DE-final.pdf

Pannwitt, H., Westerman, P. R., Mol, F. d. et al. 2017. Biological control of weed patches by seed predators; responses to seed density and exposure time. *Biological Control*, *108*, 1 – 8.

Pe’er, G., Dicks, L. V., Visconti, P. et al. 2014. EU agricultural reform fails on biodiversity. *Science*, *344*, 1090 – 1092.

Pe’er, G., Zinngrebe, Y., Hauck, J. et al. 2017. Adding some green to the greening: Improving the EU’s ecological focus areas for biodiversity and farmers. *Conservation Letters*, *10*, 517 – 530.

Pe’er, G., Zinngrebe, Y., Moreira, F. et al. 2019. A greener path for the EU Common Agricultural Policy. *Science*, *365*, 449 – 451.

Pedneault, K. & Provost, C. 2016. Fungus resistant grape varieties as a suitable alternative for organic wine production: Benefits, limits, and challenges. *Scientia Horticulturae*, *208*, 57 – 77.

Peppler-Lisbach, C. & Könitz, N. 2017. Vegetationsveränderungen in Borstgrasrasen des Werra-Meißner-Gebietes (Hessen, Niedersachsen) nach 25 Jahren. Vegetation changes in Nardus grasslands of the Werra-Meissner region (Hesse, Lower Saxony, Central Germany) after 25 years. *Tuexenia*, *37*, 201 – 228.

Peschel, A. O., Grebitus, C., Steiner, B. & Veeman, M. 2016. How does consumer knowledge affect environmentally sustainable choices? Evidence from a cross-country latent class analysis of food labels. *Appetite*, *106*, 78 – 91.

Pissarskoi, E., Vogelpohl, T., Schäfer, T. & Petschow, U. 2018. *Diskurse zum guten Leben: Analyse ihrer Begriffe, ihrer Akteure und damit verbundener politischer Strategien* [Umweltbundesamt Texte, Nr. 17/2018]. Abgerufen von https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2018-02-23_texte_17-2018_diskurse-gutes-leben.pdf

Plantureux, S., Peeters, A. & McCracken, D. 2005. Biodiversity in intensive grasslands: Effect of management, improvement and challenges. *Agronomy research*, *3*, 153 – 164.

Polanyi, M. 1966. *The tacit dimension*. Chicago: University of Chicago Press.

Ponti, T. d., Rijk, B. & Ittersum, M. K. v. 2012. The crop yield gap between organic and conventional agriculture. *Agricultural Systems*, *108*, 1 – 9.

Potthast, T. 2014. The values of biodiversity. In: D. Lanzerath & M. Friele (Hrsg.), *Concepts and values in biodiversity* (S. 132 – 146). Abingdon: Routledge.

Poux, X. & Aubert, P.-M. 2018. *An agroecological Europe in 2050: Multifunctional agriculture for healthy eating. Findings from The Ten Years For Agroecology (TYFA) modelling exercise*. Abgerufen von https://www.iddri.org/sites/default/files/PDF/Publications/Catalogue%20Iddri/Etude/201809-ST0918EN-tyfa.pdf

Prall, U. 2016. Gemeinschaftskommentar zum BNatSchG. In: S. Schlacke (Hrsg.). *Gemeinschaftskommentar zum BNatSchG* [2. Auflage] (§ 14 Rn. 59). Köln: Carl Heymanns.

Pretty, J., Benton, T. G., Bharucha, Z. P. et al. 2018. Global assessment of agricultural system redesign for sustainable intensification. *Nature Sustainability*, *1*, 441 – 446.

Rada, S., Schweiger, O., Harpke, A. et al. 2019. Protected areas do not mitigate biodiversity declines: A case study on butterflies. *Diversity and Distributions*, *25*, 217 – 224.

Rands, M. R. W. 1985. Pesticide use on cereals and the survival of grey partridge chicks: A field experiment. *Journal of Applied Ecology*, *22*, 49 – 54.

