CropLife International
Biodiversity Project

REPORT ON CROPLIFE INTERNATIONAL MEMBERS' ACTIVITIES RELATING TO BIODIVERSITY AND CLIMATE

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1. Introduction

In 2020, on behalf of CropLife International, a survey was undertaken to provide information on actions and programs by company members (BASF, Bayer, Corteva, FMC, Sumitomo, Syngenta) to support biodiversity and help mitigate the effects of climate change, and to contribute to the industry's meaningful engagement in global discussions around the post-2020 biodiversity framework. While this type of information is frequently available through various on-line sites and publications, this report aims to systematically collate a wide range of contributing activities, provide detail and links to original data and studies, and conclude on selected programs that can be scaled up to support Best Management Practices (BMPs). Although extensive, this report cannot be considered a fully comprehensive survey due to the large number of projects which have been undertaken over many years, and the recent rapid launch of new initiatives driven by the 2020 focus on biodiversity.

2. Biodiversity definition and scope

Under Article 2 of the Convention on Biodiversity,[5] "biological diversity" means the variability among living organisms from all sources including inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and among ecosystems.

The Food and Agriculture Organization of the United Nations (FAO) report, "The State of the World's Biodiversity for Food and Agriculture (2019),"[6] defines biodiversity for food and agriculture as a subset of biodiversity that contributes in one way or another to agriculture and food production. It includes the domesticated plants and animals raised in crop, livestock, forest and aquaculture systems, harvested forest and aquatic species, wild relatives of domesticated species, other wild species harvested for food and other products, and "associated biodiversity" – the vast range of organisms that live in and around food and agricultural production systems, sustaining them and contributing to their output. Agriculture is taken here to include crop and livestock production, forestry, fisheries and aquaculture.

There is an inherent conflict between agriculture and biodiversity. Agriculture reduces natural biodiversity in favor of the crop, yet some of the biodiversity in many parts of the world is dependent on human interference. The challenge is to balance biodiversity protection with productivity. This is not a new dilemma. It is often difficult to distinguish "natural," "semi-natural" and "man-made" landscapes, depending on the time scale considered. Humankind has influenced landscapes, nature and biodiversity for thousands of years. Even prime biodiversity hotspots appear to have been influenced by human activity for centuries though they may be perceived as "pristine." In Amazonia, pre-Colombian societies domesticated large portions of their landscape to make them more productive, including plant and animal populations. Growing populations caused long-term modifications in soils, creating Amazonian dark earths and transforming naturally biodiverse forests into anthropogenic forest landscapes (Clement et al. 2015).[7] For example, Levis et al. (2017)[8] concluded that forests close to pre-Colombian archaeological sites often have a higher abundance and richness of domesticated species so today's Amazonian tree communities across the basin remain largely structured by historical human use.

Similarly, much, and perhaps most, of the landscape in Europe and the Middle East has been touched by the expansion of agriculture from the "Fertile Crescent" around 6,000 years ago and its development into pastoral farming and arable and perennial crops. Nature has adapted to and become dependent on these man-influenced landscapes. For example, the weed flora and soil disturbance associated with agriculture and forest clearance is fundamental to many solitary bees which probably expanded their range from the Fertile Crescent.

The complexity of biodiversity means that potential solutions to its loss are also complex. Simplistic solutions are unlikely to be successful unless combined with many others and sufficient research is undertaken to prevent "regrettable substitutions" of current technologies with new techniques that may have unexpected and severe consequences.

The Global Biodiversity Outlook 5[9] summary of the target achievement for "Aichi target number 7: By 2020, areas under agriculture, aquaculture and forestry are managed sustainably, ensuring conservation of biodiversity" (page 64) states that: "There has been a substantial expansion of efforts to promote sustainable agriculture, forestry and aquaculture over recent years, including through farmer-led agroecological approaches. The use of fertilizers and pesticides has stabilized globally, though at high levels. Despite such progress, biodiversity continues to decline in landscapes used to produce food and timber; and food and agricultural production remains among the main drivers of global biodiversity loss. The target has not been achieved."

As a potential solution, eight interdependent "transitions to sustainable pathways" are identified (pages 20-21). All are relevant to CropLife International member companies as responsible members of and contributors to society, but five are particularly pertinent so they are quoted in full below:

1. The land and forests transition: conserving intact ecosystems, restoring ecosystems, combating and reversing degradation and employing landscape level spatial planning to avoid, reduce and mitigate land-use change. This transition recognizes the essential value of well-conserved habitats for the maintenance of biodiversity and the provision of ecosystem services for the benefit of people, and the need to move to a situation in which maintaining and improving food security no longer involves the large-scale conversion of forests and other ecosystems.

2. The sustainable agriculture transition: redesigning agricultural systems through agroecological and other innovative approaches to enhance productivity while minimizing negative impacts on biodiversity. This transition recognizes the role of biodiversity, including pollinators, pest and disease control organisms, soil biodiversity and genetic diversity, as well as diversity in the landscape for productive and resilient agriculture that makes efficient use of land, water and other resources.

3. The sustainable food systems transition: enabling sustainable and healthy diets with a greater emphasis on a diversity of foods, mostly plant-based, and more moderate consumption of meat and fish as well as dramatic cuts in the waste involved in food supply and consumption. This transition recognizes the potential nutritional benefits from diverse foods and food systems, and the need to reduce demand-driven pressures globally while ensuring food security in all its dimensions.

4. The sustainable climate action transition: employing nature-based solutions alongside a rapid phase-out of fossil fuel use to reduce the scale and impacts of climate change, while providing positive benefits for biodiversity and other Sustainable Development Goals. This transition recognizes the role of biodiversity in sustaining the capacity of the biosphere to mitigate climate change through carbon storage and sequestration and in enabling adaptation through resilient ecosystems as well as the need to promote renewable energy while avoiding negative impacts on biodiversity.

5. The biodiversity-inclusive One Health transition: managing ecosystems, including agricultural and urban ecosystems as well as the use of wildlife, through an integrated approach to promote healthy ecosystems and healthy people. This transition recognizes the full range of linkages between biodiversity and all aspects of human health, and addresses the common drivers of biodiversity loss, disease risk and ill health.

These are quoted in full because CropLife International members are actively involved in implementing and promoting aspects of each transition pathway (indicated by underlined text) and key components of the sustainable agriculture transition listed in Global Biodiversity Outlook 5 (pages 160-162):

- Promote integrated pest and disease management.
- Enhance management of land and water.
- Integrate systems of crops, livestock, fish and/or tree production.
- Maintain biodiversity.
- Promote online learning and research.
- Improve connections between farmers and consumers.
- Provide an enabling environment.

The related activities of the member companies of CropLife International have been collated, summarized and assessed using the method described in the next section.

3. Method

CropLife International member companies agreed to nominate a point person in their company to support quick access to the main projects and related documentation. While there is a focus on key science-based projects, other informal approaches by industry in relation to biodiversity are summarized as they provide the CLI BTF with additional learnings and ideas on opportunities for meaningful engagement with third parties.

This report aims to include, where possible:

- A systematic overview and detailed summaries of key activities by industry in relation to biodiversity;
- The key outcomes and data, i.e., what has been achieved in support of biodiversity (SMART criteria – Specific, Measurable, Achievable, Relevant, Time-bound – including the identification of projects that can be scaled up);
- Projects designed to address the broader nexus of climate change and biodiversity;
- Short summaries of the relevant informal engagements by the industry, with an emphasis of the means of engagement and perception by stakeholders; and
- Consideration of regulatory studies for their contribution to the biodiversity discussion.

The FAO State of the World's Biodiversity for Food and Agriculture[10] 2019 report, Figure 4.2, categorizes four major factors influencing biodiversity as received from country reports. Those considered to be directly relevant to this CropLife International report are used to categorize members' activities and contributions to the maintenance and expansion of biodiversity in agriculture (Table 1). These categories largely reflect the transitions described in Section 2.

Table 1: FAO factors influencing biodiversity and related company activities

Adapted from the FAO State of the World's Biodiversity for Food and Agriculture 2019 report[10]

Factor(s) to be addressed	CropLife International and member company activities
Agricultural intensification and expansion	Provide financial mechanisms, seeds, inputs including chemicals and biologicals, digital tools and precision farming for high productivity with less environmental impact and potentially reducing the need to expand agricultural land
Changes in land use, deforestation, habitat alteration and loss, water-cycle alteration	Provide tools for sustainable intensification: • reduce (or eliminate) further agricultural expansion • improve farm practices and soil structure to reduce erosion and run-off while improving water retention • improve and create wildlife habitats
Pests, diseases and invasive species	Provide the tools used in agriculture to maintain the supply of safe and plentiful food, and manage invasive species
Climate change	Provide techniques and tools to reduce the energy and agronomic input requirements of agriculture and to facilitate carbon sequestration and reduce greenhouse gas (GHG) emissions

Where possible, projects have been selected for which scientific data are available to demonstrate their impact. However, data are not available for all projects. It would be unfortunate to lose these company projects as they contribute to the awareness of the importance of biodiversity in agriculture, show how to improve biodiversity and illustrate companies' related activities. Some of these project summaries are sourced from "reputation" sections of corporate web pages. Where those pages include links to independent sources, they have been included in this report. Desktop research has been carried out to find independent sources on other projects, but they are not available for all projects. A small number of projects have been provided by members as "personal communications" and have no further background information. Reference sources have been checked during the preparation of this report in August and September 2020.

The projects are described under biodiversity- and climate-related topic headings. Within each of these sections, there is a mixture of types of projects:

- Practical projects implemented at the field level. Those which have developed significant scientific data are highlighted in boxes.
- Initiatives that affect technologies, company operations or policies.

Finally, conclusions are drawn on the effectiveness of the projects, lessons learned and whether they can be expanded to have widescale impact. These conclusions are, of course, subjective and reflect the opinion of the author.

4. Biodiversity implementation measures

This section is an attempt to categorize biodiversity improvement measures which may be implemented, while recognizing that there are different interpretations and classifications of these measures. Included are those affecting the three compartments of soil, water and air, and those which impact flora, fauna and climate (Table 2). Essentially, this is about the resilience of agricultural land and enhancing ecosystem services while dealing with climate change, addressing socio-economic concerns and meeting requirements for food, feed and other commodities for a growing population. Agriculture and biodiversity have to be balanced in such a way that ecological and societal needs are met while identifying and accepting trade-offs between them. Selected pictorial examples applied to arable farming are shown in a German brochure on Ecological Focus Areas.[11] Some interventions may increase the yield per unit area (e.g., multiple crops per year, breeding to enhance yield and tolerance of biotic and abiotic factors) which can reduce the need for extending the agricultural area, particularly if combined with fiscal incentives. Conversely, others may reduce yields and potentially lead to the extension of cropped areas to achieve the required volume of produce (e.g., increasing row width or reducing the seed rate in arable crops).

Agronomic systems are usually comprised of several interacting factors and inputs. Changing one of these is likely to change other parameters in the agronomic system. Systems develop around the technologies available to the grower whether following simple, traditional methods or new technologies, and individual farmers may have different perceptions and requirements related to their business and local conditions.

Table 2: Changes in land use and agricultural practices that lead to more resilience and increase biodiversity

	Agricultural activity	Target	Example
Direct action to improve biodiversity			
1. Field/farm scale: Landowner/manager			
Uncropped (set-aside) land	Outside cropped area	Field margins	Sympathetic management of edges, border areas and created areas (e.g., wildflower seeding and tree planting)
		Marginal and less-productive areas of farms	Wetlands, low fertility, steep slopes, etc.
		Fallow	Overwintered stubbles
		Scrub and woodland	Use existing structure and develop new ones
		Anti-erosion measures	Field edge buffers to water bodies
		Protection from grazing	Fenced areas to exclude livestock
	In-crop or field	Thresholds for weed removal (herbicide or mechanical)	Maintain weed growth which has low impact on crops
		Maintain ground cover in-crop	Vegetated areas between rows or trees in perennial crops
		Targeted interventions	Skylark plots, fallow plots in arable crops, etc.
		Anti-erosion measures	Anti-erosion strips (on contours, e.g., prairie strips)
Soil management	Fundamental to crop health, reducing erosion, etc.	Increase soil carbon/organic material (C-sink)	Use of conservation/minimum/no tillage; planting cover crops, integrating livestock, etc.
		Maintain/improve biodiversity of soil organisms	"Feed the soil" – same measures as above plus application of manure, compost, lime, micronutrients, special inoculants, etc.

Arable land	Crop rotation	Choice of crops	Mixed agriculture, crop rotation, balance of spring/winter-sown crops, perennial crops
		Cover crops and fallows	Use of over-winter crops like mustard to reduce leaching of nutrients
	Extensification	Reduce seed rate, increase row width	Strips in conventional cropping, etc.
	Inter-cropping, companion crops	Full and relay inter-cropping	Under-sowing cereals with clover; maize or cowpea with cassava; chili pepper with coffee, etc.
Grass and pasture-land	Hay instead of silage	Reduced intensity grassland	Allow flowering of plants, reduce impact on insects and birds
	Extensification	Reduced intensity grassland	Reduced and delayed mowing, lower livestock density, managed and free-range grazing
Complex systems	Arable and livestock farming	Mixed farming	Agriculture with forestry in tropics, crop and animal farming, landscape features (see 2 below)
2. Landscape-scale ("broad habitat provisioning"): Cooperative activity – multi-stakeholder			
Corridors and networks	Landscape connectivity	Marginal land (e.g., around waterways, tracks, field margins)	Reduce fragmentation, use existing structure and develop new structure
Landscape design	Preservation of existing natural/ semi-natural habitats		
	"Agro-ecosystem Resilience Enhance-ment Measures"		
Scale up of potential impact on biodiversity	Size of area preserved and connectivity of habitats, including wetlands, woodlands, forests, grassland and specialized habitats		
Land restoration	Improvement of degraded land	Degraded agricultural land	Soil health management and improved agricultural systems or reversion to uncropped land
		Degraded non-agricultural land (e.g., industrial)	Removal of contaminants, soil health management and cropping systems or reversion to uncropped land
Re-wilding	Minimal intervention to allow natural regeneration	Alternative to "conventional" nature reserve and landscape management	Minimum intervention, importance of grazers and predators
Management of inva-sive alien species	Protection of agricultural and non-agricultural areas	Reduce substitution of native species	Management of invasive species at local level (in nature reserves and pasturelands) and regional/ national level

Indirect support for biodiversity			
3. Sustainable intensive agriculture (land sparing)			
Increase output/ unit land	Yield improvement	Seed (breeding, genetics)	Increased yield per unit area
		Production technologies	Precision agriculture and use of data
			Reduce adverse impact of inputs (safer pesticides, biological products, etc.)
			ICM and IPM and other agricultural production systems
	Multiple harvests per year	Agronomic systems	Sequential cropping, e.g., several crops per year planted sequentially on arable land in Brazil
Eliminate/reduce land clearance (also impact on GHG emissions)	Natural ecosystems	Forest and savannah clearance for new agricultural land, etc.	Fiscal/financial/other incentives for growers to benefit from biodiversity-related actions
	Semi-natural habitats	Traditional extensive pastureland, e.g., olive and cork groves in Mediterranean	Fiscal/financial/other incentives for growers to benefit from biodiversity-related actions
Extensification (land sharing)	Existing crop land	Importance of small farmers for diversity of cropping	See also extensific tion in direct improvement above
		Reduce intensity of cropping	Policies for reduced intensity agriculture at landscape/regional levels

Indicators and metrics

It is critical to know the impact of interventions to understand whether the objectives have been met. Biodiversity is a complex topic and measures may be costly, merely cosmetic or even have unexpected negative consequences. Effective measurement of the impact of interventions can be complicated and time-consuming, reflecting the complexity of biodiversity itself, but when it is undertaken well, it provides valuable information on whether an intervention can be scaled up and used more widely. Time scale is also a critical factor in both implementation and assessing success:

- Short-term impacts up to five years, such as changes in pollinator populations after the introduction of wildflower strips, noting that short-term changes in populations are highly susceptible to weather conditions and natural cycles.
- Medium-term impacts up to 20 years, such as changes in bird species following planting new woodlands.
- Long-term impacts up to and beyond 100 years might include changes in national and international biodiversity indices.

CropLife International member companies have an opportunity to show their current contribution to reversing the decline of biodiversity and how they can further contribute by:

- Continuing to improve yields and reduce the need for further expansion of agricultural land while reducing the actual and potential impacts of their products on both biodiversity and GHG emissions;
- Creating new value-capture mechanisms to allow farmers to gain income from the ecosystem services that natural vegetation provides to incentivize maintenance of natural and semi-natural land, reducing conversion to agriculture;
- Identifying and characterizing problems or situations, then developing and promoting interventions which favor biodiversity and the resilience of agriculture that can be implemented by growers with the identification of BMPs; and

- Working with stakeholders to build trust and demonstrate the impact of what is being done to support biodiversity.

These activities also contribute to three main principles of "eco-based adaptation in the food and agriculture sector"[12] as proposed by the FAO for long-term sustainability of food production:

1. Protecting and enhancing the functioning of these agro-ecosystems and biodiversity for food and agriculture;

2. Increasing agricultural productivity and the resilience of agricultural livelihoods; and

3. Ensuring food security in the context of climate change.

Targets, quality data, indicators and audits are basic requirements to monitor progress, impact and benefit of such activities, as well as assuring stakeholders. CropLife International members have all set transparent targets in their corporate sustainability strategies. Links to these targets and annual reports are given in Annex I (company commitments on biodiversity). Reporting frequently follows international standards such as the Global Reporting Initiative[13] and principles of the UN Global Compact,[14] and statements on non-financial targets are independently assured by independent experts. Members are also guided by the Responsible Care Global Charter.[15] The process used by individual companies can be found using the links in Annex I. At the individual project level covered by this CropLife International report, many projects have not been subject to audit but, as noted in Section 3 "Methods" (page 5), independent sources have been included where they have been found and peer-reviewed publications are referenced where available.

5. Overview of company strategies related to biodiversity

All member companies have strategies that include "sustainability," each differing depending on its businesses and strengths. The companies have sustainability reports which report progress against specified goals, but new or recently redesigned companies have only recently set their goals and will report in the future (Corteva and FMC). Most of the member companies have agriculture-related sustainability goals. Sumitomo Chemical Co., Ltd (Sumitomo) has taken a different approach with a set of high-level corporate sustainability goals which feed into a wide range of businesses. Each company's achievements towards their sustainability goals are summarized in the appendix to this report.

"Biodiversity" is specifically mentioned in the corporate sustainability goals of BASF, Bayer, Corteva and Syngenta. FMC and Sumitomo both focus on the sustainability of their operations and products, which are also covered in the strategies of the other companies.

- BASF: "Biodiversity and ecosystems" is one of the three high-level corporate goals.

- Bayer CropScience: "Biodiversity and soil health" is one of six "Sustainability Focus Areas" to balance the need for crop production and nature conservation to ensure a healthy environment.

- Corteva: "Enhance biodiversity" is a goal under the high-level goal to benefit farmers.

- Syngenta: "Help biodiversity flourish" is a goal under its Good Growth Plan.

There is a common theme among the six companies that using their technologies and products – which increase crop yield per unit of land while decreasing environmental impact of their use – is beneficial to biodiversity by reducing the need for additional land to be converted to agriculture. This is frequently related to other environmental issues such as water use and quality, reduction of GHG emissions and broader impact of company operations and products on climate.

Themes presented in Table 3 are based on those listed in Section 3, which are taken from the FAO 2019 report, with examples of strategies and projects from the member companies.

The public statements and policies of these companies are provided in Annex I. References are made to them in the coming sections so there is some repetition where the statements and policies are relevant to the main sections of the report.

Table 3: Company activities related to four key FAO parameters affecting biodiversity, excluding corporate branding strategy

(A non-exhaustive list of projects and initiatives; more are described in sections 6-9.)

Factor(s) to be addressed	Objective	BASF	Bayer	Corteva	FMC	Syngenta	Sumitomo
Corporate strategy branding		"Sustainable Agriculture. Right Balance. Better Yield."	"Health for all, hunger for none."	"In it for good"	"Tomorrow's harvest"	"Good Growth Plan"	"For a sustainable future"
Agricultural intensificati-on and expansion	Increase crop yield while decreasing environmen-tal impact	Build/lead a movement for sustainable agriculture, AgBalance, projects in coconut and castor bean	Balance the need for crop production and nature conservation to ensure a healthy environment; reduce the environmen-tal impact of crop protection; agro-ecosystem resilience	Enable farmers to sustainably increase crop yields	R&D for sustainable products providing innovative solutions to food security	Increase average productivity of the world's major crops by 20% without using more land, water or inputs	Plant growth regulators and biorationals derived from naturally occurring contribute to sustainable agriculture and the stable supply of safe and secure food
Changes in land use, deforestati-on, habitat alteration and loss, water cycle alteration	Enhanced field margins and in-field strips including wildflowers/ pollinators	Monarch flower strips, bee network, farm network	Bee health, monarch butterfly, honeybee and "Feed a Bee" research programs	"Resilient and ready" project		Enhance biodiversity of farmland, Operation Pollinator, multi-functional field margins	Collaborati-on in a range of partnerships and initiatives related to pollinators, water quality and habitats
	Habitat protection and restoration	Mata Viva, Argan forest, Fundacao Espaco Eco	Restoration of native habitats with a focus on U.S. (western rangelands), Brazil (re-forestation in 3 biomes; avoid deforestation), New Zealand (pine management), Germany (upper Rhine valley)	Enhance biodiversity on grazing land and natural ecosystems		Ecoaguas in Brazil, coffee agro-forestry, landscape connectivity	

	Soil health and biodiversity improvement	Microbial soil inoculant, N-management	Soil Health Partnership, Root2Success	Resilience of arable land, improve soil health	Soil health business area	Soil health initiative, healthy soils for smallholders, conservation agriculture, Reverte in Brazil	Biorationals: rhizosphere, microbial agricultural materials
Pests, diseases and invasive species	Agro-ecology and agro-forestry		Management of olive groves			Multi-functional field margins	
	Innovation	wHen2g0 application system	DripbyDrip irrigation, Smart weeding system, Climate FieldView	Smart-Strike weed identification	Sustainability assessment tool, ARC farm intelligence	SmartBio	Biorational products, Sumika Sustainable Solutions
	Invasive species		Rejuvra. Integrated vegetation management	Integrated vegetation management in utility rights of way and pasture-land, e.g., Recanto Ranch			
Climate change	Carbon sequestration		GHG reduction commitment, rewarding farmers for climate smart practices			Carbon neural agriculture, Climate Smart Agriculture	Cooperation to develop carbon cycle technologies to reduce emissions of greenhouse gasses
	Soil health		Minimal tillage, Soil Health Partnership, nitrogen management			Healthy soil for small-holders, SOWAP	Global Soil Health Initiative

The agricultural chemicals industry, and CropLife International members specifically, have different levels of control over different aspects of biodiversity improvement. There can be full control only over biodiversity at their own facilities and land, such as manufacturing sites and seed facilities, but the provision and promotion of products and advice to users has the potential to affect biodiversity more broadly. In terms of product use, there may be significant levels of control where technology users are licensees for company products but for most products there is little or no control over the behavior of users unless controls are built into the product itself or the system for its use. Consequently, stewardship and the promotion of best practices are important to undertake biodiversity improvement and minimize environmental impact. CropLife International and its member companies promote and incentivize agri-environment and other schemes with the support of government legislation and non-governmental organizations. CropLife International promotes stewardship,[16] Integrated Pest Management[17] and other best practices on CropLife.org[18] and in its extensive farmer training (see Annex II, 5.1).