Redlich, S., Martin, E. A., Wende, B. & Steffan-Dewenter, I. 2018. Landscape heterogeneity rather than crop diversity mediates bird diversity in agricultural landscapes. *PLOS ONE*, *13*, e0200438.

Reganold, J. P. & Wachter, J. M. 2016. Organic agriculture in the twenty-first century. *Nature Plants*, *2*, 15221.

Reger, B., Otte, A. & Waldhardt, R. 2007. Identifying patterns of land-cover change and their physical attributes in a marginal European landscape. *Landscape and Urban Planning*, *81*, 104 – 113.

Rehbinder, E. 2019. Entwicklungslinien im rechtlichen Verhältnis von Landwirtschaft(srecht) und Naturschutzrecht. In: D. Czybulka & W. Köck (Hrsg.), *Landwirtschaft und Naturschutz* (S. 77 – 96). Baden-Baden: Nomos.

Rennebaum, M. 2015. Rückgewinnung von grünen Wegen und Wegeseitenstreifen. *Natur in NRW*, *1*, 16 – 19.

Risius, A. & Hamm, U. 2017. The effect of information on beef husbandry systems on consumers’ preferences and willingness to pay. *Meat Science*, *124*, 9 – 14.

Röder, N. 2017. *Greening: Wie weiter? Überlegungen zur Effizienz des Greenings*. In: J. Lange (Hrsg.). *Auf dem Weg zur Reform der Gemeinsamen Agrarpolitik?* [Loccumer Protokolle, Bd. 13/2017] (S. 101 – 110). Rehburg-Loccum: Evangelische Akademie Loccum.

Röder, N., Ackermann, A., Baum, S. et al. 2019. *Evaluierung der GAP-Reform aus Sicht des Umweltschutzes: GAPEval. Abschlussbericht* [Umweltbundesamt Texte, Nr. 58/2019]. Abgerufen von https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2019-06-17_58-2019_gapeval.pdf

Rodrigues, C. G., Krüger, A. P., Barbosa, W. F. & Guedes, R. N. C. 2016. Leaf fertilizers affect survival and behavior of the neotropical stingless bee Friesella schrottkyi (Meliponini: Apidae: Hymenoptera). *Journal of Economic Entomology*, *109*, 1001 – 1008.

Rusch, A., Bommarco, R., Jonsson, M. et al. 2013. Flow and stability of natural pest control services depend on complexity and crop rotation at the landscape scale. *Journal of Applied Ecology*, *50*, 345 – 354.

Sächsische Landesstiftung Natur und Umwelt, Senckenberg Museum für Tierkunde Dresden, Naturschutzbund Sachsen et al. 2014. *Puppenstuben gesucht: Blühende Wiesen für Sachsens Schmetterlinge*. Abgerufen von https://sachsen.nabu.de/tiereundpflanzen/insektenundspinnen/19629.html

Sadler, T., Wild, M., Wiesinger, K. et al. 2018. Fünf Jahre BioRegio Betriebsnetz Bayern: Eine Zwischenbilanz. In: Bayerische Landesanstalt für Landwirtschaft (Hrsg.), *Angewandte Forschung und Entwicklung für den ökologischen Landbau in Bayern: Öko-Landbautag 2018* (S. 161 – 162). Freising-Weihenstephan: Bayerische Landesanstalt für Landwirtschaft.

Samnegård, U., Alins, G., Boreux, V. et al. 2019. Management trade-offs on ecosystem services in apple orchards across Europe: Direct and indirect effects of organic production. *Journal of Applied Ecology*, *56*, 802 – 811.

Sanders, J. & Heß, J. (Hrsg.). 2019. *Leistungen des ökologischen Landbaus für Umwelt und Gesellschaft* [Thünen Report, 65]. Abgerufen von https://literatur.thuenen.de/digbib_extern/dn060722.pdf

Schader, C., Muller, A., El-Hage Scialabba, N. et al. 2015. Impacts of feeding less food-competing feedstuffs to livestock on global food system sustainability. *Journal of the Royal Society Interface*, *12*(113).

Schilizzi, S. & Latacz-Lohmann, U. 2012. Evaluating conservation auctions with unknown bidder costs: The Scottish fishing vessel decommissioning program. *Land Economics*, *88*, 658 – 673.

Schlacke, S. 2019. *Umweltrecht*. Baden-Baden: Nomos.

Schmidt, T. G., Röder, N., Dauber, J. et al. 2014. *Biodiversitätsrelevante Regelungen zur nationalen Umsetzung des Greenings der Gemeinsamen Agrarpolitik der EU nach 2013* [Thünen Working Paper, 20]. Abgerufen von https://www.thuenen.de/media/publikationen/thuenen-workingpaper/ThuenenWorkingPaper_20.pdf

Schneider, M. K., Lüscher, G., Jeanneret, P. et al. 2014. Gains to species diversity in organically farmed fields are not propagated at the farm level. *Nature Communications*, *5*, 1 – 9.

Schroeder, L. A., Isselstein, J., Chaplin, S. & Peel, S. 2013. Agri-environment schemes: Farmers' acceptance and perception of potential „Payment by Results“ in grassland. A case study in England. *Land Use Policy*, *32*, 134 – 144.

Schuch, S., Bock, J., Krause, B. et al. 2012. Long-term population trends in three grassland insect groups: A comparative analysis of 1951 and 2009. *Journal of Applied Entomology*, *136*, 321 – 331.

Schüler, S., Bienwald, L., Loos, J. & Lakner, S. 2018. Wahrnehmung und Anpassungsverhalten der Landwirte an Greening: Eine qualitative Studie in Südniedersachsen. *Berichte über Landwirtschaft*, *96*(3), 1 – 21.

Schumacher, J., Schumacher, A., Wattendorf, P. & Konold W. 2014. *Nationale Naturmonumente: Endbericht* [Studie im Auftrag des Bundesamtes für Naturschutz]. Abgerufen von https://www.bfn.de/fileadmin/BfN/gebietsschutz/Endbericht_NNM_barrierefrei_02.pdf

Seibold, S., Gossner, M. M., Simons, N. K. et al. 2019. Arthropod decline in grasslands and forests is associated with drivers at landscape level drivers. *Nature*, *574*, 671 – 674.

Seufert, V. & Ramankutty, N. 2017. Many shades of gray: The context-dependent performance of organic agriculture. *Science Advances*, *3*, e1602638.

Seufert, V., Ramankutty, N. & Foley, J. A. 2012. Comparing the yields of organic and conventional agriculture. *Nature*, *485*, 229 – 232.

Simon-Delso, N., Amaral-Rogers, V., Belzunces, L. P. et al. 2015. Systemic insecticides (Neonicotinoids and fipronil): Trends, uses, mode of action and metabolites. *Environmental Science and Pollution Research*, *22*, 5 – 34.

Sirami, C., Gross, N., Baillod, A. B. et al. 2019. Increasing crop heterogeneity enhances multitrophic diversity across agricultural regions. *Proceedings of the National Academy of Sciences*, *116*, 16442 – 16447.

Stein-Bachinger, K. & Gottwald, F. 2016. Naturschutzleistungen vermarkten. *Ökologie & Landbau*, (2), 49 – 50.

Steinmann, H.-H. & Dobers, E. S. 2013. Spatio-temporal analysis of crop rotations and crop sequence patterns in Northern Germany: Potential implications on plant health and crop protection. *Journal of Plant Diseases and Protection*, *120*, 85 – 94.

Stoeckli, S., Birrer, S., Zellweger-Fischer, J. et al. 2017. Quantifying the extent to which farmers can influence biodiversity on their farms. *Agriculture, Ecosystems and Environment*, *237*, 224 – 233.