CropLife International member companies provide tools for sustainable intensification of food production and guidance to growers on maintaining and enhancing biodiversity while minimizing environmental impacts of operations which use their products. Governments and NGOs provide further guidance and implement compliance and enforcement mechanisms. Additionally, grower certification organizations (e.g., Global-GAP,[19] PrimusGFS[20]) and investors (e.g., Nuveen[21]) provide guidance and checks on growers. The various stakeholders are complementary and interact to provide "checks and balances" to encourage the design, implementation and use of best practices.

Several CropLife International member companies are involved with the WBCSD (World Business Council for Sustainable Development). Although perhaps out of the strict scope of this report, these activities are mentioned to underline the scale at which sustainable agriculture is important to these companies. The WBCSD has specialist activity groups, such as the Food & Nature Program,[22] to accelerate system transformation in the areas of food, nature and water by bringing leadership standards and tools, advocacy and projects across the value chain – from production to consumption – which deliver impact at scale where the agendas of climate, nature and food systems intersect. The Scaling Positive Agriculture[23] project aims to transform global food systems by maximizing the potential of agriculture as a solution for climate, nature and farmers. The project focuses on three priority pathways where business can provide real solutions:

1. Climate positive – shifting agriculture from a net source to a net sink of GHG emissions

2. Nature positive – shifting agriculture from being the main driver of nature loss to a regenerator of nature

3. Farmer positive – strengthening agriculture's role in supporting resilient, productive farming and food-producing communities

Three CropLife International member companies have joined this project. Other initiatives and projects under the WBCSD umbrella are included under specific topic sections in this report. Whether or not individual companies are also members of the WBCSD, the projects described reflect these three pathways.

Another global business coalition which acts to protect and enhance nature and biodiversity is Business for Nature.[24] The community is inclusive and composed of a diverse and powerful group of organizations and networks working with businesses to reverse the loss of nature, notably businesses that have relevant commitments and are acting to reduce their environmental impacts. Business for Nature is amplifying a business movement for nature by:

1. Convening a united business voice to influence key political decisions regarding nature in 2020 and beyond. The coalition is calling for a global framework that will reverse nature loss through policies that protect and restore nature and incentivize its sustainable use.

2. Demonstrating business ambition and action to protect and enhance nature by aggregating, amplifying and helping scale existing business commitment platforms.

3. Showcasing business solutions that are already translating commitments into action and meaningful impact and driving business decisions.

4. Communicating the business case for reversing nature loss to galvanize change in our global economy to incorporate nature.

Commitments involving CropLife International members include:

- Biodiversity through Act4Nature[25]
- The Brazilian Business Commitment on Biodiversity[26]
- Climate Smart Agriculture (CSA 100) commitment – Section 9

6. Agricultural intensification and expansion

Factor	CropLife International
Agricultural intensification and expansion	Provide seeds, inputs including chemicals and biologicals, digital tools and precision farming for high productivity with less environmental impact, potentially reducing the need to expand agricultural land

6.1 High productivity with less environmental impact

CropLife International member companies make commitments to research and development which contribute to sustainability. The concept of higher productivity with less environmental impact is fundamental to the members' business strategies. Consequently, many of the activities in sections 7-9 are also relevant to this topic. Only a couple of examples are given here but links to member company websites and relevant topics within them are given in Annex I.

One of FMC's sustainability goals[27] is that by 2025, 100% of the research and development (R&D) spend will be on sustainable products, providing innovative solutions to food security and a commitment to creating products that are consistently better for the planet than any that currently exist in the market. Linked to this are targets to support two SDGs:

- SDG 2 – Zero Hunger: develop products that increase crop yields, ensure a quality food supply, and technologies that contribute to resilient agricultural practices.
- SDG 15 – Life on Land: technologies that save water, fuel, reduce GHG emissions and soil compaction; products that increase crop yields preserving land from conversion to farmland; targeted and low application rate products; biological products; continued commitment to R&D spend on developing sustainable products.

Syngenta's Good Growth Plan[28] outlines a set of targets to improve the sustainability of agriculture by 2020 by reducing agriculture's carbon footprint and helping farmers deal with the extreme weather patterns caused by climate change. Accelerated innovation[29] will be achieved by committing to invest $2 billion in sustainable agriculture breakthroughs with two new sustainable technology breakthroughs per year. The 2019 Sustainable Business Report[30] shows that most of the goals had been achieved by 2019 – a year earlier than scheduled. It states that reference yields from 1,659 farms have been increased by 18.8% compared to 1,928 benchmark farms and recorded efficiency improvements of more than 20% for nutrient and pesticide application.

The AgBalance® Model[31] follows the concept of Life Cycle Assessment to assess sustainability in the farming sector, applying the principles of the framework defined by ISO 14040 and ISO 14044 standards. The development is based on the Eco-Efficiency Analysis,[32] with the addition of nutrient balances and biodiversity, to offer a comprehensive assessment of the impacts of cultivation systems. A Biodiversity Calculator[33] allows farmers to estimate the impact of their farming practices on the conservation of biodiversity, based on the region a farm is in and various interventions.

At a practical farm level, scientists and breeders have developed short stature maize[34] that is better able to stand up to weather extremes without lodging and allow for more flexible in-season crop accessibility to make inputs more precise. This concept (the Vitala system[35]) aims to help farmers grow enough while using natural resources more efficiently, using a much higher density of plants (up to 40%) without increasing fertilizer or water use.

If a forest plantation is well managed, it can deliver more cubic meters of wood (or pulp) in fewer hectares, which in turn preserves native forests and encourages greater biodiversity and the protection of environmentally sensitive areas. In Brazil, research has shown that new innovations could provide significant benefits compared to the current tools used in forestry. Bayer has developed new products[36] that require fewer applications (meaning less water usage and carbon emissions) to achieve long-lasting weed control, which allows planted forests to achieve greater productivity. Implementing native species afforestation programs and including the use of herbicides to control invasive grass species has been found to provide three times greater above-ground biomass and improved species richness compared to less intensive, spontaneous regeneration methods thanks to well-selected native seedlings and modern agronomic technology. It is estimated that for each hectare of planted forests in Brazil, the forestry sector protects 0.7 hectares of natural area. More detail related to this topic is given in sections 7, 8 and 9.

7. Changes in land use, deforestation, habitat alteration and loss, water-cycle alteration

Factors	CropLife International
Changes in land use, deforestation, habitat alteration and loss, water-cycle alteration	Provide tools for sustainable intensific tion: • reducing (or eliminating) the need for further agricultural expansion • removing one driver of land use changes • improving farm practices and soil structure to reduce erosion and run-off while improving water retention

There is debate about the area to be given to nature in a farming landscape. In Europe, reference is frequently made to having 10% of farmland set aside for biodiversity, for example:

- The European Union (EU) Biodiversity Strategy 2030[37] includes a section on "bringing nature back to agricultural land," including a policy target to establish biodiversity-rich landscape features on at least 10% of farmland to provide space for wild animals, plants, pollinators, natural pest regulators, terrace walls and ponds which help enhance carbon sequestration; prevent soil erosion and depletion; filter air and water; and support climate adaptation. In addition, the strategy is based on the belief that more biodiversity often helps lead to more agricultural production. EU Member States will need to translate the 10% target to a lower geographical scale to ensure connectivity among habitats.
    - The strategy includes the use of buffer strips, rotational or non-rotational fallow land, hedges and non-productive trees.
- A BirdLife International policy briefing[38] proposes 10% "space for nature" on all farms with several references as supporting evidence. Among these references, one proposes >5% and another suggests 26-33% may be required but none specify 10%.
- A chart of "effective and less effective options within the Ecological Focus Area in the EU 2015" shows that a much greater area of farmland is down to "less effective options" (nitrogen-fixing crops and catch crops) than "effective options" (fallow and buffer strips). Fallow and buffer strips already cover nearly 30% of Ecological Focus Areas.

Work by the German Federal Agency for Nature Conservation (Bundesamt für Naturschutz,[39] BfN), to be published, concluded that 15-20% of non-agricultural area may be needed at landscape level (i.e., not at individual farm level) to restore or maintain a certain level of biodiversity. A paper[40] published in September 2020 argues for increasing native habitats to at least 20% of working landscape area where it is below this minimum, and for maintaining native habitat at higher levels where it currently exceeds the 20% minimum. This has benefits for food security, nature's contributions to people, and the connectivity and effectiveness of protected area networks in biomes in which protected areas are underrepresented. Linking habitats to create a network[41] helps reduce fragmentation of habitats to support the survival of many plants and animals, and plans are in place to create this at the national level in Germany.

Many of the landscape features and enhancements mentioned in these documents are already amongst the projects and recommendations of CropLife International member companies described in this section.

7.1 Land management and use of resources

In Europe, member companies of CropLife International are also members of CropLife Europe (formerly the European Crop Protection Association).[42] The latter is a member of a coalition with the European Conservation Agriculture Federation,[43] Spanish Association for Conservation Agriculture and French Association for Conservation Agriculture[44] in the Initiative for Sustainable Productive Agriculture (INSPIA).[45] The INSPIA project is designed to give European farmers the opportunity to improve biodiversity and natural capital while increasing the resource efficiency and competitiveness of their agricultural practices. It promotes sustainable management practices for agriculture that protect the ecosystem services provided by biodiversity and contribute to safeguarding soil and water resources on which sustainable agricultural productivity depends. It will demonstrate sustainable agriculture through the implementation of BMPs and measurement and monitoring of progress with a set of defined indicators. Among the indicators are the:

- Percentage of natural vegetation compared to the total area of the farm
- Existence of biodiversity structures to support wildlife
- Area of the farm used as multi-functional buffers
- Greenhouse gas (GHG) emissions in carbon dioxide (CO2) equivalent per hectare and per crop yield

In cooperation with other partners, including the European Landowners Organization,[46] CropLife Europe has produced a range of publications related to biodiversity: Multifunctional Role of Field Margins in Arable Farming,[47] Pesticides and Biodiversity,[48] Pesticides and Freshwater Biodiversity[49] and Pollinators in Agriculture.[50]

A development partnership under the develoPPP.de[51] program commissioned by the German Federal Ministry for Economic Cooperation and Development (BMZ) with BASF, Cargill, Procter & Gamble and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH to establish a certified coconut oil supply chain[52] and improve the livelihood of coconut farmers in the Philippines and Indonesia. The objective is to empower smallholder farmers[53] to combine agronomic expertise with local knowledge to improve agricultural practices and increase their prosperity. The private partners share their understanding of the market mechanisms and trends, while GIZ contributes its expertise to training farmers and promoting sustainability standards. Between November 2015 and October 2019, more than 4,100 coconut farmers were trained in Good Agricultural Practices (GAPs) and processing techniques as well as farm management practices. About 1,600 farmers received additional training and have been certified under the Rainforest Alliance Sustainable Agriculture Standard. Farmers who were trained and certified have on average a 47% higher income than farmers who did not participate in the program. Coconut oil is used to manufacture ingredients for cosmetic products, detergents and cleaning agents as well as for use in food.

BASF is a partner in the "Pragati[54]" sustainable castor bean program. Castor beans play an important role in the chemical industry where their oil and derivates are used as raw material in the production of plastics, coatings, paints and pharmaceuticals. Most (80%) of the world's supply of castor seed is produced annually in India, representing approximately 1.2 million tons. Here, castor bean farming provides a steady income for many smallholder and family farms. The goal is to enable sustainable castor crop production by:

- Using GAPs to increase yield and farmer income.

- Efficiently using water resources and maintaining soil fertility.
- Driving adoption of good waste management practices.
- Enabling better health and safety practices, and respecting human rights.

Farmers are audited according to 76 criteria based on 11 principles, including "ecological balance and Integrated Pest Management" and "biodiversity management." Over 2,700 farmers have been certified, covering more than 4,000 hectares of castor-growing land.

The Mata Viva[55]® initiative was established in Brazil by BASF in 1984 to protect water quality, conserve soil, and create areas to preserve native vegetation and wildlife. The first major achievement was to restore 128 hectares of forest along the Paraiba do Sul River near the company's chemical complex at Guaratinguetá. As Mata Viva® flourished, a broad range of partners from the agricultural, business and scientific communities united in their desire to foster biodiversity. In 2005, the Espaço ECO Foundation,[56] set up by BASF with the support of the German government, assumed responsibility for the program. Mata Viva® began to engage directly with farmers and agricultural communities. An educational module was developed to show future farmers how they could build a vital community by practicing conservation and sustainable land-use techniques, and later extended to educate Brazilian rural school children on environmental topics like water usage, energy efficiency, use of natural materials and recycling. In 2007, an environmental adequacy program was launched where technicians and agribusiness professionals learned how to assess the environmental impact of farming. This included identifying and mapping degraded areas in compliance with Brazilian environmental regulations, preparing the soil, planting native seedlings and providing after-care.

According to its 2019 Sustainable Business report,[57] under Syngenta's Good Growth Plan, 14.1 million hectares of farmland on the brink of degradation have benefited from improvement in soil health and 8.2 million hectares of farmland have benefited from enhanced biodiversity. Meanwhile, 26.5 million smallholder farmers have been reached through training and sales, with a 28.5% average increase in productivity on 1,659 smallholder reference farms compared to the 2014 baseline. This was almost three times greater than the average increase on 1,928 smallholder, benchmark farms.

Syngenta and the U.S.-based The Nature Conservancy[58] (TNC) have set up a multi-year collaboration[59] focusing on business practices aimed at improving soil health, resource efficiency and habitat protection in Argentina, Brazil, China, Kenya and the United States. One of the projects, known as Reverte, is a large-scale regenerative project on degraded pastureland in Brazil. Forming part of the shared vision with TNC, Reverte applies conservation and regenerative agriculture techniques, including livestock integration and crop rotation, to restore soil vitality to over a million hectares of Brazilian pasture in the Cerrado ecoregion by 2025. With the opportunity to produce food on otherwise degraded land, this project aims to reduce pressure on local woodlands and prevent deforestation. As part of this ambition, growers first need to ensure their farm complies with the Brazilian Forest Code before they can be accepted to the program. The Reverte program is the culmination of over a decade of work with TNC, beginning with the mapping of rural properties and training of local farmers to restore degraded areas and connect fragmented habitats. For the first phase of Reverte, Syngenta and TNC are working to identify available financial mechanisms to aid farmers in adopting the program.

The EcoAguas[60] project in Colombia was initiated 24 years ago to preserve, restore and protect native riparian forests (lowland), create multi-functional field margins (MFFMs) in smallholder coffee areas (highlands) and establish education processes to promote a culture of environmental awareness and activity in local communities. Such activity focuses on sustainable practices that contribute to the efficient use of water as a primary resource for planting and growing crops such as sugarcane, rice, potatoes, bananas, corn, coffee, flowers and vegetables. More than 1.2 million native trees, raised in 656 nurseries, have been planted, including more than 100 protected species. Benefits are biodiversity conservation, water provisioning, pollination and local community enhancement. In 2019, about 19,780 hectares of forest and farmland were included in the scheme and over 1.2 million trees of more than 100 protected native species were planted over 24 years. To raise awareness and promote understanding of the importance of biodiversity in agriculture, foster its conservation and improvement, BayDiversity[61] promotes the customized implementation of Conservation Action Plans (CAPs) on farms. These involve the evaluation of natural or semi-natural areas, cataloguing species of flora and fauna found on the farm, and subsequent drafting of practical recommendations to manage and recover those areas with clear improvements for biodiversity. Implementation is linked to Bayer´s loyalty program and, so far, around 65 CAPs were developed in Spain and Portugal. Farmers get advertising material after implementing biodiversity-enhancing measures to better explain "why, what and how." Measures also led to benefits for farmers, namely increased crop resilience to pests and improved ecosystem services, resulting in healthier soils and cleaner air and water.

A project in the WBCSD, the Global Agribusiness Alliance[62] is a CEO-led, private sector platform for supply-side companies committed to harnessing their collective strengths to tackle shared environmental, social and sustainability challenges. A series of six case studies on partnerships for sustainable landscapes[63] includes several biodiversity-related projects, including one from a member of CropLife International. In 2014, a broad partnership, the "Midwest Row Crop Collaborative",[64] was set up to address nutrient overload in the Mississippi River and enhance soil health and food security in its surrounding catchment. Farmers are changing their practices by, for example, incorporating cover crops and no-till into their day-to-day activities. In partnership with the with Soil Health Partnership (see pages 44 and 46), 140 farms representing nearly 6,000 acres participated in research and other sustainable farming practices to build a proof of concept. Awareness across the farming community spanned almost 35 million acres.

7.2 Measures to protect pollinators and biodiversity

A large amount of data on the potential environmental and ecotoxicological impacts of pesticide use is generated during product development and registration. It is used in risk assessments by regulatory authorities to approve products for use or not. There is a huge volume of data for public access on the Organisation for Economic Co-operation and Development (OECD) eChemPortal[65] and comprehensive reviews of the available data are published by, for example, the European Food Safety Authority.[66] Such data are significant contributions by CropLife International member companies to the biology of many species. The data generated frequently goes well beyond the statutory requirements to invest in the protection of biodiversity.

BASF, Bayer and Syngenta, in particular, have invested in schemes to maintain and increase pollinator species in agricultural areas. Each has a different approach but underlying them all are programs to improve or add new areas of plant species to provide feed and cover for pollinators. The programs are widely promoted and farmers have been engaged successfully in western Europe. The increase in flowers in field headlands and other areas on farms as well as on land such as golf courses can be readily observed and robust data on their impact on invertebrates, pollinators in particular, are reported.

Although not specifically focused on biodiversity, processes have been implemented to minimize risks to honeybees by connecting farmers and beekeepers to be informed of each other's activities. Farmers notify beekeepers when they plan to spray a pesticide that may present a risk to bees and beekeepers notify farmers of the location of their beehives. Examples involving the CropLife International network include BeeConnected[67] in Australia, BeesMatter[68] in Canada, MadhuSandesh[69] in India, Polinizadores[70] in Latin America and BeeConnected[71] in the U.K.

The Pollinator Research Task Force[72] includes all member companies of CropLife International and more. Focusing on regulatory data requirements, it reviews available information related to the potential effects of pesticides on pollinators and where gaps are found, it may develop new data for submission to the United States Environmental Protection Agency (EPA). Generic data gaps have been identified and filled, and test methods have been improved and validated, improving the information available to the EPA for use in conducting risk assessments. Members maintain active connections with academic and government researchers in the United States, Canada, Europe and Latin America to be able to obtain and use the best data possible. This is an example of the data generated by companies to register their pesticide products, which also contribute to science and reduce the risk to biodiversity.

Honeybees are domesticated throughout most of their range. The BEEHAVE computer model[73] simulates the development of a honeybee colony and its nectar and foraging behavior in different landscapes. It allows the investigation of the effect of multiple stressors of honeybee colonies, either alone or in combination, on colony development and survival. The design is based on empirical data, expert knowledge and earlier models to integrate within-hive processes with an explicit representation of foraging in heterogenous and dynamic landscapes. Teams at UK's Rothamsted Research and the University of Exeter developed the model in collaboration with the Helmholtz-Centre for Environmental Research GmbH – UFZ and Syngenta. It is being further developed for bumblebees.

Africa

In Africa, there is a general lack of baseline data on pollinator populations and effective monitoring. This was demonstrated by the 2007 FAO report "Crops, Browse and Pollinators in Africa – An Initial Stocktaking."[74] The JRS Foundation[75] Pollinator Biodiversity Program[76] aims to increase the accessibility and quality of pollinator biodiversity data through a long-term investment in collecting baseline data, developing the technologies and methods to do so, and creating data sharing platforms relevant at regional and local levels.

CropLife Africa Middle East is working on projects which will help develop data and knowledge on pollinators in Africa. It collaborates with the Centre National de Recherche Agronomique[77] in Cote d'Ivoire to work on pollinators in cocoa. Discussions have been initiated with CropLife Zimbabwe to establish a baseline map of the status of pollinators using existing data to inform future pollinator health interventions. Some important aspects include:

- Number of species and populations of bees and other pollinators existing in the country
- Knowledge on pollinators, including bee diseases, bee pests etc., and interventions to address them
- Use and potential use of pollination services in key crops
- Environmental aspects impacting pollinators, including forage, habitat destruction, pollution, climate change, agricultural intensification, increasing human settlements and potential interventions
- Ongoing projects and initiatives to promote bee health and the use of pollination services, identifying gaps that require further action

CropLife Africa Middle East has contributed to workshops organized by the African Union under the Bee Health Project.[78] The overall strategy of the project is focused on developing linkages between participatory bee health management and beekeeping technology, pollination services, market access, and bee health policy and legislation at both national and regional levels. By linking them to productive beekeeping ecosystems (forest and cropland) in the participating countries, the International Centre of Insect Physiology and Ecology based in Nairobi and the Inter-African Bureau for Animal Resources will motivate communities to maintain bee health and conserve pollinators' biodiversity, protect the environment, and improve food security and economic well-being in the regions. Member companies have provided presentations and papers by industry experts and contributed to the Guidelines to Minimize the Potential Impact of Pesticides on Bees.

Asia and Oceania

In 2011-12, Syngenta conducted a Corporate Ecosystem Services Review (ESR)[79] with the support of the World Resources Institute[80] in small farms in south India. The ESR helped the company identify risks its customers face due to ecosystem degradation and, in turn, find opportunities for the company to offer new products and services that mitigate these risks.

A decline in pollinator populations was a severe problem in India. In one South Indian state, up to 90% of pollinators vanished in the 1990s and the impacts of that loss are still lingering. Local experts linked this decline in pollinator populations to feral pollinator habitat destruction and land conversion. As a result, the biodiversity program "Operation Pollinator" (pages 25-26) was launched in the state to boost the number of pollinating insects on commercial farms.

The Chanthaburi Pollinator Project[81] in Thailand combines a beehive rental program with trainings on the responsible use of pesticides to select project farmers in the Thai province of Chanthaburi. The project is highly localized and tailored to a specific species of Stingless bees. CropLife Thailand cooperated with the Agricultural Occupation Promotion and Development Center of Chanthaburi whose research showed that these bees pollinate over a much smaller range than honeybees (300-500 meters versus an average range of 4-5 kilometres for honeybees). This allows farmers greater control of their bees to confine pollination within their farms and prevent contact with other neighboring farms that may be using pesticides. In addition, the stingless bees swarm around the same flowers continuously, increasing the chances of fruit setting in the farms compared to honeybees. The pilot project was in three districts of Chanthaburi province with a total of 43 rambutan and longan farmers. The farmers were given rented beehives and trained on beehive management for pollination and the responsible use of pesticides. In parallel a survey was conducted among the project farmers and another 38 farmers who did not rent hives to compare crop productivity from the two systems. Farmers that used bee pollination reported an average yield that was 19.5% and 27.1% higher than those who did not for rambutan and longan, respectively. Farmers seeing the benefit of bees as pollinators were eager to put into practice the responsible use of pesticides through a new, holistic awareness of the ecosystem in which their crops grow.

Another study in Thailand showed that mango production increased with the help of stingless bees. Nests are inexpensive to establish and easy to manage. Bees can increase fruit set in the off-season. The results confirm the conclusions of the Chanthaburi Project.

The Healthy Bees for Sustainable Pollination[82] project is a collaborative research project conducted by the Hawkesbury Institute for the Environment[83] at Western Sydney University in Australia and supported by Bayer CropScience and Syngenta Asia-Pacific through the Hort Frontiers Pollination Fund.[84] The project aims to secure pollination within agricultural ecosystems through a range of tactics to support and maintain healthy and diverse pollinator populations, including honeybees, stingless bees and other insects. The project assesses pollination at both a farm and landscape scale, not only addressing the crop impact, but also how floral resources within the wider environment are supporting pollinators.