Strijker, D. 2005. Marginal lands in Europe: Causes of decline. *Basic and Applied Ecology*, *6*, 99 – 106.

Strohbach, M. W., Kohler, M. L., Dauber, J. & Klimek, S. 2015. High Nature Value farming: From indication to conservation. *Ecological Indicators*, *57*, 557 – 563.

Stützel, H., Brüggemann, N., Fangmeier, A. et al. 2014. Feldversuchsinfrastrukturen: Status quo und Perspektiven [Positionspapier der DFG-Senatskommission für Agrarökosystemforschung]. *Journal für Kulturpflanzen*, *66*, 237 – 240.

Sudfeldt, C., Dröschmeister, R., Frederking, W. et al. 2013. *Vögel in Deutschland 2013* [Studie im Auftrag des Dachverbandes Deutscher Avifaunisten, des Bundesamtes für Naturschutz und der Länderarbeitsgemeinschaft der Vogelschutzwarten]. Abgerufen von https://www.bfn.de/fileadmin/BfN/monitoring/Dokumente/ViD_2013_internet_barrfr.pdf

Swaay, C. A. M. v., Dennis, E. B., Schmucki, R. et al. 2019. *The EU butterfly indicator for grassland species: 1990 – 2017. Technical report*. Abgerufen von https://butterfly-monitoring.net/sites/default/files/Publications/Technical%20report%20EU%20Grassland%20indicator%201990-2017%20June%202019%20v4%20%283%29.pdf

Swaay, C. A. M. v., Strien, A. J. v., Aghababyan, K. et al. 2016. *The European butterfly indicator for grassland species: 1990 – 2015* [Report VS2016.019]. Wageningen: De Vlinderstichting.

Swaay, C. v., Warren, M. & Loïs, G. 2006. Biotope use and trends of European butterflies. *Journal of Insect Conservation*, *10*, 189 – 209.

Swingland, I. R. 2001. Definition of biodiversity. In: S. A. Levin (Hrsg.), *Encyclopedia of Biodiversity* [Bd. I] (S. 377 – 391). Cambridge, MA: Academic Press.

Tälle, M., Fogelfors, H., Westerberg, L. & Milberg, P. 2015. The conservation benefit of mowing vs grazing for management of species-rich grasslands: A multi-site, multi-year field experiment. *Nordic Journal of Botany*, *33*, 761 – 768.

TEEB (The Economics of Ecosystems and Biodiversity). 2010. *The economics of ecosystems and biodiversity for local and regional policy makers*. London: Earthscan.

Theodorou, P., Radzevičiūtė, R., Lentendu, G. et al. 2020. Urban areas as hotspots for bees and pollination but not a panacea for all insects. *Nature Communications*, *11*, 576.

Thomas, J. A. 1995. The conservation of declining butterfly populations in Britain and Europe: Priorities, problems and successes. *Biological Journal of the Linnean Society*, *56*, 55 – 72.

Tilman, D., Reich, P. B. & Knops, J. M. H. 2006. Biodiversity and ecosystem stability in a decade-long grassland experiment. *Nature*, *441*, 629 – 632.

Tscharntke, T., Clough, Y., Wanger et al. 2012. Global food security, biodiversity conservation and the future of agricultural intensification. *Biological Conservation*, *151*, 53 – 59.

Tscharntke, T., Tylianakis, J. M., Rand, T. A. et al. 2012. Landscape moderation of biodiversity patterns and processes: Eight hypotheses. *Biological Reviews*, *87*, 661 – 685.

Tscharntke, T., Tylianakis, J. M., Wade, M. R. et al. 2007. Insect conservation in agricultural landscapes. In: A. J. A. Stewart, T. R. New & O. T. Lewis (Hrsg.). *Insect Conservation Biology* [Proceedings of the Royal Entomological Society's 23rd Symposium (S. 383 – 404). Wallingford: CABI.

Tuck, S. L., Winqvist, C., Mota, F. et al. 2014. Land-use intensity and the effects of organic farming on biodiversity: A hierarchical meta-analysis. *Journal of Applied Ecology*, *51*, 746 – 755.

Turin, H., & Boer, P. J. d. 1988. Changes in the distribution of carabid beetles in The Netherlands since 1880: II. Isolation of habitats and long-term time trends in the occurrence of carabid. *Biological Conservation*, *44*, 179 – 200.

UBA (Umweltbundesamt). 2015. *Abwasser-Reinigungsstufe auch über Abwasserabgabe finanzierbar*. Abgerufen von https://www.umweltbundesamt.de/themen/4-abwasser-reinigungsstufe-auch-ueber

UBA (Umweltbundesamt). 2018. Struktur der Flächennutzung in Deutschland. Abgerufen von: https://www.umweltbundesamt.de/daten/flaeche-boden-land-oekosysteme/flaeche/struktur-der-flaechennutzung#die-wichtigsten-flachennutzungen

UBA (Umweltbundesamt). 2019. *Umweltbewusstsein in Deutschland 2018: Ergebnisse einer repräsentativen Bevölkerungsumfrage*. Berlin: Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit.

UBA (Umweltbundesamt). 2020. Inlandsabsatz einzelner Wirkstoffgruppen in Pflanzenschutzmitteln. Abgerufen von https://www.umweltbundesamt.de/sites/default/files/medien/384/bilder/dateien/3_abb_inlandsabsatz-einz-wsg-psm_2020-05-05_0.pdf

UN-Dekade Biologische Vielfalt. 2018. *Das Konzept der Eh da-Flächen*. Abgerufen von https://www.undekade-biologischevielfalt.de/index.php?id=49&tx_lnv_pi1%5Bwettbewerb%5D=2370&tx_lnv_pi1%5Baction%5D=show&tx_lnv_pi1%5Bcontroller%5D=Wettbewerb&no_cache=1

WBAE (Wissenschaftlicher Beirat für Agrarpolitik, Ernährung und gesundheitlichen Verbraucherschutz). 2010. *EU-Agrarpolitik nach 2013: Plädoyer für eine neue Politik für Ernährung, Landwirtschaft und ländliche Räume* [Stellungnahme des Wissenschaftlichen Beirates für Agrarpolitik beim Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz]. Berlin: Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz.

WBAE (Wissenschaftlicher Beirat für Agrarpolitik, Ernährung und gesundheitlichen Verbraucherschutz). 2018a. Für eine gemeinwohlorientierte Gemeinsame Agrarpolitik der EU nach 2020: Grundsatzfragen und Empfehlungen [Stellungnahme]. *Berichte über Landwirtschaft, Sonderheft 225*.

WBAE (Wissenschaftlicher Beirat für Agrarpolitik, Ernährung und gesundheitlichen Verbraucherschutz). 2018b. *Für eine gemeinwohlorientierte Gemeinsame Agrarpolitik der EU nach 2020: Grundsatzfragen und Empfehlungen* [Stellungnahme]. Abgerufen von https://www.bmel.de/SharedDocs/Downloads/DE/_Ministerium/Beiraete/agrarpolitik/GAP-GrundsatzfragenEmpfehlungen.pdf?__blob=publicationFile&v=3

WBAE (Wissenschaftlicher Beirat für Agrarpolitik, Ernährung und gesundheitlichen Verbraucherschutz). 2019. *Zur effektiven Gestaltung der Agrarumwelt- und Klimaschutzpolitik im Rahmen der Gemeinsamen Agrarpolitik der EU nach 2020*. Abgerufen von https://www.bmel.de/SharedDocs/Downloads/DE/_Ministerium/Beiraete/agrarpolitik/Stellungnahme-GAP-Effektivierung-AUK.pdf?__blob=publicationFile&v=2

Weingarten, P., Fährmann, B. & Grajewski, R. 2015. Koordination raumwirksamer Politik: Politik zur Entwicklung ländlicher Räume als 2. Säule der Gemeinsamen Agrarpolitik. In: H. Karl (Hrsg.), *Koordination raumwirksamer Politik: Mehr Effizienz und Wirksamkeit von Politik durch abgestimmte Arbeitsteilung* (S. 23 – 49). Hannover: Akademie für Raumforschung und Landesplanung.