Europe

BASF's Farm Network[85] in Germany promotes biodiversity while maintaining as much productive land as possible and identifies success factors for practical measures that can be promoted and implemented. Independent experts evaluate the progress of each farm in the Farm Network. Data tracked includes the number of birds, pollinators and other beneficial insects living on the farm. Water management measures and sustainable soil treatments are also carefully monitored. A diversity of measures to increase biodiversity is promoted because the quality of the landscape structures as well as the size of the available area are essential for biodiversity and meet the different demands of individual species. Unproductive areas with low yield potential are suitable for implementation. Measures include:

- Wildflower strips and surfaces[86]
- Water and erosion protection strips[87]
- Piles of stones and deadwood
- Nesting aids and perches
- Skylark windows[88] (see also the Lerchen Brot action[89])
- Open ground
- Field drains and road and track sides[90]

A comprehensive manual[91] on biodiversity and water protection provides background science and guidance on implementation of broad biodiversity measures. The last annual report, "Modern Agriculture and Biodiversity Results Report Farm Network 2017,"[92] covered the period up to 2017. Farm Network initiatives[93] are active in the Czech Republic, France, Germany, Italy, Poland and the United Kingdom. Key partners work together in each country to test sustainable practices locally and promote their adoption.

The Farm Network began in Germany in 2013 and the five-year results were summarized in a two-page document.[94] Ten independent experts monitored 10 of 53 farms in the network in 2017 and reported findings from 63,535 hectares, including 42,963 hectares of arable land.

- Birds:
    - At the large-scale farm in Quellendorf (Saxony-Anhalt), the populations of seven out of 10 bird species used as indicators of quality landscapes increased by 20% over the five years.
    - Breeding pairs of Tree Sparrows colonized nesting boxes set up 2017 in Quellendorf.
    - Lapwing returned to breed at Trebbin (Brandenburg).

- Flower strips:
  - Quellendorf averaged 16,649 flowers per square meter on flower strips from counts made from March to September.
  - Good wildflower establishment is not easy but 94% of the sown species can be found in the flower strip with moisture, precise seeding and patience.
- Bees:
  - Flower strips offer plentiful food for bees and other insects and attracted up to 32 species, with the peak months being June to September.
  - At the four sites from which data are reported, all showed increased numbers of wild bee species compared to 2013 on the five-year-old flower strips in 2017 compared to the beginning of the investigation. The maximum number of species recorded was 44 in 2016 and the greatest increase was six-fold between 2013 and 2016.
- Beetles:
  - Up to 130 different types of rove beetles *(Staphylinidae)* were found in large East German farms, up to 20% of which are threatened species.
  - Numbers of individual beetles were much higher in the field center than at the margin or in flower strips, but the diversity of species was greater in the flower strips.
- Spiders: There was a 67% increase in spider species and doubling of endangered species within three years in Weißensee (Thüringen).

Conclusions: The landscape of large-scale agriculture can be species-rich. Sustainable agriculture can be enhanced by using less productive land for biodiversity. Biodiversity measures in the agricultural landscape are much more effective when networked and will have a long-term impact.

BASF's Farm Network UK[95] farm at Rawcliffe Bridge is a 350-acre intensive arable farm near Goole in East Yorkshire. Since the biodiversity work was started by the farmer in conjunction with BASF in 2002, the practices have achieved the following:[96]

- Birds
  - 110 bird species, 63 of which hold breeding territory, which are above average for a lowland farm and include 64 species on the list for conservation concern
  - Tree sparrow numbers increased from six to 59 pairs between 2003-2010 following the introduction of "bed and breakfast" nest boxes and feeding stations
  - Successful breeding between 2004-2010 for kestrels, tawny owls and little owls

Table 4: Results for key bird species at Rawcliffe Farm

Species	Number of territories compared to UK lowland average
Skylark (25 territories)	2x
Corn Bunting	3x
Grey Partridge	6x
Meadow Pipit (in field boundarie)	>2.5x
Yellow Wagtail	47x the UK lowland average

- Plants: 154 plant species identified on field boundaries
- Insects: 165 species of moths, 22 species of butterflies, eight species of dragonflies and two species of bats were identified
- Aquatic life: 56 species of water plants surveyed, including five rare species; good water quality evidenced by common stonewort, dragonflies, damselflies and sticklebacks

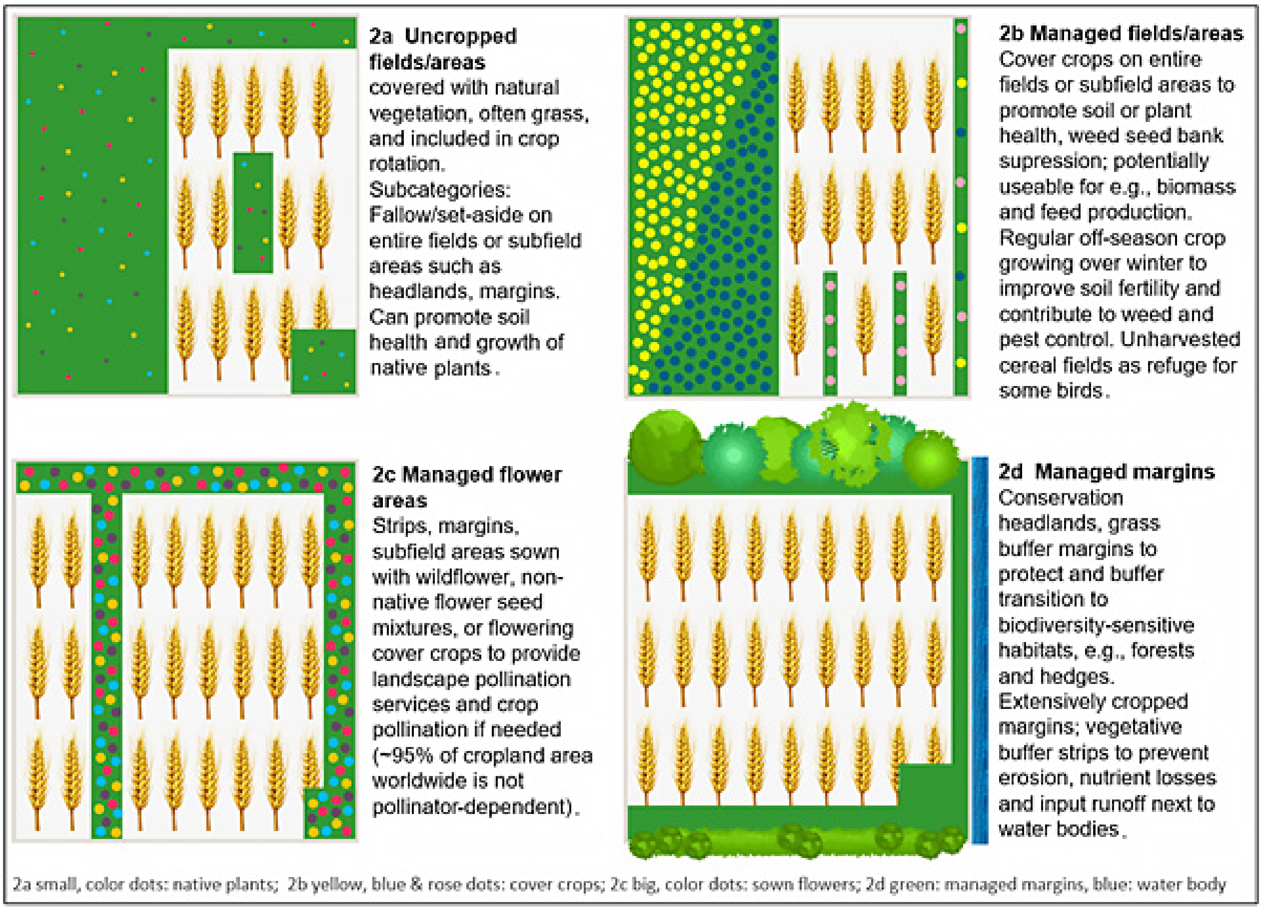
Bayer CropScience set up Biodiversity Centres[97] at its UK Field Centres in 2003. The report published in 2007 shows the practical implementation of measures to support biodiversity on farmland with a focus on UK Biodiversity Action[98] Plan species in cooperation with the Farming and Wildlife Advisory Group.[99]

A new study submitted for publication in November 2020 (Dollacker et al.), entitled "Mainstreaming Biodiversity in European Crop Production by Means of Dually Beneficial Habitats for Farmers and the Environment," shows how to achieve the dual benefits of habitat creation within cropland for biodiversity and crop production. There are two main ways of enhancing biodiversity in cropland. Firstly, apply GAPs at the field level and, secondly, maintain semi-natural habitats where present or create new semi-natural habitats across the landscape to ensure connectivity for wildlife species. The restoration or creation of semi-natural habitats in cropland, such as fallow land or wildflower areas within fields, is a key strategy to address habitat loss and has been widely recommended. While the habitats' benefits to biodiversity have been well researched, their effects on crop production benefits have been neglected (Holland et al. 2017[100]). For instance, research relating to the effects of flower areas mostly focus on insect biomass assessment rather than on yield, quality or fruit set increase; pollination benefits to crop production are often implied by indicating that 75% of crops are pollinator-dependent,[101] while most crop production land (about 95%) worldwide is wind- or self-pollinating (IPBES 2016[102]). This neglect is also associated with a lack of data relating to farm economics and distorts the view on key relevant agro-ecosystem services, especially on those relating to soil, which these habitats could provide. These knowledge gaps should be closed to enable a more meaningful interdisciplinary sciences' perspective.

There are a huge number of different semi-natural habitat recommendations. Some exhaustive European studies were analyzed to identify those with potential to support an integrated strategy to mainstream the sustainable use of biodiversity into crop production and provide dual benefits for both of these public goods. With closer scrutiny, the nearly 100 habitats identified in the analysis contained different terms used synonymously (e.g., fallow or set-aside land), implementation options (entire fields, subfield areas, strips, headlands, margins, patches) or duration (annual, perennial). They could be clustered under four groups (Figure 1). The effects of these habitats on biodiversity, key agro-ecosystem services and disservices (weeds, pests, diseases), trade-offs and synergies were elucidated. Figure 1 summarizes the four groups, their subcategories, implementation options and strategic intents for farmers to choose from according to local environmental conditions and market needs.

To identify dually beneficial habitats, those that provide refuge, feed and/or breeding ground for multiple species were selected along with those that are readily integrable into common crop management practices. This approach was made to save costs in terms of labor and time, while also providing agro-ecosystem service benefits. The use of cover crops in particular can contribute to soil fertility-related agro-ecosystem services enhancement, such as organic matter content or soil structure provision, while suppressing the weed seed bank reservoir or preventing pest build-up. All other habitats may, however, also enhance disservices such as weeds and pests, hence require effective control options to achieve a more balanced and meaningful system approach. New digital imaging tools will enable farmers to better identify subfield areas or unproductive field zones which are best suited for dually beneficial habitat creation. All these habitats provide biodiversity benefits at the local level and improve connectivity at the landscape level, especially if they are deployed in highly intensively cropped areas, where little natural or non-crop habitats remain (Müller-Früh et al. 2019[103]). The identification of such habitats may provide an additional tool to mainstream biodiversity into crop production, thus have the potential to support a transformative change in crop production.

Figure 1. Graphic visualization of four dually beneficial habitat groups, which farmers can choose for different strategic intent
Adapted from Müller-Früh et al. 2019[103]



In collaboration with farmers and other partners, the Bayer ForwardFarming[104] initiative enables knowledge-sharing about modern and sustainable agriculture through first-hand experiences on independent farms around the world. Farmers, value chain partners, academia, scientists and civil society engage in dialogue and experience modern sustainable agriculture. The network demonstrates how tailored solutions, modern tools and practices, proactive stewardship measures and partnerships can enable farmers to run successful businesses and provide enough food in a way that preserves farmland, biodiversity and natural resources. Currently, there are 16 farms in the network across 12 countries with at least 25 different crops and there have been over 33,000 visits to Forward Farms. Regarding biodiversity, the farms are incorporating concepts developed in the model of semi-natural habitats shown in Figure 1.

Bayer collaborates with the Institute for Agroecology and Biodiversity in Mannheim, Germany and the Institute for Landscape Ecology and Nature Conservation in Bühl, Germany to conduct a research project entitled “Ecological enhancement of farmland in the Upper Rhine Valley.”[105] Two sites of intensively farmed arable land in the Upper Rhine Valley of southwest Germany were selected. Following a baseline survey in 2010, the project has created various wildflower areas and nesting sites for wild bees since 2011. The project evaluates, quantitatively and qualitatively, the impact of these ecological enhancement measures (EEMs) on the biodiversity of wild bees and butterflies in an agricultural landscape.

Results of the EEMs (2011-16) show that providing a continuous supply of a combination of annual, winter-hardy and perennial wildflower mixes can make a valuable contribution to promoting wild bee and butterfly populations and enhancing species diversity of these groups. Providing a continuous, simultaneous supply of the three types of wildflower mixes make a valuable contribution to supporting wild bee and butterfly populations and their species' diversity. In the experimental plots where EEMs were tested, noticeable increases were observed in the number of species and individuals per species – particularly among wild bees and to a lesser extent for butterflies. The bee banks were less successful than wildflower areas. They were only used as nest sites when the vegetation was regularly cleared. The main findings were:

- The creation of wildflower areas on 10 percent of arable land in EEMs resulted in a considerable and sustained increase in the number of species and total wild bees and butterflies.

- Patches of perennial and winter-hardy flowers are particularly important to provide an early supply of flowers for foraging along with the creation of a variety of different types of wildflower areas.

- Wildflower areas should be renewed in sections as individual plant species can become dominant over the years.

- A wildflower area management strategy helps provide and control the optimum supply of foraging plants and keeps unwanted vegetation in check.

- It is also helpful if wildflower areas are supplemented with a mosaic of lightly covered arable areas (i.e., sown at a lower seed rate and less densely covered). This practice is especially effective for supporting birds such as partridges, skylarks and mammals like hares.

- Corridors to connect natural or semi-natural areas across landscapes fragmented by farming have general benefits for biodiversity as well as bees. These may be flowering strips, hedgerows, small forest patches with surrounding vegetation or other landscape structure.

Table 5: Effect of environmental enhancement measures on bee abundance and biodiversity and butterfly diversity

			2010	2012	2013	2014	2015	2016
Number of bee species	Rheinmünster	EEM	8	14	23	31	28	23
		control	10	9	11	12	12	8
	Dettenheim	EEM	8	17	33	43	35	36
		control	11	14	13	15	13	10
Total number of wild bees	Rheinmünster	EEM	14	208	724	501	271	332
		control	16	34	64	60	50	26
	Dettenheim	EEM	13	101	1,445	1,080	1,000	1,190
		control	15	19	31	45	37	14
Number of butterfly species	Rheinmünster	EEM	10	increasing numbers	23	12		
		control	10	5 to 10 species				
	Dettenheim	EEM	7	19	21	19	16	25
		control	6	7	7	14	6	7

The number and abundance of wild bee species were similar at both sites:

- At Rheinmünster, the number of wild bee species per sampling area in the ecological enhancement area increased from an average of eight in 2010 to a peak of 31 in 2014. In 2016, the average was 23 species. The average number of species in the control area was around 10 per sampling area and remained stable over the years.

- At Dettenheim, the number of wild bee species per sampling area in the ecological enhancement area increased from an average of eight in 2010 to a peak of 43 in 2014. In 2016, the average was 36 species. The average number of species in the control area was around 11 per sampling area and remained stable over the years (with an average of 10 species in 2016). Natural variability is expected between years and impacts of EEMs.

Several "red-listed and vulnerable" species of bees were only found in the ecological enhancement areas at both sites. The abundance of wild bee specimens per sampling area increased greatly after 2010 in those areas while numbers remained low in the control areas. The number of butterfly species in the ecological enhancement area at Dettenheim increased after the first year of counting, while the number remained stable in the control area. Sightings included the Short-tailed blue *(Cupido argiades)* and Small copper *(Lycaena phlaeas),* two species classified as "vulnerable" in Baden-Württemberg, along with the Mallow skipper *(Carcharodes alceae).* At Rheinmünster, more butterfly species were recorded in the ecological enhancement versus control areas, but the difference was less marked than at Dettenheim. During the period, 16 species, some of them vulnerable, were sighted in the ecological enhancement area but not in the control area. It should be noted, however, that some of these species were recorded only in one year or in some cases, in very small numbers.

Syngenta has helped growers create rich habitats in field margins and riparian zones alongside rivers; promoted managed forests and agroforestry, which also help protect water bodies; and worked with groups that conserve wild crop relatives to integrate them into farming practice. The biodiversity dataset[106] shows aggregated hectares of farmland that benefited from biodiversity conservation practices which were established or managed in collaboration with Syngenta. The dataset also includes a description of the project's geography, scope and objectives. The number of hectares of benefited farmland is locally tracked through in-field assessments and documented and reported by project managers. The total of 8.2 million hectares benefiting from biodiversity conservation practices exceeds the target of 5 million set in 2014. Of these, nearly 6.2 million hectares were MFFMs.

In 2018, Syngenta, together with Arcadis and Biodiversity International, developed a paper: "Multifunctional Field Margins: Assessing the benefits for nature, society and business."[107] MFFMs include, but are not exclusively, pollinator schemes under the "Operation Pollinator" program described in the next section. The objective is to encourage farmers to manage less-productive farmland alongside fields and waterways, reintroduce local species, provide buffers for soil and water, and connect wildlife habitats. This enables sustainable intensification on the more productive land. Benefits for farmers include reduced soil erosion and better soil nutrient cycling, crop pollination, pest control and water quality regulation. Wider social gains include enhanced genetic diversity, carbon sequestration, flood attenuation and recreation opportunities. In addition to Operation Pollinator (pages 25-26), several other projects are referenced in Appendix 2 of the report:

- Brazil: "Greener soy" project restoring riparian forests to conserve biodiversity and improve water quality in rivers. Restoration along watercourses provides corridors.
- Colombia: "EcoAguas" (page 16)
- China: "GroMore" project with MFFMs in rice fields acting as ecological corridors for pest control of invertebrates. Benefits include increased natural pest control, biodiversity conservation, reduced pesticide use and stable or increased yields.
- USA: Conservation Seed Program – Donation of seeds of discontinued varieties to create habitats for wildlife. Benefits include increased biodiversity and improved water quality. Donated seeds and harvested plants may not be resold.

Table 5 below lists the "natural capital" benefits supported by scientific studies (this information is in Table 2 of the MFFM report). The report also estimates the monetary value of the natural and social capital benefits from MFFMs. Reference sources are provided for each of the natural capital benefits.

Table 6: "Natural capital" benefits of different interventions to improve biodiversity

Adapted from "Multifunctional Field Margins: Assessing the benefits for nature, society and business"[107]

Reintroducing local species and supporting genetic diversity	Margins with higher plant diversity support higher densities of invertebrate species. It is assumed that high genetic variation in MFFMs allows for more rapid adaptation to climate change.
Pollinator species	Pollination is one of the most important natural capital benefits provided to agriculture by natural habitats.
Natural pest-controlling species	Restoring habitat can increase natural enemy populations and thus, effectively suppress pests. Predators in natural ecosys-tems provide an estimated 5–10 times increase in pest control.
Earthworm populations and activity	MFFMs increase soil abundance of soil macro fauna, including earthworms, woodlice and beetles.
Food sources and nesting sites	Uncropped areas and non-farmland habitats offer supplemen-tary food resources to many farmland birds and mammals.
Migration corridors	MFFMs can act as ecological corridors when connected to each other, forming a biodiversity corridor.
Soil quality	Soil structure and fertility provide essential ecosystem services. Soil pore structure, soil aggregation and decomposition of organic matter are influen ed by the activities of soil micro and macro fauna, which are supported by the presence of MFFMs as food and habitat sources.
Erosion prevention	MFFMs can help erosion control by reducing water and sediment discharge and controlling floods.
Water pollution, flood attenuation and water retention	More complex plant community composition and, to some extent, species richness, reduces leaching of inorganic nitrogen from grasslands.
Carbon sequestration	Carbon sequestration potential increases with increasing margin width and depends on plant diversity.
Windbreaks	Wind breaking field ma gins help in reducing wind speed, control wind-blown soil erosion, provide shade and alter the microclimate in the sheltered area.
Product branding	Farmers may have greater market access with biodiversity-friendly products. Farmers may obtain specific certifications if they help develop landscape-scale wildlife corridors.
Wood and food provisions	Field margins can provide fruit and firewood to local communities. Also, traditionally, hedgerows have been the source of local foods, drinks and medicines.

Operation Pollinator[108] aims to boost the number and variety of pollinating insects on cropland, including bees, beetles, ants and other flying species such as hoverflies and butterflies. Syngenta provides appropriate seed mixtures of local origin, agronomic training, and advice for establishing and managing field margins for pollinators.

The concept was introduced over 15 years ago and first reported in a paper by Carvell et al. (2007)[109] "Comparing the Efficacy of Agri-Environment Schemes to Enhance Bumblebee Abundance and Diversity on Arable Field Margins." The authors concluded that the "results suggest that the legume-based 'pollen and nectar flower mix,' as prescribed under Entry Level Stewardship in England, can quickly provide a highly attractive forage resource for bumblebees, but issues of seasonal flowering phenology and longevity of the mixture need to be addressed. Establishment of 'floristically enhanced margins' under Higher Level Stewardship will be important to provide diverse perennial communities of forage plants and to support a greater range of *Bombus* species and other pollinators. The population-level responses of bumblebees to introduced seed mixtures and other agri-environment options require further study to maximize the benefits of such schemes in intensively farmed landscapes." Data are presented on the flower abundance and species richness of plants in flower on different field margin options and bumblebee abundance and species richness for the options over a three-year period.

Subsequent research, both independent and sponsored by Syngenta, has refined the approach. Several papers have been published that provide field data to back up the initial findings and optimize the recommendations. Sutton et al. (2017)[110] reported the outcomes of several collaborative farm-scale studies: four in the UK (The Buzz project,[111] Hillesden experiment,[112] Insect Pollinators Initiative[113] and Farm4Bio[114]) and one in the Netherlands (farmland bird project). The authors "suggest that the value of the various agri-environment schemes will be enhanced if they include a combination of field margins, winter bird seed plots and flowering hedges to provide wildlife habitat all year round. The data from these farm-scale studies shows that at least 3-5% of the arable landscape should be uncropped and positively managed for biodiversity with targeted options (such as pollen and nectar mixes, winter bird food and flowering hedges). We postulate that encouraging farmers to create these high-quality habitats across the landscape with appropriate training will deliver considerable benefits for biodiversity whilst maintaining food production." A chart and a table from the paper are extracted below to show the percentage of habitat required to support farmland biodiversity.