Wenzel, M., Schmitt, T., Weitzel, M. & Seitz, A. 2006. The severe decline of butterflies on western German calcareous grasslands during the last 30 years: A conservation problem. *Biological Conservation*, *128*, 542 – 552.

Wesche, K., Krause, B., Culmsee, H. & Leuschner, C. 2012. Fifty years of change in Central European grassland vegetation: Large losses in species richness and animal-pollinated plants. *Biological Conservation*, *150*, 76 – 85.

Westrich, P., Frommer, U., Mandery, K. et al. 2011. Rote Liste und Gesamtartenliste der Bienen (Hymenoptera, Apidae) Deutschlands. *Naturschutz und Biologische Vielfalt*, *70*, 373 – 416.

Wezel, A. 2017. *Agroecological practices for sustainable agriculture: Principles, applications, and making the transition*. Singapur: World Scientific Publishing Europe.

Wietzke, A., Westphal, C., Gras, P. et al. 2018. Insect pollination as a key factor for strawberry physiology and marketable fruit quality. *Agriculture, Ecosystems & Environment*, *258*, 197 – 204.

Willer, H. & Lernoud, J. 2019. *The World of Organic Agriculture. Statistics and Emerging Trends 2019*. Research Institute of Organic Agriculture (FiBL), Frick, and IFOAM – Organics International, Bonn.

Williams, P. H. 1982. The distribution and decline of British bumble bees (Bombus latr.). *Journal of Apicultural Research*, *21*, 236 – 245.

Winfree, R. & Kremen, C. 2009. Are ecosystem services stabilized by differences among species? A test using crop pollination. *Proceedings of the Royal Society B: Biological Sciences*, *276*, 229 – 237.

Winfree, R., Fox, J. W., Williams, N. M. et al. 2015. Abundance of common species, not species richness, drives delivery of a real-world ecosystem service. *Ecology Letters*, *18*, 626 – 635.

Wissenschaftlicher Beirat zum Nationalen Aktionsplan Pflanzenschutz. 2019. *Pflanzenschutz und Biodiversität in Agrar-ökosystemen* [Stellungnahme]. Berlin: Bundesministerium für Ernährung und Landwirtschaft.

Wolter, M. 2017. *Ökologische Leistungen der Mutterkuhhaltung in Wert setzen: „Landwirtschaft für Artenvielfalt“*. Abgerufen von http://docplayer.org/105928340-Oekologische-leistungen-der-mutterkuhhaltung-in-wert-setzen-landwirtschaft-fuer-artenvielfalt-artenreiches-gruenland-insel-vilm.html

Würriehausen, N., Ihle, R. & Lakner, S. 2015. Price relationships between qualitatively differentiated agricultural products: Organic and conventional wheat in Germany. *Agricultural Economics*, *46*, 195 – 209.

Yachi, S. & Loreau, M. 1999. Biodiversity and ecosystem productivity in a fluctuating environment: The insurance hypothesis. *Proceedings of the National Academy of Sciences*, *96*, 1463 – 1468.

Zander, K. & Hamm, U. 2010. Consumer preferences for additional ethical attributes of organic food. *Food Quality and Preference*, *21*, 495 – 503.

Zinngrebe, Y., Pe’er, G., Schueler, S. et al. 2017. The EU’s ecological focus areas: How experts explain farmers’ choices in Germany. *Land Use Policy*, *65*, 93 – 108.

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