Figure 2. Change in abundance of farmland birds with percentage uncropped land

Adapted from Sutton et al. (2017)[110]

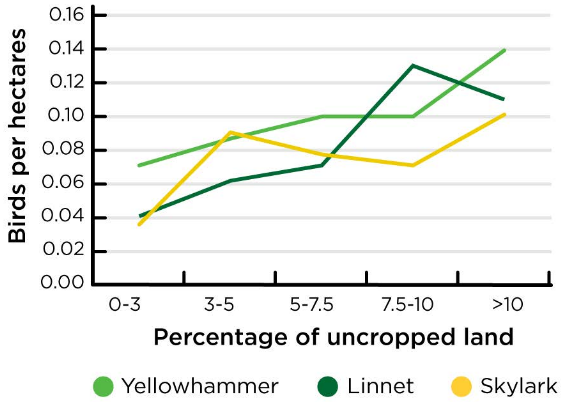


Table 7. Estimates of area of quality habitat required to support farmland biodiversity

Adapted from Sutton et al. (2017)[110]

Reference	Estimated Percentage	Type of habitat	Organisms to benefit
Dicks *et al*. (2015)	2%	Pollen & Nectar	Bumblebees and Solitary bees
	+ 1000 m	Flowering hedge	
Redhead *et al*. (2016)	1–3%	Pollen & Nectar, (<500 m between plots)	Bumblebees
Holland *et al*. (2014)	3–5%	Pollen & Nectar, Winter bird food	Bumblebees, Solitary bees, Butterflies and Farmland Birds
Hindsley *et al*. (2010)	5%	3% pollen and Nectar + 2% Winter Bird Food	Farmland Birds
Hammers *et al*. (2015)	3.6%	Winter Bird Food	Farmland Birds

During the nearly 20 years since the research commenced, Operator Pollinator spread in and beyond the UK. Farmers have helped establish and manage field margins in oilseed rape, sunflower, apples, pears, melons, vines, and olive crops to provide nesting and food resources for pollinators, beneficial insects as well as farmland birds, while enhancing overall biodiversity. Operation Pollinator provides farmers with important ecosystem services like pollination and pest control to balance agricultural productivity needs in an environmentally sustainable way. It supports growers to enhance biodiversity on their farms and demonstrates that profitable intensive farming can go hand-in-hand with the protection of natural resources and biodiversity. Country Operation Pollinator projects are operating in Europe (Austria, Belgium, Czech, Denmark, France, Germany, Greece, Hungary, Ireland, Italy, Netherlands, Poland, Portugal, Serbia, Slovakia, Slovenia, Spain, UK), Asia (China, South Korea) and the Americas (Brazil, Canada, Chile, USA). Independent monitoring has shown that within three years, habitat creation for pollinators increased bumblebees by six-fold, butterflies by 12-fold and beneficial insects by 10-fold.[115]

Operation Pollinator programs at the country level for which some details are provided[115] include:

- Belgium: regional landscape project with MFFMs along fruit orchards (apple and pear). Benefits include increased pollination, natural pest control and biodiversity.
- Canada: MFFMs on agricultural plains benefit biodiversity. conservation and pollination. Restoring riparian habitats benefits biodiversity conservation and water quality and provides ecological corridors.
- Germany: MFFMs along a range of crop fields (e.g., canola and milling weed) enhance biodiversity and act as ecological corridors for deer.
- Korea: MFFMs in apple orchards benefit pollination.
- UK: MFFMs on agricultural land that benefit pollination, soil quality and natural pest control. Syngenta provides instructions and covers 25% of the seed pack cost.

Data on the benefits of wildflower strips were collected in Spain:

1. In field tests in southern Spain in 2011 and 2012, edges of natural vegetation were created along margins of intensively managed vegetable fields (Sanchez et al., 2014116). Edges planted with herbaceous and shrubby plants produced an increase in the number of most of the wild bee taxa (e.g., *Lasioglossum, Andrena, Panurgus and Halictus*) and their diversity compared to non-revegetated fields. Flowering edges were well used by A. mellifera so the revegetation of field margins may also translate into benefits to apiculture. The use of plant species with different blossoming periods increases the availability of pollen and nectar through extended periods.

2. Strips of approximately 100 m2 were sown at four localities in Murcia in autumn 2014 in the margins of vegetable crops using nine plant species (Pérez-Marcos et al., 2017117). The richness and abundance of bees varied according to plant species. *Echium vulgare, Borago officinalis* and *Coriandrum sativum* had the highest richness and abundance scores. The floral margins were also frequently used by *Apis mellifera*. The composition of the floral margin is critical to the maintenance of diverse and flourishing communities of bees. The use of different plant species with different blossoming periods increases the availability of pollen and nectar through extended periods.

Further data have been collected on the benefits of wildflower strips on the island of Bornholm, Denmark. The results are summarized in a paper published in 2018[118] and show that the sown flower strips/fields are successful in attracting insects, especially bees (honeybees and wild bees). As well as pollinators, other insects like ladybirds, ants and rove beetles thrived. The sown flower strips/fields generally attract more insects than both the ditch edges and fallow fields. The study recommends that flower strips be placed in cropped fields to break up the uniformity of the crop and provide corridors to support insects and birds. It also stresses the importance of site connectivity.

North America

The Living Acres Monarch Challenge[119] in the United States helps restore this butterfly population. Since it started in 2015, 83,000 milkweed plants, which monarchs eat, have been established on farms and golf courses in 29 states. The results of research under the Monarch Butterfly Research Project[120] provides best practices for establishing and maintaining milkweed plants in non-productive areas. The important message to farmers is that they can grow areas of milkweed and help increase monarch butterfly populations without any impact to their agricultural productivity or farming operations. The initial research shows that creating milkweed refuges takes an upfront investment of time, but once established, they should be self-supporting with minimal effort.

Healthy Hives 2020 USA[121] aimed to find measurable and tangible solutions for improving the health of honeybee colonies by the end of 2020. Research focused on studying critical bee health topics, including bee nutrition, *Varroa* mites, disease management and enhancing colony management techniques through "smart hive" technology.[122]

Under its U.S. Habitats Initiative, Bayer supports the protection of endangered species. Its Regulatory Science group has a coordinated approach to pollinator protection to defend existing product registrations and maintain its license to operate. Many programs also support the overall company biodiversity strategy. Bayer AgroScience funds and provides other resources to support partners in a range of activities under this approach, including those summarized below.

- From 2015 through 2017, the National Fish and Wildlife Federation (NFWF) Monarch Butterfly and Pollinators Conservation Fund[123] has supported 68 projects that are providing significant amounts of new habitat as well as engaging the many organizations and people needed to expand this effort.

Table 8: Outcome of NFWF monarch butterfly and pollinators program 2015-17

Total Projects	68
Acres restored or enhanced	163,469
Pounds of native milkweed and other forb species collected	901
Native milkweed seedlings propagated	781,951

- The Bee & Butterfly Habitat Fund's Seed a Legacy Pollinator Habitat Program[124] is establishing high-quality pollinator habitat to ensure honeybee and monarch butterfly populations thrive, working with landowners, conservationists, scientists and beekeepers to build healthy and sustainable pollinator habitats with maximum benefits. Pollinators' precise needs are met by providing appropriate diversity, density and duration of flowering to optimize forage.

Table 9: Results of Seed a Legacy Pollinator Habitat Program

Year	Projects	Acres of habitat	Milkweed seeds
2017	59	749	2.2 million
2018	88	690	2.6 million
2019	67	544	1.8 million

By spring 2020, 311 projects had been established in a 19-state region that planted 3,808 acres of new pollinator habitat, including 13.8 million milkweed seeds. The majority of the habitat outcomes are found in a 12-state region of the country that is the current focus of the Seed a Legacy program, which provides access to free or heavily discounted seed mixtures. Projects supported outside of this region are typically established with new, ground-mounted solar energy panels. The work with solar energy has been an expanding and unique opportunity to combine pollinator habitat with renewable energy efforts and provide multiple benefits.

- The University of Kansas Monarch Watch[125] program awards milkweed plugs to school/educational and restoration projects > two acres. Between 2016-2019, there were 110,000 plugs/year provided and a further 55,000 in 2020.

- Seeds for Bees Project *Apis m.*[126] encourages the use of cover crops to increase the density, diversity and duration of bee forage in California orchards, farms and vineyards, while improving soil health. The seed mixes are designed to bloom at critical times of the year when natural forage is scarce but managed and native bees are active. The table summarizes the overall impact of the program which is supported by many funders.

Table 10: Impact of Project *Apis m.*

Program year	Participants	Area of cover crops (acres)
2017-18	140	6,500
2018-19	149	8,005
2019-20	169	10,130

- Bayer is one of many investors in the IVM Partners[127] project, which is designed to improve and expand pollinator and wildlife habitats on public rights-of-way (ROWs) in upland and wetland ecosystems across eight U.S. states. Since 2015, 16 habitat sites (roadsides, golf courses, electric ROWs) have been established, monitored and used for outreach and training. For example, electricity transmission ROWs[128] can be managed as a Wire Zone – Border Zone with selective chemistry treatment under the conductors to develop meadow "prairie" habitat. Selective application techniques are used to retain shrub habitat along the ROW border and in ravines.

- Monarch and pollinator habitats have been planted by Pheasants Forever[129] at more than 70 Bayer research and manufacturing sites. In total, since 2013, >1,000 acres of habitat have been established across the whole project. From 2016–20, support was given to help the next generation of conservationists via a Youth Habitat Program to develop respect and appreciation for the land through upland habitat projects. In 2019, there were >40 habitat outreach events with >800 participants, and further exposure to 22,000 attendees at the Pheasants Forever national conference.

- HabiTally[130] (section 8.2)

- More than 3 billion wildflower seeds were distributed in the U.S. between 2015-18 by Bayer's Feed a Bee initative.[131] In 2019, about 75,000 packets of pollinator seeds (15 million) were distributed at trade shows, etc. In 2020, the Feed a Bee seed giveaway program was relaunched.

- An industry-wide collaboration, the Keystone Monarch Collaborative,[132] was launched in 2018 to ensure consistent messaging and provide resources to the agricultural community regarding involvement in monarch butterfly recovery efforts and habitat creation, with social media and broader communication strategy implemented in 2020.

- The goal of Missourians for Monarchs[133] is to increase pollinator habitat in Missouri by 385,000 acres (19,000 acres per year) by 2036. As of 2019, pollinator habitat in the state of Missouri had increased by 309,000 acres. Funding supports a coordinator who tracks the work of the collaborative and enters habitat accomplishments into a Monarch Conservation Database managed by the U.S. Fish and Wildlife Service.

U.S. farmland typically has less field margin compared to European farms because the average field size is about 10 times larger. One approach to create habitats within fields, similar to the grouping of habitats described in Figure 1, while keeping farmers' needs in mind, is STRIPS[134] (Science-based Trials of Row crops Integrated with Prairie Strips), undertaken by Bayer in cooperation with the University of Iowa. Prairie strips provide benefits for both agriculture and biodiversity, including stopping the loss of soil and nutrients in farmland and creating habitat for birds and beneficial insects. In Iowa, where prairie is the dominant vegetation type, strips are sown in narrow bands along contours and at the base of slopes on corn and soybean fields. More than 20 species of grasses and flowering plants are used. Advice is to place the strips on 10% of sloping fields, complimenting and enhancing the benefits of other crop management practices, such as the use of cover crops, strip tillage and nutrient management practices, which all contribute to improved soil health.

Valent USA, a fully owned subsidiary of Sumitomo, has a range of partnerships related to pollinators, water quality and habitat including:

- The North American Pollinator Protection Campaign[135] promotes conservation, protection and restoration of pollinator habitats and, consequently, the health of bees and ecosystems

- Project *Apis m.* (projectapism.org[136]) funds research to enhance the health and vitality of honeybee colonies while improving crop production

- FieldWatch (fieldwatch.com[137]) supports communication, collaboration and cooperation between crop growers, beekeepers and pesticide applicators in support of ongoing stewardship activities

- The Pesticide Stewardship Alliance (tpsalliance.org[138]) works to actively educate and promote reduced spray drift and protection of pollinators, among other projects.

- Coalition for Rural and Urban Environmental Stewardship (curesworks.org[139]) helps California farmers and other agricultural industry partners learn and practice better pesticide stewardship practices. As a sponsor, we support their efforts to assemble and disseminate important scientific information on diverse range of topics, including surface water quality, spray drift and pollinator protection.

- The University of California at Davis' Department of Fish and Wildlife Project Nigiri (nigiriproject.com[140]): As a public-private initiative, Project Nigiri researches the use of winter-flooded rice fields at fish nurseries to help restore wild salmon populations. In addition to the university and Valent, other members of the project include the California Rice Commission, California Trout and California Department of Fish and Wildlife.

Starting in 2020, Corteva Agriscience UK has partnered with LEAF (Linking Environment and Farming) in Resilient and Ready[141] to support four farmers to undergo a tailored program of training, consultancy and trials, measuring their performance and sharing their experiences with other farmers across the UK. Practical work to measure and improve aspects of their farms identified as crucial by the participants will focus on Integrated Farm Management and include soil health, water quality and biodiversity.

Trees and woody vegetation reduce soil erosion and provide habitat for pollinators. When planted along waterways as riparian buffers, they reduce run-off of nutrients and soil sediment in-stream. In the United States, Trees Forever,[142] has been planting trees and shrubs alongside agricultural land in Iowa and Illinois for over 20 years.

South America

Linked to the BASF's Mata Viva program, the leading citrus co-operative in Brazil, Coopercitrus supported an independent study on "Pollinators and Birdlife Biodiversity"[143] in collaboration with the Center for the Study of Social Insects at the Department of Biology, Universidade Estadual Paulista. Research conducted in three co-operative farms that had restored degraded forests showed the presence of more than 195 species of birds and about 50 species of bees, proving that the ecological restoration of native forests contributes to the return of flora and fauna. The forest restoration now covers 730 hectares and more than 1.2 million seedlings have been planted.

Healthy Hives Latin America 2020[144] (Salud Apícola 2020 Latinoamérica) is a long-term project on honeybee health, following a "forerunner" project in 2015-16 and now covering Chile, Colombia, Costa Rica and Argentina. It is a collaboration between the Bayer Bee Care Center and Fraunhofer Chile Research Foundation, working alongside local researchers at universities and beekeeper associations. The program's activities focus on monitoring honeybee health and the factors that affect it; disseminating knowledge to educate beekeepers about the best apicultural practices; and creating networks and research collaborations to jointly work on honeybee health. The following improvements to beekeeping practices and honeybee health were noted after capacity-building in Chile (details presented on the web page):

- Hive hygiene and positioning
- Knowledge and record-keeping
- Pests and pathogens
- Colony/hive strength

In 2020 alone, more than 1,730 beekeepers were trained on different aspects of bee health.

Two other Bayer pollinator projects in Latin America are described briefly below based on personal communications, but no reports are available for reference.

- An evaluation of the pollination of coffee plantations in Colombia with the Universidad National de Columbia showed high diversity of native pollinators, mainly due to the surrounding landscape structures which provide food sources throughout the year. The project has not been completed but, so far, 19 different genera and 34 species have been identified, including 33 native species of *Halictidae.* The two different management practices examined had limited effects on the diversity and abundance of pollinators. Although coffee is typically self-pollinated, these pollinators improved fruit sets, yield quantity and quality by 8-20%. This is in line with other independent research,[145] which showed that local pollinators accounted for approximately a 10% increase in coffee fruit set and that conventional farm management, using synthetic inputs, can promote pollinators, especially if they are in close proximity to natural forest fragments.

- Avocado plantations in central Chile are being studied to examine the relationship between landscape structure, managed flower patches, native bees, pollination and yield. A mix of different wild pollinators led to the best pollination performance and subsequent yield quality and quantity. Honeybees seem to play a minor role when there were sufficient wild pollinators. The preservation of surrounding landscape structures is key to maintain the pollination services of a variety of wild bees. The introduction of flower patches serves as additional food source for wild pollinators and honeybees.

Modeling the impact[146] of rapid land-use/land cover changes in Brazil on the provision of pollination services showed that by 2030, the demand for pollination will increase by 40% on average, while pollinator supply – estimated using suitability values for the different land-use/cover classes – will show a 3% decrease on average. This highlights the importance of considering the dialogue among stakeholders, governments, institutions and scientists to find alternatives and strategies to promote pollinator-friendly practices and safeguard the provision of pollination services with future land use/cover changes.

7.3 Agroecology and agroforestry

Agro-ecosystems have existed since humans first herded livestock and cultivated crops. "Agro-ecosystems" generally differ from natural ecosystems through maintenance of an early successional state, a limited range of selected crops that are generally planted in rows, simplified in-crop biodiversity and cultivation of the soil. Agriculture can have significant impacts on the environment. While negative impacts are serious – and can include pollution and degradation of soil, water and air – agriculture can also positively impact the environment, for instance, by trapping GHGs within crops and soils or mitigating flood risks through the adoption of certain farming practices. The OECD provides a set of agri-environmental indicators[147] from its members, including the Agricultural Land Area, Farm Birds Index, Soil Erosion and other factors. CropLife International is an observer of the OECD through Business at OECD.[148]

Since the 1920s, scientists and researchers have used the term agroecology to refer to the application of ecological principles to agriculture. CropLife International supports the OECD definition:[149] "agroecology is the study of the relation of agricultural crops and environment." This differs from some recent approaches, which include socio-economic factors as well as agricultural ecology and even "organic" production. agroecology provides the scientific basis to address the production by a biodiverse agro-ecosystem able to support its own functioning. Although agroecology principles may be common across different situations, the practice is highly influenced by local conditions in a site-specific way. Natural resource management can be tailored and adapted to highly variable and diverse farm conditions and become part of Integrated Crop Management and Integrated Pest Management (IPM) programs, contributing to sustainable agriculture and resilience to climate change. Farmers have this local knowledge which is enhanced by science and research to their benefit.

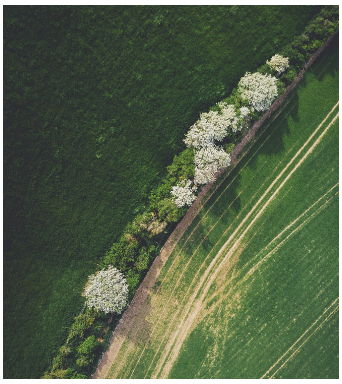
A few examples of the application of the principles of agroecology by CropLife International member companies follow in this section. Other examples are in other sub-sections of section 7.

Mixed flower strips in apple orchards in the UK were found to attract both pollinators and natural enemies of pests (e.g., parasitoid wasps, predatory flies and beetles). Natural enemy densities on apple trees were higher in plots containing open-nectar plants compared to other treatments, but effects were stronger for predators which do not prey on aphids. Predation of sentinel prey was enhanced in all flowering plots compared to controls, but pest aphid densities and fruit yield were unaffected by flower strips. The paper concludes that "multi-functional" flower strips, which contain flowering plant species with opposing floral traits, can provide nectar and pollen for both pollinators and natural enemies but further work is required to understand their potential for improving pest control services and yield in cider apple orchards (Campbell et al., 2017a[150]).

In a related study, flower strips enhanced overall wild insect abundance but not pollination services in cider orchards. Positive effects of ground flora on wild insect abundance in orchards suggest that flower mixtures or orchard management could be optimized for *Andrenid* bees, the single most important pollinator taxa, by increasing the availability of early-flowering plants in orchards. Equally, wild insect richness was highest in areas close to semi-natural habitats. Therefore, whilst flower strips can boost abundance of the existing species pool, only large-scale preservation of semi-natural habitats will maintain pollinator diversity in apple orchards (Campbell et al., 2017b[151]).

The potential of ground cover management in an olive grove in southern Greece, with mixtures of selected plants to provide habitats for pollinating insects and natural enemies of pests, was studied over a period of three years (2011–13) (Karamaouna et al., 2019[152]). The management consisted of the establishment of three-square-meter patches of sown plant species or spontaneous natural vegetation between trees along tree lines. Sowing was performed in autumn or spring and the peak flowering period occurred at the end of March to end of April and at the end of May to end of June, respectively. Patches with sown plant mixtures attracted higher numbers of pollinating *Hymenoptera* compared to native vegetation, especially mining bees and honeybees *(Apis mellifera)* as well as megachilids and bumblebees *(Bombus* species). *Sinapis alba,* present in both sown and native vegetation patches, attracted mainly mining bees and honeybees. The flowering mixture with *C. sativum* and *B. officinalis* was more attractive to honeybees than the one with *G. coronaria* as main flowering species but they were both equally attractive to mining bees, although the species composition may well have been different. Hymenopterous parasitoids, primarily *Braconidae* and *Chalcidoidea,* were sampled from the patches and the olive fruit fly parasitoid *Opius concolor (Hymenoptera: Braconidae)* was recorded on olive trees adjacent to the flowering patches.

Large numbers of predators, *Orius* species *(Hemiptera: Miridae)* and lacewings *(Neuroptera: Chrysopidae),* were recorded in the patches, principally in those with the mixture containing mostly *S. alba.* The results suggest that ground cover in patches with suitable flowering species could be part of a sustainable olive crop management system, providing food and refuge for pollinating insects and beneficial arthropods.



Growing trees, shrubs and other vegetation inside and around farmland in the form of a MFFM is one of the methods employed to improve biodiversity on farms. By the time the Syngenta February 2020 public policy report[153] was written, this had been implemented to benefit around 6.4 million hectares of farmland. A partnership between Louis Dreyfus Company[154] and Syngenta on projects around the world has helped promote the development of agroforestry systems and protect natural forest habitats. In Vietnam,[155] Syngenta, Louis Dreyfus and Douwe Egberts[156] have been collaborating to demonstrate the business case of agroforestry in coffee production,[157] using local fruit trees to provide shade to coffee crops. One key component of the project is the development of 30 demonstration plots to model good agroforestry practices, especially on water harvesting and irrigation.

These studies and many of those in other sections of this report show that more complex agricultural landscapes benefit biodiversity. Further confirmation is given by a Bayer study in Germany aimed to find which habitat structure can best enhance (wild) bee diversity and abundance in apple orchards. Different orchard management approaches were evaluated at 19 sites to see possible differences in species richness of bees. Establishing landscape elements, such as flowering strips adjacent to apple orchards, has a clear benefit for wild bees, but their presence did not have any measurable effect on yield and quality. Overall species richness was significantly higher in the flower strips than in the hedge habitats. The floral resources (number of blossoms) had a significant positive effect on the abundance and species richness of wild bees and abundance of honeybees. The results of this study were reported in late 2020 (personal communication).

7.4 Large scale (landscape) enhancement for biodiversity

The Brazilian Forest Code,[158] originally from a law passed in 1965, was revised in 2012 (Law 12.651). It sets limits for areas which can be used for production while establishing protected areas and mechanisms for achieving these because forests and other types of vegetation are goods of common interest to all inhabitants of the country.

- Areas of Permanent Protection (APPs):
    - These are protected areas, covered by native vegetation or not, with the environmental function to preserve water resources, landscapes, geological stability and biodiversity; facilitate genetic flows of fauna and flora; protect the soil; and ensure human well-being. Examples of APPs are as riparian areas, springs, hilltops, mountain slopes and mangroves.
    - Owners of APPs that have been converted must restore the APP. Reforestation must be completed within 20 years, with at least 10% of the total area rehabilitated every two years.
- Legal Reserves:
    - These are portions of land that must be set aside in native habitats, depending on property size and location. Legal Reserves ensure sustainable economic use of natural resources, support conservation and provision of ecological processes, and promote conservation of native fauna and flora. The size of a legal reserve depends on where the property is located (Table 10).
    - Medium and large landowners and possessors who deforested more than what was allowed before July 22, 2008 are obligated to either restore their legal reserves on the property itself or via an "offset" through a compensation process in areas of equivalent size in the same biome.
- Areas of Restricted Use
    - These include swamps and Pantanal plains that require special regimes of sustainable use as well as areas with latitudes between 25° and 45° where deforestation is prohibited.

Table 11: Percentage of land for protection and productive use under Brazil Forest Code

Land use	Legal Amazon			Rest of Brazil
	Forest	Cerrado	Grasslands	
Legal Reserve	80%	35%	20%	20%
Productive use	20%	65%	80%	80%

In farmland, it is the responsibility of the farmland owner or "possessor" to meet the requirements and it is their liability in case of non-compliance. They can be audited and subject to significant fines. According to the Brazilian Agricultural Research Corporation (Embrapa), satellite surveys indicate there is currently around 65% compliance and illegal deforestation continues at an expanding rate. Some owners and investors in agriculture have adopted a zero deforestation policy to ensure that investments in Brazil discourage the depletion of forested areas and native vegetation on their land (e.g., Nuveen[159]). Such activities provide an additional framework for and enhance the activities of CropLife International members.

These members support the implementation of the Forest Code and bring value to growers from preserved areas, for example:

1. Brazil is one of the countries where Bayer is initiating a pilot study to investigate carbon sequestration in preserved areas in relation to growers' activities and whether they can contribute to farmers' income through carbon credits under the company's carbon initiative (page 45).

2. Syngenta: One of the conditions for farmers to participate in its Reverte project, which regenerates degraded pastureland in the Cerrado biome, is that their farm complies with the Brazilian Forest Code (page 16).

BASF established the Fundaçao Espaço ECO® (FEE) in Brazil in 2005. To celebrate its 10th anniversary, a book[160] compiling its activities was published. During the 10 years, the foundation developed projects for more than 20 big companies and 23 agricultural cooperatives. Partnerships were set up with more than 20 organizations, such as universities, business schools, non-governmental organizations, research centers and others, resulting in more than 80 eco-efficiency and socio-eco-efficiency projects. The FEE[161] acts as a sustainability consultancy, developing customized projects for organizations to measure and understand environmental, social and economic impacts of their products and processes based on lifecycle thinking.

The PRÁTICAS AGRÍCOLAS ASPIPP Por uma agricultura sustentável[162] addresses water cycle management in the Brazilian Region of Alto Paranapanema. In the 1970s, this area suffered low rates of human development. In order to reverse this situation, researchers and farmers sought management alternatives to enable agricultural production in the region that has characteristically sandy soils and low water availability due to climatic conditions, especially in the "summers" that occur in winter (10 to 15 days without rain and with strong heat) – an important phase of plant development. As a result, in the early 1980s, the first agricultural projects with irrigation and no-tillage (in straw) began, which led to an increase in the diversity of agricultural production, boosting the development and transformation of the region's economic scenario with the generation of wealth. With the advent of the water crisis in 2014, there was concern because irrigation accounted for 72% of the use of this resource in the country. The adoption of BMPs was the main criterion for water and soil conservation. Conventional agricultural practices that do not adopt planting in straw and dams, and which are without native vegetation in Brazil, were the worst scenario for water and soil conservation. The scenario that considered the agricultural practices adopted by Associação do Sudoeste Paulista de Irrigação e Plantio na Palha (ASPIPP) associates – including planting straw, dams and Areas of Permanent Protection (APP) designated under the Forestry Code covered with native vegetation – is the main intervention to reduce soil erosion and degradation in rural landscapes. Conventional agricultural practices that do not adopt straw planting, but that have native vegetation in APP, were not as efficient as the ASPIPP model. The production of 1,000 tons of a mix of corn (500 tons), soybeans (300 tons) and wheat (200 tons) comparing the two production systems showed that irrigated production is more eco-efficient than dryland production by 45% in economic impact and 27% in environmental impact. The production costs of the mix in the irrigated system are 33% lower than in the dry system, this difference mainly attributed to the higher average productivity of the irrigated system in tons produced per hectare and lower consumption of agricultural inputs and diesel, generates a more favorable and profitable economic scenario for irrigated production.

Creating landscapes with healthy, functioning ecosystems is not only key to making progress towards the environmental targets embedded in the UN Sustainable Development Goals, but also to addressing multiple social and economic targets that depend partly or wholly on the benefits that ecosystems provide to people. Biodiversity is damaged as species' habitats are lost or fragmented. Smaller, more isolated species populations limit genetic variation and evolutionary adaption and increase the possibility of extinction; climate change exacerbates these trends. Encouraging land users to connect rich habitats alongside fields and waterways to create interconnected habitat infrastructures and corridors. In 2017, Syngenta worked together with the WBCSD[163] to produce a publication entitled "Landscape Connectivity: A Call to Action."[164]

Included in this report is "Soja + Verde," a collaboration between Syngenta, TNC, and other public and private sector partners empowering farmers to recover rainforest in agricultural landscapes. The 2016 results of the project reflect the success of the partnerships with a range of stakeholders where the project alone contributed 2.8 million hectares.

In its position paper on deforestation and forest degradation,[165] Bayer has committed to help 100 million smallholder farmers increase their livelihood in farming in order to decrease the need to convert forest into agricultural land or find additional income in forest exploitation. As described above, within the framework of the Brazil Forest Code, landowners must restore forest cover on part of their land. Weed control has been identified by Bayer as the most expensive part of afforestation efforts (US$ 0.7-1.2 billion per year until 2030 to implement the full plan). Different afforestation and weed control options will be tested in the next five years (Mata Atlantica, Cerrado, Amazon) in collaboration with the University of São Paulo. Field trails established back in 2004 revealed that intensive fertilization and weed control enhanced above ground biomass accumulation by a factor of three to four compared to plantings with high density and functional diversity or spontaneous natural restoration. This increase of biomass accumulation mediated by intensive silviculture plays a crucial role for biodiversity recovery in restored forests. More broadly, Bayer and its South American suppliers have developed a program called "RevitaBayer,"[166] which plants trees for every tonne of CO2 emitted by carriers.

8. Pests, diseases and invasive species

Factor	CropLife International
Pests, diseases and invasive species	Provide the tools used in agriculture to maintain the supply of safe and plentiful food and to man-age invasive species

All CropLife International member companies have corporate business strategies on sustainability. Broadly, they cover business practices and their environmental footprint. Commonalities include the development of innovative manufacturing processes with reduced environmental and societal impact and products that allow for less land conversion to agriculture, for example by:

- Increasing yield per unit area while having less impact on the environment and
- Improving soil health, including its structure and biodiversity.

Links to annual reports and sustainability pages are in Annex II. Backing up the technological aspects are training and education programs to promote best practices. There are numerous examples, including the National Stakeholder Team for Pesticide Safety Education Program Funding[167] (nst-psep.net), an independent team of stakeholders formed to strengthen and support the 50-state, land-grant university Pesticide Safety Education Programs. "Adopt-A-PSEP" connects these programs to sponsors that commit funds to promote public sector education of all pesticide users in the agricultural, specialty and consumer markets to promote BMPs, including soil health, water quality, and biodiversity. BASF, Bayer CropScience, Corteva, Syngenta and Sumitomo are CropLife International members participating in this project.

8.1 Innovation – Data-driven

wHen2gO[168] is a smart tool that helps improve application timings of two BASF herbicides (metazachlor and quinmerac) to minimize the risk of movement to water. The system was developed in conjunction with Agrimetrics,[169] using the latter's database of fields in the UK. By evaluating a combination of soil type, drainage, cultivation method and weather, the tool provides an eight-day forecast with a traffic light system to indicate the optimum timing for water stewardship. By following the recommendation, the herbicide application is timed so that it stays in the field where it is needed and minimizes threat to water. By accounting for soil type, drainage and cultivation method, the tool calculates the approximate drainage rate of the soil. By pairing this information with past and forecasted weather, it estimates the soil wetness and soil capacity. Depending on the result of this calculation, it can then make a recommendation as to when a product should be applied.

In 2020, FMC launched the Arc™ farm intelligence[170] platform, which is the first mobile platform to use predictive modeling based on real-time data to help ensure the right crop protection products are applied precisely where and when they are needed to improve sustainability, optimize crop yield and enhance grower return on investment. The tool predicts insect pressure one week in advance with more than 90% confidence for key insects in select crops. It has been launched in Greece for use in cotton and is being piloted in other countries, including Brazil, Spain and the United States, on a broad range of crops from *Brassicas* to corn to lettuce.

For the third consecutive year, as reported in the 2019 Sustainable Business report,[171] the SmartBio initiative in sugarcane in Brazil was Syngenta's largest project in the country, benefiting 1.9 million hectares. SmartBio is a third-party platform developed in partnership with Syngenta that allows sugarcane milling companies to map areas susceptible to different stress factors and select the best crop management mix for each of them, combining digital agriculture and IPM. Other sustainable soil and digital solutions[172] are being developed across Asia; Europe, Africa and the Middle East; and North America. In China, projects such as soil health training in Dingxi and straw incorporation in Qihe have been established in the past two years.

The loss, degradation and fragmentation of habitats are major threats to biodiversity. Reinstalling multi-functional habitats in the agricultural landscape help mitigate this threat. Digital technologies like Climate FieldView[173] use multi-year yield data from harvesters to precisely identify areas of low productivity and profitability. By taking those areas out of production, farmers can optimize their overall return on investment and convert them to habitats, ideally in collaboration with nature conservationists. A half million acres currently being farmed by FieldView users could potentially benefit from alternative management plans and conversion to multi-species habitats. This was demonstrated by a pilot program[174] in 2019 in the U.S. Prairie Pothole region.

From 2018-20, Bayer contributed to The Climate Corporation (development of an app) and Iowa State University (housing of app and data). The HabiTally[175] app was launched in 2019 to give farmers, ranchers, landowners and private citizens an easy-to-use tool to record data about their habitat conservation efforts on farms, in yards or other locations and to share the information with the U.S. Fish and Wildlife Service. Thus far, 738 acres of pollinator habitat and 27,330 milkweed stems have been tracked by the app.

In Egypt, small-scale farmers often make field decisions based on generic recommendations or historical information rather than scientific data. The Ardena project[176] aims to adapt precision farming technology to deliver farming-related information via mobile phones to smallholder farmers in Egypt in order to help them make sound decisions specific to their fields. An Early Disease Warning System utilizes a dynamic disease model based on ground truth data as well as weather and satellite data to provide up to seven days of disease risks for tomato crops. Farmers and retailers will be able to sign up to receive tailored, disease-specific risks and actionable advice. These messages will be sent to farmers whose crops are at risk of disease via text messages, interactive voice response and WhatsApp. Retailers will receive a similar message, enabling them to stock the necessary products and prepare to engage with farmers.

8.2 Innovation - Precision application

The Bilberry Intelligent Spot Spraying System[177] uses an array of cameras mounted directly on pesticide sprayers. With weed recognition algorithms, it can identify any weed in real time before applying the appropriate herbicides with great precision. The deep-learning software and constant gathering of new field data from farms around the world enables continual improvement of the precision of the system and adds new types of weeds to the ever-growing library.

In partnership with Bilberry, Bayer Environmental Sciences in France has adapted the Smart Weeding System[178] for use on the company's spray train to treat railways with herbicide. By connecting this information to the spraying system, herbicides are applied only in the necessary locations, reducing the volume of herbicide applied by up to 50%[179] depending on weed density. Other information is communicated to the spraying system, such as crossing a non-treatment area. As the ultra-precise GPS coordinates have been recorded, these areas are not processed. The data collected (mapping the intensity of infestation, dose and type of herbicide applied, the total volume applied) are stored on a web platform accessible by the customer for traceability and transparency of vegetation control activities. Infestation intensity mapping is a tool available to infrastructure managers to define the right prevention strategy. This information can also be exploited in the event of a dispute or in the event of a check by the authorities. The specifications of the smart weeding system-equipped train have taken into account the 26 requirements of the "PPP Application in Service Delivery" repository. This accreditation was audited by Bureau Veritas, a French certification body and issued by the DRAAF (French Ministry of Agriculture).

The Smart Spraying[180] solution combines Bosch's camera sensor technology and software with xarvio's crop optimization platform.[181] Depending on the local conditions, this may lead to a reduced need for crop protection products in specific applications. Smart Spraying shows up to 70% herbicide volume reduction in its experimental stage. The solution is expected to be launched with a limited number of machines in 2021.

Various other products are on the market and being further developed to identify weeds as a sprayer is passing through a field. An example is SmartStriker[182] from Carbon Bee Agtech. For example, there was an 85% reduction[183] in the amount of product to control thistles in sugar beet than with a conventional sprayer by identifying and treating individual thistles and patches. In this example, there was an 85% reduction in product used. The exact saving varies depending on the density of the weed infestation.

Precision technology also determines whether to apply water or other inputs. Lines are placed directly in the field, allowing farmers to monitor humidity sensors that gather data on soil moisture and the crop's needs. The DripByDrip[184] concept uses drip irrigation systems to deliver chemical and biological crop protection products, applying the active substances precisely to the plant, resulting in higher efficacy, less need for crop protection compound and lower environmental impact. Under the collaboration between Bayer and Netafim,[185] comprehensive data sets will be generated experimentally to calibrate digital prediction models for optimized application of crop protection compounds via drip irrigation. This includes laboratory and field studies evaluating the behavior of the Bayer nematicide Velum® in soils and plants under typical agricultural conditions in arid regions. DripByDrip is part of the Root2Success[186] approach to improve and sustain root health in horticultural crops. As well as water management, this includes preventive measures, curative treatments, root health enhancers and biostimulants. Root2Success has been successfully used and tested in tomato cultivation in Mexico, bananas in Central America, potatoes in Australia and a variety of crops grown by smallholder farmers in Kenya.[187] Yields and grower income increased significantly.

A different approach to innovation for precision and good application is the Spray Service Provider[188] (SSP) scheme from CropLife Africa Middle East,[189] the regional organization which includes CropLife International members. An SSP is a farmer who has received special training on how to apply pesticides, IPM and biodiversity, who hires out his services to fellow farmers to spray their lands. The scheme is linked to member companies of a local CropLife association. It implies that untrained farmers will no longer handle pesticides and that their application will only be undertaken by those who are properly trained and certified. CropLife Africa Middle East has developed the SSP concept to improve access to and application of quality pesticides, resulting in higher yields. The SSP concept was successfully introduced in Cameroon, Cote d'Ivoire, Egypt, Ethiopia, Ghana, Kenya, Madagascar, Malawi, Mali, Nigeria, Sudan, Tanzania, Uganda and Zambia in a variety of crops. So far, more than 12,000 SSPs have been trained, who in turn, help more than 90,000 farmers yearly (information sourced from CropLife.org 24 August 2020).

8.3 Innovation - Drones

The World Government Summit 2018 report "Agriculture 4.0: The Future of Farming Technology"[190] foresaw drone technology as giving agriculture a "high-tech makeover" and proposed six ways drones will be used throughout the crop cycle:

- **Soil and field analysis**: By producing precise 3-D maps for early soil analysis, drones can play a role in planning seed planting and gathering data for managing irrigation and nitrogen levels.
- **Planting**: Start-up companies have created drone-planting systems that decrease planting costs by 85%. These systems shoot pods with seeds and nutrients into the soil, providing all the nutrients necessary for growing crops.
- **Crop spraying**: Drones can scan the ground, spraying in real time for even coverage. Aerial spraying is five times faster with drones than traditional machinery.
- **Crop monitoring**: Inefficient crop monitoring is a huge obstacle. With drones, time-series animations can show the development of a crop and reveal production inefficiencies, enabling better management.
- **Irrigation**: Sensor drones can identify which parts of a field are dry or need improvement.
- **Health assessment**: By scanning a crop using both visible and near-infrared light, drone-carried devices can help track changes in plants and indicate their health, alerting farmers to disease.

In 2020, CropLife International produced the "Drones Manual: Stewardship Guidance for use of Unmanned Aerial Vehicles (UAVs) for Application of Crop Protection Products."[191] It considers the potential benefits of this technology, including:

1. Agronomic:
    - There are considerable time and labor requirement advantages for UAVs operating above small rice paddies compared to manual backpack sprayers walking through water-logged environments to make applications.
    - UAVs allow access to steeply sloping cultivated areas in some vineyards that are hard to reach with ground-based sprayers.
    - Remote-sensing and spraying enables variable rate application and can decrease the amount of pesticide applied by 50%.
    - UAV access to fields is not limited by wet soil conditions, offering flexibility in timing.
    - Overall, UAVs are superior to ground-based systems in small- to medium-sized production units, especially if they are in water (e.g., rice paddies) or on irregular or sloping ground. They can treat larger areas in the same time compared to manual backpack sprayers and small mechanical ground sprayers, also giving advantages in mixing and loading turnaround times.
    - UAV-sensing and monitoring in addition to spraying enables variable rate precision agriculture which increases efficiency through targeted pesticide application and overall reduced amounts of pesticide applied.
2. For users:
    - Application by UAV separates the applicator from the actual spray application and as a result, reduces the applicator's exposure exponentially to no more than that of a bystander, around 2-3 orders of magnitude less than when using a backpack sprayer.
    - UAV operators are not subject to the risk that backpack sprayer applicators have of falling and slipping with a full tank during operation.

3. For precision agriculture and reduced pesticide use:
    - If field maps are not available, up to date or sufficiently accurate, UAVs are important tools in establishing and updating the local base-set of geographical information. This is the base dataset which much precision agriculture depends upon. Once this is established, checked and calibrated, it can be used with sensing or monitoring equipment fitted to a UAV and the appropriate computer-based software to interpret the data that has been gathered. Near infrared sensors can monitor crop photosynthesis.
    - Data interpreted using Normalized Differential Vegetable Index can be used to determine plant health, water stress, fertilizer inadequacy as well as pest and disease stress. Hyper-spectral or thermal sensors can be used to identify water pooling or broken equipment. These systems enable targeted application from a UAV and an overall reduction in the amount of pesticide applied.

All CropLife International member companies are developing recommendations and when necessary, new formulations of their products to engage with this technology. Information can be found on each of their websites. In a feasibility study of the potential use of drones by smallholder rice farmers[192] in Colombia, undertaken by BASF, farmers and partners tested the application of crop protection products with drones and were trained on the responsible use of crop protection products.

8.4 Innovation – Pesticide products

Member companies continuously review their product portfolios based on social, ecological and economic parameters to identify areas that require increased attention and develop appropriate action plans. These may be research projects, reformulations to reduce user exposure and environmental impact or the replacement of a product with an alternative. By such reviews, the development of new, innovative solutions that can contribute to sustainable agriculture is encouraged. Regulatory requirements for registering products change according to scientific developments. The data generated to meet these requirements often requires innovative study methodology to be developed, particularly for ecotoxicological testing in the laboratory and field. The data generated contributes to the science and our understanding of agro-ecological systems as well as supports regulatory risk assessments.

FMC utilizes the Sustainability Assessment Tool to determine if new active ingredients and formulated products in its R&D pipeline meet the sustainability requirements which, along with other stewardship processes and tools, ensures the introduction and continued use of environmentally sustainable agricultural solutions. It researches new bioinsecticides, bionematicides, biofungicides and biostimulants at the European Innovation Centre in Hørsholm, Denmark, and it is a founding member of the Plant Biologicals Network,[193] which aims to create a knowledge and innovation hub in southern Scandinavia. A new collaboration with Zymergen[194] will develop a new and faster natural products discovery process by targeting biochemical processes specific to known pests and scaling production for viable natural product gene clusters.

The "Sumika Sustainable Solutions"[195] initiative is a Sumitomo contribution towards building a sustainable society. In relation to agriculture, the products and technologies under this designation include:

- **Vector-control pesticides**: In addition to fulfilling an important role in repelling and exterminating insects that spread infectious diseases, these pesticides facilitate adaptation to the effects of climate change.
- **Biorationals**: Microbial pesticides, plant growth regulators and biorational rhizosphere microbial agricultural materials are active ingredients derived from naturally occurring substances that contribute to the promotion of sustainable agriculture and the stable supply of safe and secure food.
- **Seed treatment agents**: Accurate treatment of seeds prior to sowing makes it possible to substantially reduce spraying dosage and frequency of crop protection products, contributing to reduced environmental burdens in food production.
- **Plant growth regulators (PGRs)**: These have been certified as Sumika Sustainable Solutions (see Annual Report 2020,[196] page 57), which have such effects as improving fruit set, size and quality of fruits and vegetables. In addition, as the timing of flowering and ripening of crops can be adjusted by PGRs, they are effective in cultivating crops in areas where cooling or droughts caused by climate change has progressed, thereby contributing to an increase in food production around the world.

Biological-based products are receiving considerable research investment by CropLife International member companies. They include biopesticides and biostimulants that may support the "Global Standards for Nature-Based Solutions" promoted by the IUCN.[197] These biological products include micro-organisms (e.g., bacteria, fungi, nematodes), fermentation products, biochemicals and products of natural origin such as plant extracts. Such products are a key component of IPM[198] programs which, in turn, contribute to Integrated Crop Management. Protecting natural habitats near farmland is the best way to conserve biodiversity, including many natural pest enemies. Careful management of farmland edges, including trees and hedges, is important for wildlife habitats and ecosystem services, providing cover and refuge for beneficial insects and animals (e.g., field bunds in rice paddies provide refuge for predatory spiders that help control several insects).

Valent BioSciences, a subsidiary of Sumitomo, launched its Global Soil Health Initiative[199] in late 2019. The key product line in the soil health platform contains a scientifically selected consortium of arbuscular mycorrhizal fungi (AMF) species under the brand name MycoApply.®[200] Mycorrhizae are important beneficial fungi that comprise a major portion of microbial life in the soil. They form a symbiotic relationship with an estimated 85% of the world's plant species, contributing to plant health through an expansion of the root zone and replenishing depleted soils with important contributions to healthy soil structure. AMF are soil-borne microbes that form a symbiotic relationship with about 80% of all plant species. By connecting to roots and forming filamentous strands called hyphae, mycorrhizae can extend the absorption area of plant root systems. AMF provide several benefits to the plant, including increased water and nutrient uptake and abiotic stress mitigation. Mycorrhizal hyphae also produce a sticky glycoprotein called glomalin that forms the basis of stable soil structure by improving soil aggregation which results in improved stability, water penetration and holding capacity. AMF are a cornerstone and indicator species of soil health but can be negatively impacted by soil disruption and intensive agricultural practices. Supplemental applications of AMF, in combination with cultural practices such as cover crops and no-till programs, promise to improve soil health while providing shorter-term crop health and yield benefits. AMF cannot persist in soils without a living host plant, and tillage practices common to so many cropping systems leave soils bereft of the fungi that contribute to strong soil structure. Without AMF and glomalin, soil aggregates become unstable, which reduces the soil's water holding capacity and the availability of water and nutrients to the plant. AMF are a unique example of a crop input that has both short-term (plant health) and long-term (soil health) productivity benefits.

To help understand the symbiotic interactions between AMF and plant roots, Valent BioSciences entered into a joint research collaboration[201] with the Donald Danforth Plant Science Center in 2016, later expanded to include Sumitomo, which is focused on the non-destructive imaging of plant roots grown in soil. Using X-Ray Tomography, X-Ray Microscopy and Virtual Reality applications to create a world-class suite of technologies, the collaborative efforts are providing unique insights into the soil microbial ecosystem fostered by plant roots.

8.5 Management of invasive species and Integrated Vegetation Management

The growing movement of goods and people around the globe is introducing animals, fungi, plants and pathogens to areas outside their natural range at an ever-increasing rate.[202] These alien species can become invasive, negatively impacting their new environment, threatening biodiversity and ecosystems. According to the IUCN Red List of Threatened Species™[203] and the 2019 IPBES Global Assessment Report on Biodiversity and Ecosystem Services,[204] invasive alien species are one of the main direct drivers of biodiversity loss and species extinctions. Furthermore, they are one of the most serious and rapidly growing threats to the security of food, health and livelihoods. The UN Sustainable Development Goals Target 15.8[205] calls for measures to prevent the introduction and reduce the impact of invasive alien species.

For invasive plants, the design of a successful long-term management program should include combinations of prevention and cultural, biological, mechanical and as needed, chemical methods. This is particularly true in restoration programs where seedling establishment is dependent upon suppression of competitive species. The goal of any management plan should not be to just manage the invasive plant but to improve the desirable plant community and prevent re-invasion or invasion by other undesirable plants. Containing existing populations, restoring natural areas severely degraded by invasive plants and preventing the establishment of invasive plants in non-infested lands are critical for maintaining the ecological health and economic integrity of rangeland and natural areas. This can be achieved by identifying management options that will promote a healthy, weed-resistant plant community consisting of diverse groups of species which occupy most of the niches. Corteva produced a practical and technical guide for natural area managers "Invasive plant management"[206] and describes various management techniques on its vegetation management webpages.[207]

Integrated vegetation management on transmission line ROW involves two phases: initially using herbicides and/or mechanical treatments to control undesirable trees incompatible with the objectives of rights of way function, then developing a plant cover to reduce the invasion of tall trees underneath the transmission cables, while maintaining tall shrub cover in the border zone against the surrounding land. Corteva has undertaken research into plant and animal response to long-term vegetation management practices on ROW.[208] Researchers began documenting game species, such as white-tailed deer and eastern cottontails, on power line ROW on Pennsylvania State Game Lands sites[209] in the 1950s and continue to monitor and measure plant and animal biodiversity within both study areas. From 1982 to the present, there has been a concerted effort to examine wildlife usage of ROW through a series of studies focusing on songbirds, large and small mammals, butterflies, amphibians and reptiles. The relative species richness in a variety of ROW treatments was increased compared to the adjacent mature forest.

Table 12: Difference between populations of groups of species in rights of way compared to adjacent mature forest

Group of species	Number of species relative to adjacent mature forest
Butterfly specie	2x
Bird species	8x
Small mammals and reptiles	5x
Herbaceous species	Increased diversity

Properly maintained vegetation within a ROW benefits many bird species, especially those adapted to brushy, early successional habitats, such as the Chestnut-sided Warbler and Eastern Towhee. Reports on the findings of these groups of species and early findings from bee monitoring are available.[210]

Uncontrolled and invasive vegetation growing in critical areas can result in power outages or prevent crews from maintaining the safety and operation of utility ROW corridors. Integrated Vegetation Management[211] has proven effective in managing vegetation while improving habitats for wildlife as well as pollinators. The goal is to develop sustainable vegetation — such as native forbs (wildflowers), shrubs and grasses that do not interfere with overhead power lines or underground pipelines, pose a safety hazard for highway drivers or wildfires, or hamper access to these areas — while supporting healthy environments. Tall growing trees and invasive weeds are controlled while allowing native flowering vegetation to prosper and enhance pollinator habitats. Combining mechanical and chemical control methods with appropriate herbicides and timing takes advantage of biological controls that encourage the natural order of plant competition (and wildlife consumption) while ridding the area of undesirable weeds. Over time, this reduces the need and carbon footprint of mechanical (mowing and cutting) maintenance; lowers utility costs to consumers; minimizes habitat disturbances such as erosion, sedimentation and wildlife disruption; and reduces the threat to nesting animals or endangered species. At the same time, early successional vegetation and native plants thrive. Stewardship advice[212] and product use guidance[213] is given to avoid damage to desirable species and to restore degraded areas.

Invasive annual grasses[214] are a major threat to native plant communities in U.S. rangelands. The lifecycle of these species increases their invasiveness because few native species behave as winter annuals, providing a niche for invasive annual grasses to exploit moisture and nutrients when the most desirable plants are dormant. Downy brome alone infests over 22 million hectares of U.S. rangeland and five other invasive winter annual grasses cause significant economic and ecological impacts: feral rye *(Secale cereale),* Japanese brome *(Bromus japonicus),* jointed goatgrass *(Aegilops cylindrica),* medusahead *(Taeniatherum caput-medusa)* and ventenata *(Ventenata dubia).* Managing these species is a challenge in many parts of the United States and there have been few control options that work consistently, provide multiple years of control and do not injure desirable plant communities. The results of this study suggest that two applications of indaziflam over a five-year period could substantially reduce or possibly eliminate the winter annual grass seed in the soil seed bank.

By controlling invasive annual grasses, remnant desirable perennial grasses and forbs can recolonize. Forage quantity and quality is improved and wildfire risk is reduced. Trial work across the western United States showed that areas treated with the commercial indaziflam product Rejuvra[215] demonstrated a two-to-three-fold increase in perennial grass biomass compared to untreated areas. A single pre-emergent application provides consistent control for multiple years, reducing costs associated with time and labor. The frequency and severity of wildfires in sagebrush scrub[216] are increasing well above natural levels so managing rangeland to reduce the risk is important to maintain the ecosystem and biodiversity it supports.

Other examples of vegetation management contributions to the maintenance of biodiversity[217] include:

- The maintenance of critical shorebird nesting sites in the East Bay Regional Park District,[218] San Francisco, USA by managing excessive plant growth which discourages terns from nesting.
- The enhancement of ranch pasture land[219] to increase numbers of Lesser Prairie Chickens by introducing light to moderate grazing to leave the tall grasses which are required nesting habitat, and treating strips of sagebrush with herbicide to reduce density and, therefore, the risk of predation.
- Controlling mesquite[220] to make groundwater available to recharge springs feeding into saline lakes which are important roosting sites for Sandhill Cranes in winter.
- Pasture improvement in Brazil, which helps to increase production while reducing pressure on forests. For example, at Recanto Ranch,[221] Algoas, Brazil, productivity of beef has increased by three-fold by controlling weed growth and improved pasture management.

Further examples of biodiversity conservation and enhancement by managing invasive species and habitats with the use of herbicides to improve habitats, particularly those which have been invaded by alien or other undesired plant species, include:

- The control of Spartina anglica222 (cord-grass) and closely related species which have invaded salt marshes in western Europe, China and the United States. Spartina can stabilize shorelines leading to build up of sediment and reduce the availability of feeding areas for shore birds. It can be managed by using herbicide to maintain open channels to encourage natural scouring of the shore or directly reducing the density of Spartina (Garnett et al., 1992).
- In the UK, glyphosate223 is used in a targeted manner to help manage invasive plants such as Reynoutria japonica,224 Heracleum mantegazzianum,225 Impatiens glandulifera, Pteridium aquilinum226 and Rhododendron ponticum.227 These "invasive alien" species require a planned, landscape-scale management approach to optimize the desired outcome of improved biodiversity, in which the use of a herbicide is only a component. Special application techniques have been developed, such as stem injection228 of R. japonica. There is a considerable volume of company and independent literature and advice on this topic as well as a significant industry based around the control of invasive species.
- Two-stage water channels:229 Water channels blocked by dense weed growth can become self-managing biodiverse channels with the judicious application of glyphosate. Targeted treatment of the center of the channel maintains vegetation on the bank and at the sides of the channel. The vegetation in desired course of the channel is reduced or cleared, allowing the higher velocity water flow to further discourage vegetation growth and scour this part of the channel. Over two to three years, this creates a two-level channel with an area of lower density vegetation at the center and denser vegetation at the sides (Garnett, 2002).
- Management of vegetation in carp ponds:230 Glyphosate was evaluated for use as a novel management tool to improve the efficiency of intensive carp (Cyprinus carpio) production in Poland. The survival and growth of the carp fry was greatest in ponds in which natural vegetation had been treated with glyphosate prior to flooding, which favored the natural development of food organisms. The yield was greater than merely flooding the vegetation or the alternative technique of maintaining a bare fallow prior to flooding. Using glyphosate as part of the pond management program proved to be cost-effective and had no deleterious effect on the carp fry or their food organisms.

9. Climate change

Factor	CropLife International
Climate change	Provide techniques and tools to reduce energy requirements of agriculture and inputs to it and to facilitate carbon sequestration

Previous sections have emphasized the complexity of biodiversity and of measuring the impact of initiatives on biodiversity. Climate change is also complex but contribution of projects to climate change can be measured by a single parameter: the CO2 equivalent not released into the atmosphere. Reduction of CO2 and other GHGs is a theme through all of CropLife International members' sustainability programs.

At global and regional levels, several of these companies are members of coalitions, alliances and other organizations that have climate change initiatives. Examples are given at the start of this section before progressing to company initiatives because they set a framework for activities. Making progress on climate change mitigation in the food and agriculture sector is crucial to meeting mandates of the Paris Agreement.[231] As this sector represents 25% of global GHG emissions, it is most vulnerable to climate change. Deforestation and forest degradation account for another 10-15%, which risks US$906 billion in annual corporate turnover, according to the We Mean Business[232] coalition.

The BioCarbon Fund Initiative for Sustainable Forest Landscapes[233] (ISFL) is a multilateral fund, supported by donor governments and managed by the World Bank. It promotes reducing GHGs from the land sector, including efforts to reduce deforestation and forest degradation in developing countries, sustainable agriculture as well as smarter land-use planning, policies and practices. The ISFL partners with other public and private sector actors. Public-private partnerships are essential to mobilize capital and align objectives to create sustainable and scalable models for long-term improved land use. The private sector – from subsistence farmers to global, multinational firms – have significant influence on the way land is used. The ISFL works closely with the private sector to provide livelihood opportunities for communities in each jurisdiction and to mobilize finance for critical investments. This engagement can take several forms, from collaborating on sustainability approaches to blending finance in-country to convening stakeholders to work toward complementary goals. Membership includes at least one CropLife International member.

The ISFL currently supports programs in Colombia, Ethiopia, Indonesia, Mexico and Zambia. These large-scale programs are pioneering work that enables countries and the private sector to adopt changes in the way farmers work on the ground as well as informing policies at the international level. Land use initiatives that distribute result-based payments for emission reductions need to define transparent and equitable benefit-sharing plans for how these incentives flow to a diverse range of stakeholders. The "Benefit Sharing at Scale: Good Practices for Results-Based Land Use Programs"[234] study synthesizes good practices for benefit-sharing in jurisdictional land use programs that make result-based payments for emission reductions. The report draws lessons from large-scale programs and other relevant initiatives that involve benefit-sharing focused on forests, land use, natural resources and climate change to support government and program staff in developing and implementing benefit-sharing arrangements.

A global initiative within the WBCSD is the CSA (Climate Smart Agriculture) 100[235] designed to accelerate this type of agriculture across the food sector in order to bring it into closer alignment with the ambitions set out in the Paris Agreement[236] on climate change. CSA 100 aims to bring together 100 leading companies to make science-based and measurable climate-smart agriculture commitments to 2030 across three pillars:

1. Sustainably increasing agricultural productivity and incomes
2. Adapting and building resilience to climate change
3. Reducing and/or removing GHGs

The founding companies of CSA 100 include Unilever, Olam, Syngenta, Rabobank, Barry Callebaut and a range of supporting organizations such as the World Economic Forum, We Mean Business coalition and North American Climate Smart Agriculture Alliance (NACSAA).[237] Bayer is also a member of CSA 100.

The NACSAA is a farmer-led alliance for inspiring, educating and equipping agricultural partners to innovate effective local adaptations that sustain productivity, enhance climate resilience and contribute to the local and global goals for sustainable development. The NACSAA membership includes two CropLife International member companies and CropLife North America. The scope covers all scales of agriculture in Canada, Mexico and the United States, ranging from small landholders to mid-size and large-scale producers. Actions are based on the belief that the use of a CSA framework is foundational to any agricultural climate strategy. By enabling farmers to lead and focus on the economic viability of farming operations as they respond to the changing climate, policymakers can encourage win-win scenarios in which agriculture presents a solution for climate impacts while improving environmental resilience. This builds strong rural communities, engages consumers and ensures public health and access to nutritious food, supporting the attainment of multiple global SDGs.

The Carbon Insetting Framework[238] is a tool developed by a collaboration between the Soil Health Partnership and others, including Bayer, to help farmers verify and validate carbon that has been put into

the ground and take advantage of the economic benefits of climate-smart practices. It provides a framework for quantifying ecosystem services, such as carbon storage and sequestration, within the scope of a company's supply chain that could be used to demonstrate GHG impacts. The WBCSD publication "Smarter Metrics in Climate Change and Agriculture"[239] refers to Bayer's commitment[240] to a 30% reduction of field GHG footprint (per kilogram of yield) of the most emitting cropping systems in regions Bayer operates. This includes Bayer helping farmers use climate-friendly methods, such as reducing plowing, which can release CO2 sequestered in the soil. A paper by McNunn et al., 2020[241] provides some of the science behind the Carbon Insetting Framework. Modeling was used to quantify the potential impact of land management practices on soil GHG fluxes, including CO2 and nitrous oxide. A process-based biogeochemistry modeling framework coupled with published data on soils, weather and yield were used to estimate regionally specific soil GHG reductions associated with the adoption of CSA practices in maize and soybean fields in 11 U.S. Corn Belt states. Significant reductions in GHG emissions corresponded with a conversion from conventional tillage to no-till practices. Additional reductions were predicted for the adoption of cover and improved nitrogen fertilizer timing. The adoption of multiple CSA practices is estimated to have the greatest mean reduction potential of 2,861 kilograms CO2 per hectare per year. Use of this spatially explicit subfield modeling approach based on public data provides a relatively low-cost approach for strategically targeting CSA practices to agricultural regions where adoption is most impactful.

9.1 Carbon Sequestration

In July 2020, Bayer launched a new carbon initiative[242] enabling growers to be rewarded for adopting certain farming practices which sequester carbon, such as cover crops, no-till practices and reducing encroachment into natural vegetation areas. The incentive helps generate additional revenue sources while improving soil quality that can improve yield, profitability and sustainability in the future. The program's 2020-21 season will include approximately 1,200 farmers in Brazil and the United States. In both countries, farmers will receive assistance in implementing climate-smart practices and Bayer will acquire the carbon removals created by those practices at transparent prices. The company is also collaborating with partners such as Embrapa to build a viable carbon market for farmers.

The initiative supports Bayer's sustainability targets for climate protection by 2030,[243] which commit to working with farmers to reduce the ecological footprint of agriculture and help reduce GHG emissions in major agricultural markets by 30 percent by 2030 per kilogram of crop yield. In agriculture, the use of tilling and plowing, fertilizers, fuel and other tools emits GHGs. Agriculture is uniquely capable of removing just as many or more GHGs than it emits. Tilling the soil releases GHGs stored in the soil and contributes to erosion. In 2018, the permanent CO2 savings (2,456 million kilograms) from reduced fuel use from no-till farming was the equivalent of removing 1.6 million cars from the road for a year and the additional soil carbon sequestration gains (20,581 million kilograms CO2) were equivalent to removing 13.6 million cars (PG Economics, UK[244]).

One of Syngenta's Good Growth Plan commitments is to strive for carbon neutral agriculture[245] by measuring and enabling carbon capture and mitigation in agriculture and enhancing biodiversity and soil health on 3 million hectares of rural farmland every year, while reducing the carbon intensity of its operations by 50% by 2030.

9.2 Soil health

Healthy soil is fundamental to a healthy crop, biodiversity and maintaining water balance while minimizing erosion. Global soils contain two to three times more carbon than the atmosphere and, by working with nature and improving soil health, increased carbon sequestration can help reduce emissions and withstand some of the unavoidable effects of climate change. Soil health is related to carbon sequestration in Section 9.1 since healthy soils sequester carbon and carbon sequestration encourages healthy soil.

The "Business Case for Investing in Soil Health" was published by the WBDSC in 2018.[246] It identifies three key next steps to accelerate action in this area:

1. **Lower the hurdles to practices that promote soil health:** For example, explore value-capture systems to support growers in off-setting the initial cost of implementing sustainable practices that promote soil health.

2. **Take advantage of the national context and act locally**: Alignment with national soil health policies and the UN Convention to Combat Desertification commitments, such as the Land Degradation Neutrality baselines, could open up financial options and technical support for in-country projects.

3. **Build partnerships for soil health**: An investment in soil health delivers both public and private benefits but adapting action to local context is key. Businesses can explore supply chain cooperation, public-private partnerships and landscape alliances that spread costs and risks, promote innovation and knowledge exchange, and ensure locally appropriate solutions.

There is a fundamental link between soil health and carbon sequestration by soil so actions on soil health are likely to have dual benefits (see also Section 9.1).

Erosion is a major global soil degradation threat to land, freshwater and oceans. According to recent modeling,[247] if agricultural practices remain the same as today and no additional policies are implemented to limit global warming, yearly soil loss could increase by 66% compared to around 71.6 billion tonnes today. The global south is estimated to bear the brunt of the erosion. Rich countries with high fertilizer use and moderate climates can expect erosion at a lower rate. Erosion makes soil less fertile because of nutrient loss, so farmers compensate with fertilizer, which makes soil less able to store carbon. Economically vulnerable tropical countries are projected to be hit particularly hard by increased soil erosion.

“Climate smart” soil practices have tremendous potential to reduce farm GHGs and increase carbon sequestration (Syngenta Public Policy Position on Soil Conservation,[248] updated in 2018). Minimum tillage, crop rotation and effective nutrient management enhance soil carbon stocks and influence carbon fluxes between the soil and the atmosphere. Used in combination with permanent crop cover strategies, such as leaving crop residues and using cover crops and fallows, fields can effectively serve as carbon sinks and help remove CO2 and other GHGs from the atmosphere. Syngenta has encouraged farmers to adopt these practices and build the business case for climate-smart agriculture as part of its contribution to the CSA[249] project led by the WBCSD. Implementing these approaches to reduce the carbon footprint of agriculture, particularly in China, are a contribution to the UN's Climate Change Race to Zero[250] campaign.

The Soil Health Partnership[251] (SHP) in the United States promotes the adoption of soil health practices for economic and environmental benefit. Bayer is a sustaining member of the SHP with farmers and environmental organizations. Farmers and regional field managers collaborate to conduct field trials that compare soil health practices to historical field management. The SHP works closely with farmers throughout the year as they try new practices such as cover crops, collect data to improve decision-making and reduce risk from adopting alternative practices. Initial analyses suggest statistically significant increases in soil organic matter over the network. (See also section 9.)

The SOil and WAter Protection project[252] (SOWAP) was created to take a holistic approach to comparing conservation tillage crop establishment methods, with more traditional moldboard, plow-based systems. SOWAP was jointly implemented by a variety of partners including a CropLife International member. The project operated in the UK, Belgium and Hungary. The three main principles of conservation agriculture were followed: reduced/minimum tillage, permanent soil cover and appropriate crop rotations. The economic, ecological, environmental and yield outcomes from both methods were compared side-by-side.

- **Erosion and run-off:** Soils vulnerable to erosion benefited from reduced tillage and soil losses from the farmer's field were minimized, particularly in spring-planted crops. In the UK, concentrations of nitrogen and phosphorus in eroded sediment are lower for the conservation tillage treatments. At one of the sites, conservation tillage also reduces the levels of phosphorus in runoff. There is no effect of soil management on the loss of carbon in sediment or runoff.

- **Birds:** Conservation tillage favors earlier skylark nesting and may increase the length of the effective breeding season. The maintenance of seed over winter benefited birds because they were not buried by plowing.

- **Soil microbes:** Microbial community structure is significantly affected by tillage type at both UK field sites. Plowing results in greater variation in the microbial community structure than in soils under conservation tillage. In most soils, earthworm and soil microbe populations, particularly fungi, were enhanced by conservation tillage.

- In plowed catchments, there was a slight decrease in invertebrate species richness compared to conservation tillage and semi-natural catchments. *Gammarus pulex* (a freshwater shrimp) was more abundant in plowed catchments, possibly due to reduced competition from smaller populations of more sensitive species. Initial results for diatoms indicate that there are differences in some key indicator species between conservation tilled and plowed catchments, suggesting that more eutrophic conditions may exist in the latter.

- Crops grown under conservation tillage produce similar yields to those established by plowing.

Unsustainable cropping practices, such as slash-and-burn agriculture, continuous monocropping and poor nutrient management, have greatly decreased soil health and fertility in many parts of Africa, leading to reduced yields and limited resilience of cropping systems. This is likely to aggravate in the context of climate change as degraded soils offer limited capacity to store moisture, while more rapidly eroding during excessive rains. In recent years, "push" initiatives have been launched to improve soil fertility and health in developing countries. However, improving soil health needs clear and sustainable "pull" incentives for farmers to implement and maintain them at scale, both in spatial and temporal contexts. This means tailored combinations of commercially viable, risk-reducing interventions with near-term return on investment for farmers and their business partners. The Syngenta Foundation's "Risk Reduction Through Soil Health Improvement"[253] details concepts to transform soil management amongst East African farmers ("healthy soils for smallholders"[254]). Kenya is the initial focus since it offers a comparatively liberal and enabling policy framework (e.g., no rigid fertilizer subsidy schemes) and existing or developing private sector supply chains for inputs (such as nutrient blends and soil diagnostic tools). Different mechanisms will be tested for tailoring combinations of soil health-promoting interventions to individual farmers to identify flexible, effective, replicable models that can be adopted widely. The first interventions will include farm diversification through market-led introduction of new rotational crops, building on existing legume rotation work in Africa, part of the Seeds2B program.[255] Rotating crop types can increase soil nutrients and break pest and disease cycles, reducing agrichemical costs. The second intervention will involve state-of-the-art tools for low-cost soil diagnostics linked to advising and training on appropriate input use and improved links to supply chains. Today, unfortunately, balanced fertilizer blends or soil supplements, such as lime, are often not available to smallholders at all or not at the right time. Thirdly, building on a partnership with the World Bank's BioCarbon Fund,[256] smart and sustainable financial incentives for farmers will be developed to encourage them to improve the health of their soils.

Other examples of projects related to building healthy soils through minimum tillage and leaving residues of previous crops on the soil surface, supported by crop rotation, are in Mexico[257] and eastern Russia.[258]

CropLife International members are also members of CropLife America.[259] Among other activities, this U.S. organization promotes the use of cover crops[260] (i.e., grasses, legumes, or flowering plants) to increase soil health by reducing erosion; improve soil structure, moisture-holding ability and nutrient content; suppress weeds; provide habitat for beneficial predatory insects; and serve as forage for farm animals. Cover crops can also reduce carbon in the atmosphere because their consistent use on the same fields over time can increase soil organic matter and thereby, carbon sequestration. The latter is also supported by no-till farming,[261] which reduces the annual fuel requirement for plowing and CO2 emissions.

CropLife America activities reflect those of their members. For example, the "Stronger Soil Equates to a Healthier Ecosystem"[262] program brings together solutions to support improved harvests while maintaining soil health:

- Practices such as no-till, reduced-till and conservation tillage allow farmers to reduce or eliminate plowing a field, leaving its soil undisturbed to promote health. When soil is broken up and turned over in the tilling process, it releases carbon stored in the soil and increases the possibilities that the soil will erode via wind or rain. Reduced tillage practices allow nutrients and moisture to remain in the soil, limit soil erosion, reduce water run-off and enable farmers to make better use of rainwater. These practices have the potential to decrease the need for irrigation and allow farmers to protect freshwater sources. No-till methods can also help sequester carbon in the soil. With minimal or zero tillage, farmers reduce their GHG emissions and protect the soil ecosystem for earthworms, nematodes, mites, insects, fungi and bacteria.

- Cover cropping is the practice of planting various plants like radishes, clover and mustard between growing seasons. Plants such as the tillage radish can provide relief, delivering improved erosion protection and increased moisture retention by breaking up the soil. Legumes like crimson clover use natural soil bacteria to pull nitrogen from the atmosphere and attach it to their roots, which benefits plants the following year. Cover crops help keep nutrients and organic matter in the soil, making it healthier and more sustainable, leading to better harvests.

- Plant nutrition: Over 3% of the world's GHG emissions and 3% of natural gas used globally comes from the use and production of synthetic nitrogen. Researchers are working on bacteria to help crops extract nitrogen from the air and radically reduce the need for synthetic fertilizer.

9.3 Manufacturing and distribution

All member companies work to make their manufacturing processes more resource-efficient with reduced impact on health and the environment and reduced yield of GHGs. The sustainability reports referenced in Annex I frequently progress against targets.

While largely out of the scope of this report, the following example illustrates the importance of developing improved processes. A project between Shimane University and Sumitomo Chemical Company, Limited[263] aims to accelerate joint research on a highly effective method of synthesizing methanol from CO2 at a yield ideal for practical implementation. Methanol is an industrial alcohol that is widely used as a basic raw material for such chemical products as adhesives, drugs, coating materials and synthetic resins as well as for light olefins, including ethylene and propylene. With an annual global demand of approximately 80 million tons, methanol is currently manufactured from fossil resources, mainly natural and coal gases, through several manufacturing processes under high temperatures and pressures. To help address climate change on a global scale, academia and industry are cooperating to develop carbon cycle technologies, aiming to reduce emissions of GHGs. Combining CO2 generated from waste incineration with hydrogen derived from renewable energy produces methanol, which can be used to produce useful industrial products while also reducing GHG emissions. In addition, methanol can be produced from syngas (a mixture of hydrogen, carbon monoxide and CO2). A complete carbon cycle can be achieved by converting used plastics and biomass resources into syngas as the raw material for the production of methanol.

A different aspect of manufacturing is seed production. As part of its support for water stewardship advances in global agriculture production by 2030, Corteva[198] has set a goal to reduce water consumption while increasing yields on 2.5 million hectares of seed production and water stressed land by 2030 compared to 2020. It is also working to help seed growers be more productive and improve the health of their soils by understanding the nutrient requirements on different soil types.

10. Effective and scalable strategies

10.1 Effective project planning

There are several themes amongst the projects that point towards factors required for successful and impactful implementation. Small-scale projects will not necessarily need all of them but most will contribute to major, successful, and impactful projects.

- **Passion** for positive outcomes leads to innovative and participative projects. Tapping into and maintaining this energy is essential for success, otherwise projects are likely to remain local or fail completely despite good science and planning. The projects summarized in the report demonstrate the passion of CropLife International member companies and their employees.
    - The passion can be generated "bottom up by individual employees initiating projects and promoting their benefits and "top down" when senior managers set policy. Examples of both are covered in this report.
- **Incentives** are necessary at all levels. The global concern on biodiversity and its nexus with the two major challenges of climate change and food security have incentivized businesses to incorporate biodiversity into their company sustainability strategies, yet farmers also need incentives to drive inclusive change.
    - Farmers need income and that provides a formidable incentive. Such incentives are not always financial but may be facilitative, for example, through less labor and time-intensive practices or personal and communal prestige. If the target audience does not see the benefit for themselves, projects rarely succeed.
    - This report provides evidence that CropLife International member companies have been active for over 20 years and this engagement has now accelerated at both corporate level and field levels.
- **Way of working:** The most successful projects are created and completed when the implementation is undertaken with sufficient desire and energy, and they are designed appropriately for the target audience or market.
    - Projects are likely to be doomed if the resources and energy are not maintained sufficiently throughout their life. This may explain why some projects in this report remain local and have not been scaled up as foreseen.
    - Partnerships are particularly important for success within and external to a company. A holistic approach to sustainability and biodiversity can help companies align internally to link historically disparate strategies ("silos").
- **Partnership and dialogue** are fundamental for success. They are necessary to identify opportunities, develop solutions to problems, pilot projects and scale-up implementation to be impactful.
    - Farmers are essential partners for implementation. Their enthusiasm and expertise are essential for the success of field level projects in agriculture. CropLife International companies deal directly with farmers as end users of their products, providing a foundation for their engagement and involvement, and providing another link between policymakers and their necessary partners. The involvement of farmers and other producers is central to on-farm change. It allows them to contribute their knowledge and experience to shape meaningful, on-farm research trials for researchers and policymakers to develop a deep understanding of real-life hurdles to adopting proposed agricultural practices.
    - CropLife International and its members, along with other organizations, can further support advising authorities and helping with implementation.
    - Other participants in the food supply chain can contribute to implementation and help provide reward to farmers.
    - The nature-based-solutions concept promoted by IUCN[197] recommends that sustainable solutions should offer benefits for all stakeholders. CropLife International suggests that large-scale uptake by farmers will require a reasonable farmer income.
    - At the government level, fiscal incentives for best practices (and disincentives for poor practices) boost the likely scale of the implementation stages of suitable projects and of support by extension agents, research institutes and academia.
    - NGOs may provide knowledge and other resources to focus projects on biodiversity benefits.

- **Holistic approach**: Biodiversity is a complex topic and successful actions recognize the diversity of agricultural landscapes, ecosystems and socio-economic aspects to enable producers to utilize the systems and practices that best support their farming operations. To have a significant impact, a project must extend beyond a field or farm.

- **Stepwise**: A stepwise process generating incremental, positive changes and impacts is key to staying focused and to meeting the longer-term goals that are essential to maintaining and improving biodiversity. Practical milestones within the overall goals are necessary to demonstrate progress.

- **Science**: A background of good science is essential when planning for changes to enhance biodiversity to minimize the risk of unexpected negative outcomes. This frequently requires independent expert partners but also needs scientific expertise amongst company staff to translate the science into implementation practices appropriate to the company.

    - Science-based decision-making – in conjunction with farmers' knowledge of their own farming operations and innovation – is the foundation for adopting appropriate technologies and practices for sustainable agriculture and global food production, and for supporting biodiversity.

    - Measurement of the effects on biodiversity, progress towards the defined target and their impact are critical to fully engage employees and partners and demonstrate that corporate strategies are effective and not "greenwashed."

- **Trade-offs**: Trade-offs are inevitable and must be recognized and transparent. Context-specific priorities and solutions should be aligned with company and national policies and priorities. They are determined based on the social, economic and environmental conditions of the situation, including the diversity in type and scale of agricultural activity. They should be subject to the evaluation of potential synergies, trade-offs and net benefits.

10.2 Scalable projects

All CropLife International member companies have sustainability strategies. To have a significant effect on biodiversity, initiatives usually must be taken up by farmers on a large scale. Projects usually must transition from concept to small scale (e.g., field trials or on-farm tests) through pilot implementation (e.g., multiple farms or local expansion), then full implementation at a landscape, national or regional level (i.e., there are several steps towards the goal). There are examples of each of these steps in the projects reviewed in this report, including projects which have gone through all three steps. Of course, this takes time and there are several examples of long-term projects in this report, for example:

Step 1: Concept

A project must address a need or problem. Usually, the concept should be based on robust evidence supporting that need or problem and be framed in such a way that the goal is "SMART:" specific, measurable, attainable (but perhaps with a "vision" that may be difficult to achieve), relevant and time-based.

Step 2: Small-scale

The definition of small-scale is project-dependent. It could be a field scale if the project aims to investigate the impact of farm practice on insects or at a landscape level (or greater) if it aims to test incentives for changes in farm practices. A small-scale project will test basic feasibility.

Step 3: Pilot implementation

Lessons learned from step 2 are tested at a wider scale to evaluate whether a project is suitable for full-scale implementation and that it will be used by target stakeholders.

Step 4: Landscape, national and regional

Broad implementation of the project. It may take years before it becomes widely used and implemented.

CropLife International member company projects have the greatest impact when the companies' tools are combined with science-based, data-driven policy measures so that farmers and the entire value chain have the incentives and tools to reduce their impact on biodiversity. These tools make it easier to combine food security, safety and quality with the conservation and improvement of biodiversity. The focus must be on the target audience at all stages of the project, remembering the "what's in it for me" of all partners and collaborators.

10.3 Examples of successful scale-up

"Operation Pollinator" is an example of a project that has passed through all stages from very local to global. It started as an assessment of the effects of different management options for arable land as prescribed under the newly introduced Environmental Stewardship Scheme in England (the concept), with six small field trials (small-scale testing). These trials were established in 2001 and carried on through 2004. They built the foundation for farm-scale studies in the UK and Netherlands, which proved the concept. Further field and landscape studies were undertaken while the project began to be promoted in the UK as "Operation Pollinator" from 2004. Based on success in the UK, it was extended internationally and new countries continue to be added.

The "Forward Farming" initiative has a foundation built on numerous developments and lessons learned over many years. These include the ecological enhancement of farmland in the Upper Rhine project, which commenced with a baseline survey in 2010, followed by the creation of various wildflower areas and nesting sites for birds, with monitoring of the results between 2011 and 2016. Recommendations from these field and farm-scale studies have been built into the "Forward Farming" initiative which has extended beyond Germany around the world.

Similarly, the Farm Network began in Germany in 2013 and expanded to 53 farms in 2017. Monitoring data show the benefits of several interventions, which can be undertaken by farmers to improve biodiversity, and they have been promoted. The Farm Network now extends beyond Germany.

Some projects are more limited in their scale but develop data that demonstrate how farm biodiversity can be improved and these messages can be used in promotional activities. Again, this builds from initial small projects to wide impact even though the data may be at a limited scale. "The Mata Viva" is one such project. Three farms that had restored degraded forests in Brazil were monitored and the results showed how the restoration of native forests on farms can benefit biodiversity.

11. Conclusion

There are many more projects from small-scale studies to landscape-scale projects than were expected at the start of this report. CropLife International members are highly active in this field with several projects coming on stream on an ongoing basis.

Members as individual companies are acting in partnership with other groups to implement biodiversity-related actions. They are also involved in wider industry collaborations and consortia, so that the overall aim of maintaining and improving biodiversity is achieved through a variety of mechanisms but almost always in some form of partnership.

Several projects have had demonstrated broad impact on maintaining and improving biodiversity with detailed scientific data. These can be found throughout the report. CropLife International members have tested and established many workable examples and concepts, which are compiled in this survey. However, member companies are suppliers of tools to farmers and not themselves farmers.

All CropLife International members have transparent sustainability programs, some of which have been running for many years while newly formed companies, of course, have only recently set in place this type of program. They are usually set up according to external guidelines and auditing procedures.

Unfortunately, it has proved impossible to assess the net impact on the total number of square kilometers of farmland that have benefited from CropLife International members' projects, but the number and scale of the projects indicates that a huge area around the world has been impacted.

Table 13: Total area benefited by company projects for which such targets are available

	Target	Status	Source
BASF	Climate-smart farming: 30% reduction in CO_2 emissions per ton of crop produced by 2030	New target in 2020	**BASF sustainability targets**[264]
Corteva	Improve soil health on 30 million hectares of agricultural land by 2030	New target in 2020 for the new company	**Corteva Agriscience 2030 Sustainability Goals: The Land**[265]
	Enhance biodiversity on over 10 million hectares of grazing lands and natural ecosystems globally through sustainable management practices and habitat conservation by 2030	New target in 2020 for the new company	
Syngenta	Improve the fertility of 10 million hectares of farmland on the brink of degradation	14.1 million hectares of benefited farmland (cumulative since 2014)	**Good Growth Plan**[28]
	Enhance biodiversity on 5 million hectares of farmland	8.2 million hectares of benefited farmland (cumulative since 2014)	

Many of the studies and activities reported also demonstrate how CropLife International and its member companies have contributed towards efforts to achieve the Aichi targets. Some examples of this are shown in Table 14 (page 57).

The report shows that member companies have engaged in activities to promote biodiversity in relation to agriculture over the past 20 years. The momentum towards this has increased in recent years. Further, the programs and projects run by the companies and in which they are partners are a contribution towards addressing several of the key components of the sustainable agriculture transition listed in the Global Biodiversity Outlook 5, including:

- Promote integrated pest and disease management.
- Enhance management of land and water.
- Integrate systems of crops, livestock, fish and/or tree production.
- Maintain biodiversity.
- Promote on-line learning and research.
- Improve connections between farmers and consumers.
- Provide an enabling environment.

Examples of the practical application include enhancing carbon sinks through the reforestation of degraded land and forest areas, conservation and natural regeneration of habitats, restoration and conservation of forest ecosystems, and sustainable water use and management. CropLife International and its member companies offer their support and experience to policymakers and authorities, and their help with implementation in collaboration with other organizations. Policymakers and authorities can select relevant examples and create policies and incentives that expand the use of these at larger scale among farmers and other relevant users like forest managers.

ANNEX I: Company commitments for biodiversity

BASF

Corporate Global Sustainability

https://report.basf.com/2019/en/[266]

https://www.basf.com/global/en/who-we-are/sustainability.html[267]

https://www.basf.com/global/en/who-we-are/sustainability/we-produce-safely-and-efficiently.html[268]

We create chemistry for a sustainable future:	• We resource responsibly. • We produce safely for people and the environment. • We produce efficiently. • We drive sustainable product. • We value people and treat them with respect.
Responsible Care:	• Responsible Care management system • Energy and climate protection • Water • Ecosystems

Agriculture

https://agriculture.basf.com/global/en/sustainable-agriculture.html[269]

Sustainable Agriculture. Right Balance. Better Yield.

Over the coming decades, our agricultural food system will undergo an accelerated transformation in order to provide access to enough healthy and affordable food for the growing population. At the same time, it will need to mitigate its impact on our planet so that future generations can flourish. This transformation will be driven by the call for better yield – yield produced in ways that are recognized as valuable by society, are kind to the planet and help farmers earn a living.

What do we mean by better yield? Here are some examples with our products and technologies:

- Less CO2 per ton of protein by enabling no-till farming with innovative herbicides.
- More biodiversity protection per ton of wheat produced with new business models like "Lark Loaf."
- Reduced food waste in households through seed breeding that produces innovating products like mini watermelons.
- Higher yield with lower environmental impact in rice enabled by Seltima® fungicide.

Sustainability targets:

- Climate-smart farming: 30% reduction in CO2 emissions per ton of crop produced by 2030 https://agriculture.basf.com/global/en/sustainable-agriculture/climate-smart-farming.html[270]
- Sustainable solutions: 7% annual increase in our share of solutions with sustainability contribution https://agriculture.basf.com/global/en/sustainable-agriculture/sustainable-portfolio.html[271]
- Digital farming: 400+ million hectares supported with digital technologies by 2030 https://agriculture.basf.com/global/en/sustainable-agriculture/how_digital_farming_contributes_to_sustainability.html[272]

- Smart stewardship: safe use of our products with the right stewardship. https://agriculture.basf.com/global/en/sustainable-agriculture/smart-stewardship.html[273]

Position on biodiversity:

https://agriculture.basf.com/global/en/media/positions-on-agriculture/biodiversity.html[274]

Bayer

Bayer Corporate

https://www.bayer.com/en/sustainabilitystrategy.aspx[275]

https://www.bayer.com/en/sustainability-reports.aspx[276]

Sustainability strategy: Health for all, hunger for none.

Food security	Access to food
	• Supporting smallholder farmers
Healthcare	• Access to contraception
Climate protection	• Climate protection
	• Access to self-care solutions
	• We value people and treat them with respect.
Sustainability targets: core competencies	• SDG 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture.
	• SDG 3: Ensure healthy lives and promote well-being for all at all ages.
Work to promote:	• Gender equality (SDG 5)
	• Reducing greenhouse gases, tackling climate change (SDG 13)
	• Supporting life on land (SDG 15)

Bayer CropScience

Our sustainability commitments:[277]

https://www.bayer.com/en/position-biodiversity.aspx[278]

https://www.bayer.com/en/sustainability/position-deforestation-and-forest-degradation[279]

https://www.bayer.com/en/sustainability/our-views-insect-decline[280]

https://www.cropscience.bayer.com/people-planet/biodiversity[281]

Bayer takes steps to make carbon sequestration a farmer's newest crop opportunity – Bayer News[282]

Biodiversity creates opportunity for all

Bayer CropScience aims to:

- Steward and pioneer innovative solutions that empower farmers to farm better, like advanced digital tools, plant breeding, biotechnology and other technologies that that help improve land use to grow enough food while using fewer resources and preserving space for natural ecosystems.

- Protect habitats alongside farmers and external partners by avoiding deforestation and supporting reforestation efforts around the world.

- Support sustainable farming practices such as Integrated Weed Management, cover crops, conservation tillage, crop rotation and other methods that help farmers conserve natural resources, maintain natural habitat and protect the environment.

- Maintain rigorous standards in environmental safety testing, risk assessment and transparency to produce solutions that minimize agriculture's effect on biodiversity.

- Collaborate with others within and outside of our industry to pursue new ideas that foster compatibility between agriculture and all organisms.

https://www.cropscience.bayer.com/innovations/a/integrating-crop-production-and-biodiversity[283]

Corteva

Sustainable Agriculture.[284] "We're in it for good: a mission with a purpose."

Corteva Agriscience is committed to advancing sustainable agriculture to enrich lives and our planet for generations to come. We've established 14 goals to achieve by 2030 that will increase the resilience of our global food system.

Our 2030 Goals

Sustainability matters more than ever for farmers, for the land, in our communities and in our operations. Our goals are focused on sustainable agriculture and farming, and on our on-farm relationships.

For farmers: https://www.corteva.com/sustainability/goals-to-benefit-farmers.html[285]

For the land: https://www.corteva.com/sustainability/goals-to-benefit-the-land.html[286]

In our communities: https://www.corteva.com/sustainability/goals-to-benefit-communities.html[287]

In our operations: https://www.corteva.com/sustainability/goals-to-benefit-operations.html[288]

Corteva Agriscience 2030 Sustainability Goals: The Land[265]
Enhance biodiversity on over 10 million hectares of grazing lands and natural ecosystems globally through sustainable management practices and habitat conservation by 2030.

- We plan to provide expertise, resources, technical and product support (including digital tools), and engagement to enhance biodiversity in each of our six global commercial regions.

- We plan to collaborate with partners to identify local priority areas for biodiversity enhancement. Regional teams will determine the most beneficial initiatives and approaches locally.

- Sustainable management practices will be locally relevant and will generally align with the core principles of preserving natural resources, supporting people and the community, promoting animal health and welfare, efficiency and innovation.

- Sustainable management practices on grazing land promote the co-existence of livestock and wildlife, while increasing productivity (e.g., technology adoption, stocking rate, rotational grazing).

FMC

FMC's Sustainability Goals[289] were re-set in 2019 based on new business strategy and using 2018 as the baseline year. A key goal is that by 2025, 100% of the R&D spend will be on sustainable products providing innovative solutions to food security and a commitment to creating products that are consistently better for the planet than any that currently exists in the market. Linked to this are targets to support two UN SDGs:

- SDG 2 – Zero Hunger: develop products that increase crop yields and ensure a quality food supply and technologies that contribute to resilient agricultural practices.

- SDG 15 – Life on Land: technologies that save water, fuel, reduce GHG emissions and soil compaction; products that increase crop yields preserving land from conversion to farmland; targeted products with low application rates; biological products; continued commitment to R&D spend on developing sustainable products.

FMC states in its 2019 Sustainability report[290] that with "strong capabilities in our R&D organization, we create innovative solutions to address food security, one of the largest global challenges, without compromising the environment. We commit to creating products that are consistently better for the planet than any that currently exist in the market. FMC utilizes the Sustainability Assessment Tool to determine if new active ingredients and formulated products in our R&D pipeline are sustainably advantaged. This assessment, along with other stewardship processes and tools, ensures the introduction and continued use of environmentally sustainable agricultural solutions. The R&D spend used in the metric is inclusive of all variable and fixed costs related to the discovery and development process across all regions. It does not include spend associated with the defense of existing products."

https://investors.fmc.com/financials/annual-reports-and-proxy-statements[291]

Sumitomo

Sumitomo established its "Basic Principles for Promoting Sustainability[292]" in January 2019. By positioning these principles next to its business philosophy, Sumitomo demonstrates its management commitment to promoting sustainability.

Principle 1:	Create economic value along with social value. Our business must benefit society at large, not just our own interests.
Principle 2:	Contribute to solving globally vital issues.
Principle 3:	Actively participate in global initiatives.
Principle 4:	Collaborate with stakeholders.
Principle 5:	Top management commitment and participation by all.
Principle 6:	Enhance corporate governance.

These Basic Principles define Sumitomo's efforts of promoting sustainability as "contributing to the establishment of a sustainable society while achieving the sustainable growth of our business."

Taking biodiversity into consideration is one of Sumitomo's most important pillars as it strives toward building a sustainable society. Sumitomo's Biodiversity Preservation Initiatives[293] cover five key areas:

- The conservation of biodiversity as one of the most important management issues to help protect the global environment.

- Continual reduction of the environmental impact of production operations and development and supply of products and services, and in cooperation with third parties, in the supply chain and to contribute to the conservation of biodiversity.

- Education programs to ensure that employees fully recognize and understand the importance of biodiversity and promote Sumitomo's commitment to its conservation.

- Corporate social responsibility activities that contribute to environmental protection and lead to greater trust and confidence from society.

- Disclosure of results and effective communication with the general public.

https://www.sumitomo-chem.co.jp/english/ir/library/annual_report/files/docs/ar2020e.pdf[294]

https://www.sumitomo-chem.co.jp/english/sustainability/information/library/files/docs/sustainability_data_book_2020e.pdf[295]

Syngenta

The Good Growth Plan[28] was launched in 2013 with a set of targets to improve the sustainability of agriculture by 2020 by reducing agriculture's carbon footprint and helping farmers deal with the extreme weather patterns caused by climate change. The achievements were reported in The Good Growth Plan Progress Report 2019.[296] Most of the goals had been achieved by 2019, a year earlier than scheduled. Building on the progress and lessons learned, a new Good Growth Plan was launched in 2020[297] with a new set of targets and commitments for 2025. Further detail and progress towards these is reported in the Environment, Social and Governance Report (ESG Report) 2020.[298] Farmland which benefitted from biodiversity enhancement measures covered 1.7 million hectares in 2020 and 1.8 and 0.8 million hectares in 2019 and 2018, respectively, around the world (page 30 of the ESG Report).

1. Accelerate innovation for farmers and nature.
    a. Invest $2 billion in sustainable agriculture breakthroughs.
    b. Two new sustainable technology breakthroughs per year.
    c. Strive for the lowest residues in crops and the environment.
2. Strive for carbon neutral agriculture.
    a. Measure and enable carbon capture and mitigation in agriculture.
    b. Enhance biodiversity and soil health on 3 million hectares of rural farmland every year.
    c. Reduce the carbon intensity of our operations by 50% by 2030.
3. Help people stay safe and healthy.
    a. Goal of zero incidents in our operations.
    b. Train 8 million farm workers on safe use every year.
    c. Strive for fair labor across our entire supply chain.
4. Partner for impact.
    a. Build cohesive partnerships and publish their sustainability objectives.
    b. Launch innovation dialogues for inclusive consultation on sustainability.
    c. Board level governance of sustainability.

Table 14: Examples of how CropLife International and its member companies have contributed towards achieving the Aichi targets[299]

	Aichi target	General activities of CLI and its members	Examples of specific activities
1	By 2020, at the latest, people are aware of the values of biodiversity and the steps they can take to conserve and use it sustainably.	* Biodiversity Task Force set up with all member companies and CLI strategy defined, 2020.	* Publication of the "Report on CropLife International member companies activities relating to biodiversity and climate", 2021.
4	By 2020, at the latest, Governments, business and stakeholders at all levels have taken steps to achieve or have implemented plans for sustainable production and consumption and have kept the impacts of use of natural resources well within safe ecological limits.	* All member companies have publicly available corporate strategies which incorporate aspects of sustainability including biodiversity, including targets and metrics (see CLI Report). * CropLife International and its regional associations have implemented projects to raise awareness of issues and implemented specific plans relating to biodiversity, climate and sustainability.	* Links to the relevant web pages for each member company are given in the Report (pp. 52-56). Examples relating directly to biodiversity include: https://agriculture.basf.com/global/en/media/positions-on-agriculture/biodiversity.html; https://www.cropscience.bayer.com/people-planet/biodiversity; https://www.corteva.com/sustainability/goals-to-benefit-the-land.html; https://www.syngenta.com/en/sustainability/good-growth-plan/strive-carbon-neutral-agriculture
5	By 2020, the rate of loss of all natural habitats, including forests, is at least halved and where feasible brought close to zero, and degradation and fragmentation is significantly reduced.	At different scales, CLI member companies are actively involved in managing and conserving biodiversity in agriculture which contribute to this target.	* "Regenerating a million hectares of degraded pasture in Brazil" (p. 17) reported in https://www.syngenta.com/sites/syngenta/files/company/presentations-and-publications/Syngenta-and-agricultural-systems-2020.pdf) * The Mata Viva Program in Brazil has planted more than 1.2 million Atlantic Forest native seedlings, reforesting about 730 hectares of land contributing to the return of flora and fauna. (p. 31) https://www.espacoeco.org.br/wp-content/uploads/2021/05/Activity-Report-FEE-2020.pdf
7	By 2020 areas under agriculture, aquaculture and forestry are managed sustainably, ensuring conservation of biodiversity.	At different scales, CLI member companies are actively involved in managing and conserving biodiversity in agriculture which contribute to this target.	* For pollinators, numerous science-based and practical implementation projects have been lead by CropLife International members alone or in collaboration with other experts. Successful measures to improve pollinator success and diversity have been developed and promoted. (pp. 18-31) * Growing trees, shrubs and other vegetation inside and around farmland to benefit around 6.4 million hectares of farmland (p. 33). https://www.syngenta.com/sites/syngenta/files/company/presentations-and-publications/Syngenta-and-agricultural-systems-2020.pdf * Good ground cover management in olive groves in southern Greece provides habitats for pollinating insects and natural enemies of pests. (p.32)

8	By 2020, pollution, including from excess nutrients, has been brought to levels that are not detrimental to ecosystem function and biodiversity.	Reduction of potential pollution by innovation, including new pesticides such as biologicals, improved application to minimise non-target effects and optimise efficacy, innovative formulations allowing dose reduction, training advice to users, CropLife International Spray Service Provider scheme.	* Precision technology can determines whether to apply water or other inputs. Lines are placed directly in the field, allowing farmers to monitor humidity sensors that gather data on soil moisture and the crop's needs. (p. 37) * Intelligent spraying systems use an array of cameras mounted directly on pesticide sprayers. With weed recognition algorithms, it can identify any weed in real time before applying the appropriate herbicides with great precision. (p. 37) * An innovation for precision and good application is the Spray Service Provider (SSP). An SSP is a farmer who has received special training on how to apply pesticides, IPM and biodiversity, who hires out his services to fellow farmers to spray their lands. (p.37) *Biological-based products are receiving considerable research investment by CropLife International member companies. They include biopesticides and biostimulants that may support the "Global Standards for Nature-Based Solutions" promoted by the IUCN. (p. 40) * Innovation in manufacturing processes to reduce greenhouse gas emmissions and reduce resources including water needed for manufacturing. (p. 47)
9	By 2020, invasive alien species and pathways are identified and prioritized, priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment.	Several member companies are involved in the management of invasive insects and plants	* Integrated vegetation management in U.S. Rights of Way to increase relative species richness compared to adjacent natural forest (pp. 40-41). * Management of invasive annual grasses in U.S. rangelands to maintain native plant communities (pp. 41-42). * Management of cord-grass (Spartina in salt marshes in the U.K. and U.S.A., and Reynoutria (Japanese Knotweed) and other species near waterways in the UK. (p. 42)
14	By 2020, ecosystems that provide essential services, including services related to water, and contribute to health, livelihoods and well-being, are restored and safeguarded, taking into account the needs of women, indigenous and local communities, and the poor and vulnerable.	CropLife International regions and member companies are actively involved in projects to reduce potential losses of pesticides from farm land to water.	* A broad partnership, the "Midwest Row Crop Collaborative" addresses nutrient overload in the Mississippi River and enhance soil health and food security in its surrounding catchment. Farmers are changing their practices by, for example, incorporating cover crops and no-till into their day-to-day activities. (p.18)

			* The PRÁTICAS AGRÍCOLAS ASPIPP Por uma agricultura sustentável addresses water cycle management in the Brazilian Region of Alto Paranapanema (p. 34). https://www.espacoeco.org.br/wp-content/uploads/2019/11/e-book-ASPIPP.pdf * The Soil Health Partnership works closely with farmers as they try new practices such as cover crops, collect data to improve decision making and reduce risk from adopting alternative practices. Initial analyses suggest statistically significant increases in soil organic matter over the network. (p. 45) * "Risk Reduction Through Soil Health Improvement" details concepts to transform soil management amongst East African farmers ("healthy soils for smallholders"). (p. 46)
15	By 2020, ecosystem resilience and the contribution of biodiversity to carbon stocks have been enhanced, through conservation and restoration, including restoration of at least 15 per cent of degraded ecosystems, thereby contributing to climate change mitigation and adaptation and to combating desertification	Member companies have their own projects and cooperate with other organisations to improve carbon sequestration in farm soils and restore degraded farm land.	* The Carbon Insetting Framework is a tool developed by a collaboration with the Soil Health Partnership to help farmers verify and validate carbon that has been put into the ground and take advantage of the economic benefits of climate-smart practices. It provides a framework for quantifying ecosystem services, such as carbon storage and sequestration, within the scope of a company's supply chain that could be used to demonstrate GHG impacts. (p.44) * A new carbon initiative enables growers to be rewarded for adopting certain farming practices which sequester carbon, such as cover crops, no-till practices and reducing encroachment into natural vegetation areas. The incentive helps generate additional revenue sources while improving soil quality that can improve yield, profitability and sustainability in the future. (p.44) * The "Benefit Sharing at Scale: Good Practices for Results-Based Land Use Programs" study synthesizes good practices for benefit-sharing in jurisdictional land use programs that make result-based payments for emission reductions. (p. 43)

ANNEX II: Background

1. Natural capital and the protection of biodiversity

The critical nature of the status of biodiversity is highlighted by the Global Biodiversity Outlook 5,[300] published in September 2020. The UN Summit on Biodiversity followed shortly after on 30 September 2020. Notable statements at the summit suggested the high level of commitment to biodiversity protection and defense, and the direction of future policy (reported by the Earth Negotiations Bulletin[301]):

- UNDP Administrator Achim Steiner said the "planetary blind spot" of our economies, because of which we fail to recognize the value of ecosystem services, could mean our generation will become the "librarians of extinction."
- IPBES Chair Ana María Hernández Salgar said humanity has already lost 14 out of 18 "contributions" that nature provides us, including its ability to regulate pollination, climate and air quality. She called for integrating biodiversity and nature in all policies and across all sectors.
- Elizabeth Maruma Mrema, Convention on Biological Diversity (CBD) executive secretary, described nature as a "shock absorber," saying 14 out of the 17 UN SDGs depend on biodiversity.
- UNEP Executive Director Inger Andersen called for scaling up proven solutions, such as urban planning efforts to integrate nature into cities; actively restoring natural environments; and safeguarding the rights of indigenous peoples. She said the time to "pollute our way to wealth" has passed, pointing to the COVID-19 pandemic as a reminder of the risks entailed in "pushing nature into a corner."

Closely related to these problems and offering potential solutions is the concept of "natural capital." It is the world's stocks of natural assets, including geology, soil, air, water and all living things. Nature-based solutions[302] are "actions to protect, sustainably use, manage and restore natural or modified ecosystems which address societal challenges, effectively and adaptively, providing human well-being and biodiversity benefits." They can simultaneously helped protect, manage and restore the environment while delivering tangible and sustainable benefits for people. Nature-based solutions, such as watershed protection, can generate income for local communities as well as benefits for municipalities that depend on these resources for their health and well-being. There is overwhelming evidence that nature plays a critical role to in meeting our societal needs, from investing in the restoration of degraded lands and shorelines to optimizing the performance of traditional infra-structure, such as dams and levees.

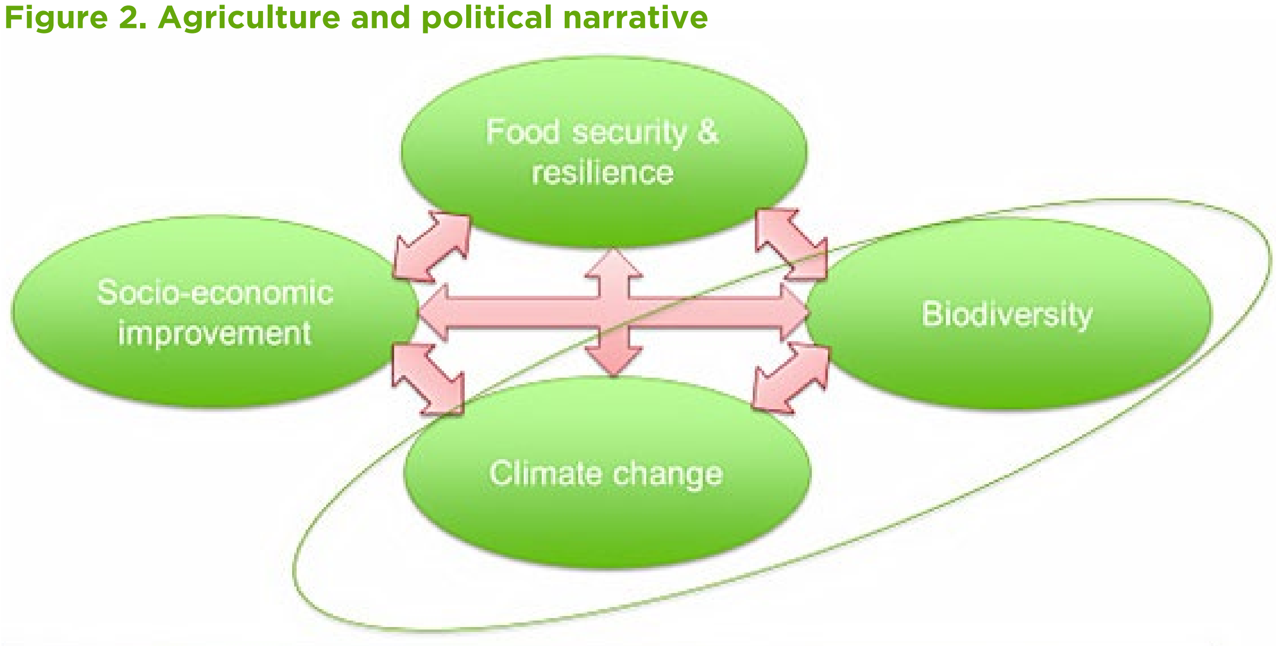
Research highlights that nature-based solutions could provide around 30% of the cost-effective mitigation needed by 2030 to stabilize global warming to below 2°C. They can also provide a powerful defense against the impacts and long-term hazards of climate change, which is the biggest threat to biodiversity. Finding ways to work with ecosystems, rather than relying solely on conventional engineered solutions, can help communities adapt to climate change impacts.

Figure 1. Nature-based solutions address societal challenges (IUCN 2016)

1.1 Agriculture and biodiversity

Biodiversity is essential to sustainable agriculture and a major component of agricultural science and political narratives. Biodiversity interacts with and is dependent on climate change, food security and socio-economic improvement. A prevailing narrative in Europe and North America is that agriculture is responsible for many of our current concerns about the decline of biodiversity and this has gained traction amongst many politicians and policymakers.

Figure 2. Agriculture and political narrative



The Sustainable Development Goals Report 2020[303] notes that biodiversity continues to decline (SDG 15). The species extinction risk has worsened by about 10% over the last three decades, with the Red List Index declining from 0.82 in 1990 to 0.75 in 2015 and to 0.73 in 2020 (a value of 1 indicates no species are at risk of extinction in the immediate future, while a value of 0 indicates all species are extinct). If current trends continue, the Red List Index will drop to or below 0.70 by 2030. Meanwhile, under SDG 2, the global prevalence of undernourishment (chronic food insecurity) has remained virtually unchanged at slightly below 9% since 2014 and the total number of people going hungry has slowly increased for several consecutive years. Yet the share of government contribution to agriculture compared with the sector's contribution to GDP fell from 0.42 in 2001 to 0.31 in 2015 and 0.28 in 2018 worldwide. Agricultural aid has fallen due to a shift in donors' focus to social-sector issues, such as improving governance, building social capital and helping fragile states.

The 2050 Vision of the CBD "is a world of living in harmony with nature where: 'By 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for all people.'" Within this framework, the 2030 mission is to "take urgent action across society to put biodiversity on a path to recovery for the benefit of planet and people." The updated zero draft (17 August 2020) of the Post-2020 Global Biodiversity Framework[304] applies a "theory of change" approach, which requires transformative actions to put in place tools and solutions for implementation, mainstreaming of biodiversity into productive sectors and eventually, conservation and sustainable use of biodiversity. Such transformative actions should be supported by enabling conditions and adequate means of implementation, including financial resources, capacity and technology. This approach also assumes that progress is monitored in a transparent and accountable manner with adequate stock-taking exercises. The updated draft includes four long-term goals for 2050, related to:

(a) The area, connectivity and integrity of natural ecosystems increased by at least [X%*] supporting healthy and resilient populations of all species while reducing the number of species that are threatened by [X%*] and maintaining genetic diversity;

** Percentages to be determined by CBD.*

(b) Nature's contributions to people have been valued, maintained or enhanced through conservation and sustainable use, supporting global development agenda for the benefit of all people;

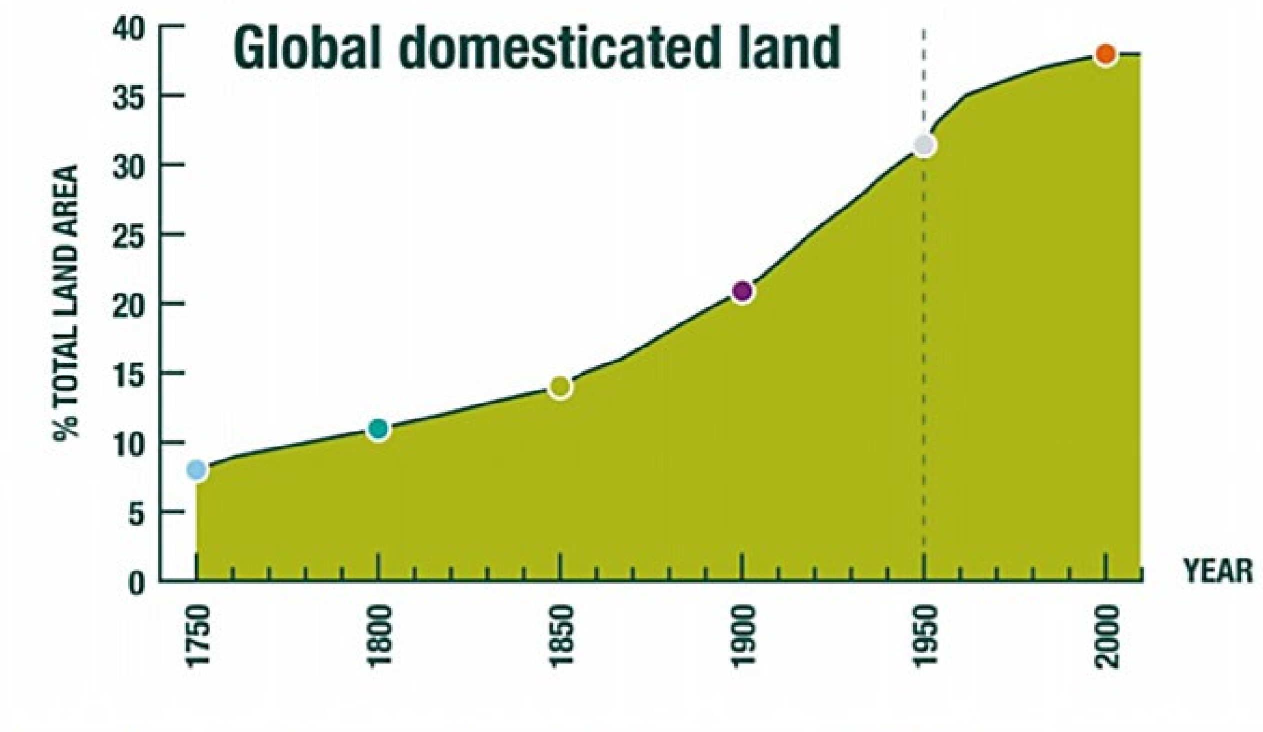
(c) The benefits, from the utilization of genetic resources are shared fairly and equitably; and

(d) Means of implementation are available to achieve all goals and targets in the framework.

Its 2030 mission is to take urgent action across society to put biodiversity on a path to recovery for the benefit of planet and people. The draft includes 20 action-oriented targets for 2030, organized in clusters on reducing threats to biodiversity; meeting people's needs through sustainable use and benefit-sharing; and tools and solutions for implementation and mainstreaming. The private sector is a required participant with all other relevant stakeholders: non-governmental organizations, youth, civil society, local and subnational authorities, the private sector, academia and scientific institutions through a whole-of-society approach and through inclusive and representative multi-stakeholder and multi-sectoral platforms.

The interim report of the Dagupta Review[305] provides an overview of next steps for the review in the run-up to COP 15 to the CBD. It notes "the clash between provisioning services and regulating maintenance services has been accentuated with population growth, rising standards of living and changing consumption patterns. There has been an increase in global demand for provisioning goods and services like food, fiber, timber and fuel. This increase in demand is illustrated in the chart below, which shows the increase in domesticated land – measured by agricultural land area, including cropland and pasture – as a percentage of total land area. This has come at the cost of regulating and maintenance services, and in great measure, cultural services, too."

Figure 3. Global domesticated land as a proportion of total land area



Domesticated land = Agricultural land area (including cropland and pasture) as a percentage of total land area.

Note: Graph of global domestic land percentage. Source: Steffen, W., Broadgate, W., et al. (2015) 'The trajectory of the anthropocene: The great acceleration', Anthropocene Review, 2(1), pp. 81–98.

2. Threats to biodiversity from food and agriculture

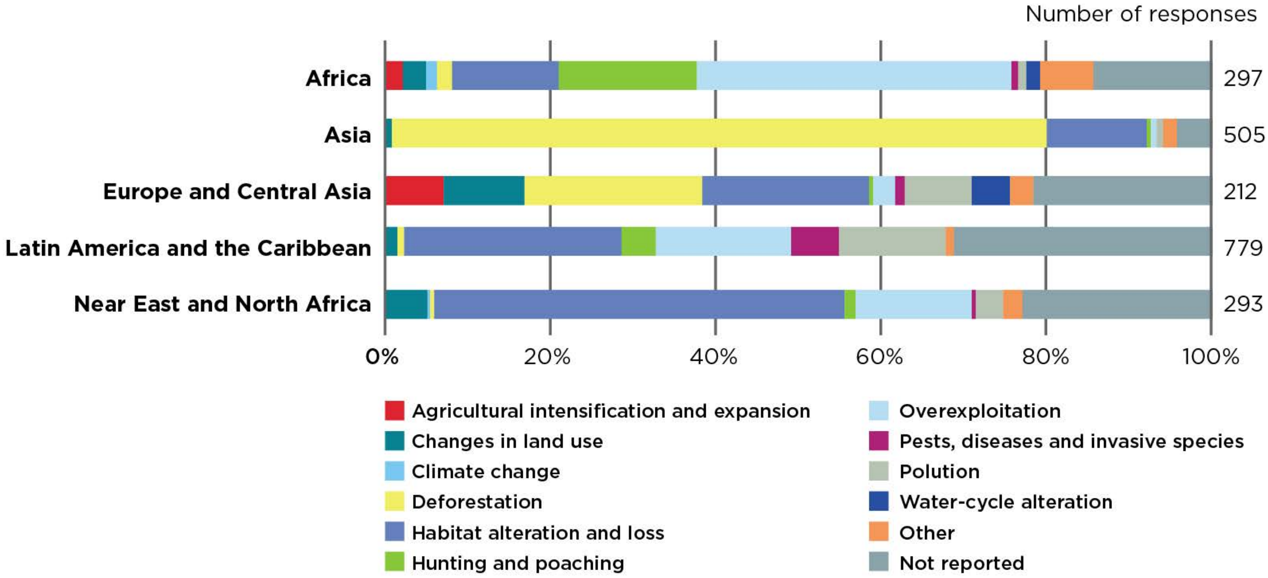
Biodiversity is a complex concept, and measuring and interpreting changes is correspondingly complex. Consequently, establishing the precise causes of changes in biodiversity, and even of individual species, is very difficult.

Agriculture is a human intervention in this complicated picture. All species interact with their habitats and have an impact on biodiversity compared to when they are not present in the ecosystem. Thus, man impacted the environment long before formal agriculture was practiced. From that perspective, cultivating plants and maintaining livestock have an inevitable effect on biodiversity. A reduction of plant biodiversity in cropped areas is an inherent part of agriculture irrespective of the agricultural system, whether by mechanical means and/or plant protection products to control unwanted weeds. Thus, the dilemma of agriculture is that on one hand, it can provide essential ecosystem services, but on the other hand, it can negatively impact aspects of biodiversity.

Several studies have attempted to quantify the different factors that negatively impact biodiversity for food and agriculture, including the FAO report "The State of the World's Biodiversity for Food and Agriculture (2019)."[306]

Based on responses by 91 countries to requests from the FAO, the main threats reported are deforestation (547); habitat alteration and loss (490 responses); overexploitation (286); pollution (134); hunting and poaching (86); change in land use (52); pests, diseases and invasive species (49); agricultural intensification and expansion (19); water-cycle alteration (14) and climate change (5). Figure 4 provides a regional breakdown.

Figure 4. Reported threats to associated biodiversity by region



Notes: A "response" is a mention by a specific country of a specific component of biodiversity (species or higher taxonomic group). No data are available for North America or the Pacific. Analysis based on 91 country reports.
Source: Country reports prepared for *The State of the World's Biodiversity for Food and Agriculture.*

The report's key findings were:

1. Biodiversity for food and agriculture is indispensable to food security, sustainable development and the supply of many vital ecosystem services.

2. Multiple interacting drivers of change are affecting biodiversity for food and agriculture. While a range of drivers of change are having major negative impacts on biodiversity for food and agriculture and the ecosystem services it delivers, some provide opportunities to promote more sustainable management.

3. Many key components of biodiversity for food and agriculture at genetic, species and ecosystem levels are in decline. Knowledge of associated biodiversity, in particular microorganisms and invertebrates, and of its roles in the supply of ecosystem services needs to be improved. Monitoring programs for biodiversity for food and agriculture remain limited.

4. The sustainable use and conservation of biodiversity for food and agriculture call for approaches in which genetic resources, species and ecosystems are managed in an integrated way in the context of production systems and their surroundings. The use of a wide range of management practices and approaches regarded as favorable to the sustainable use and conservation of biodiversity for food and agriculture is reported to be increasing. Although efforts to conserve biodiversity for food and agriculture *in situ* and *ex situ* are increasing, levels of coverage and protection are often inadequate.

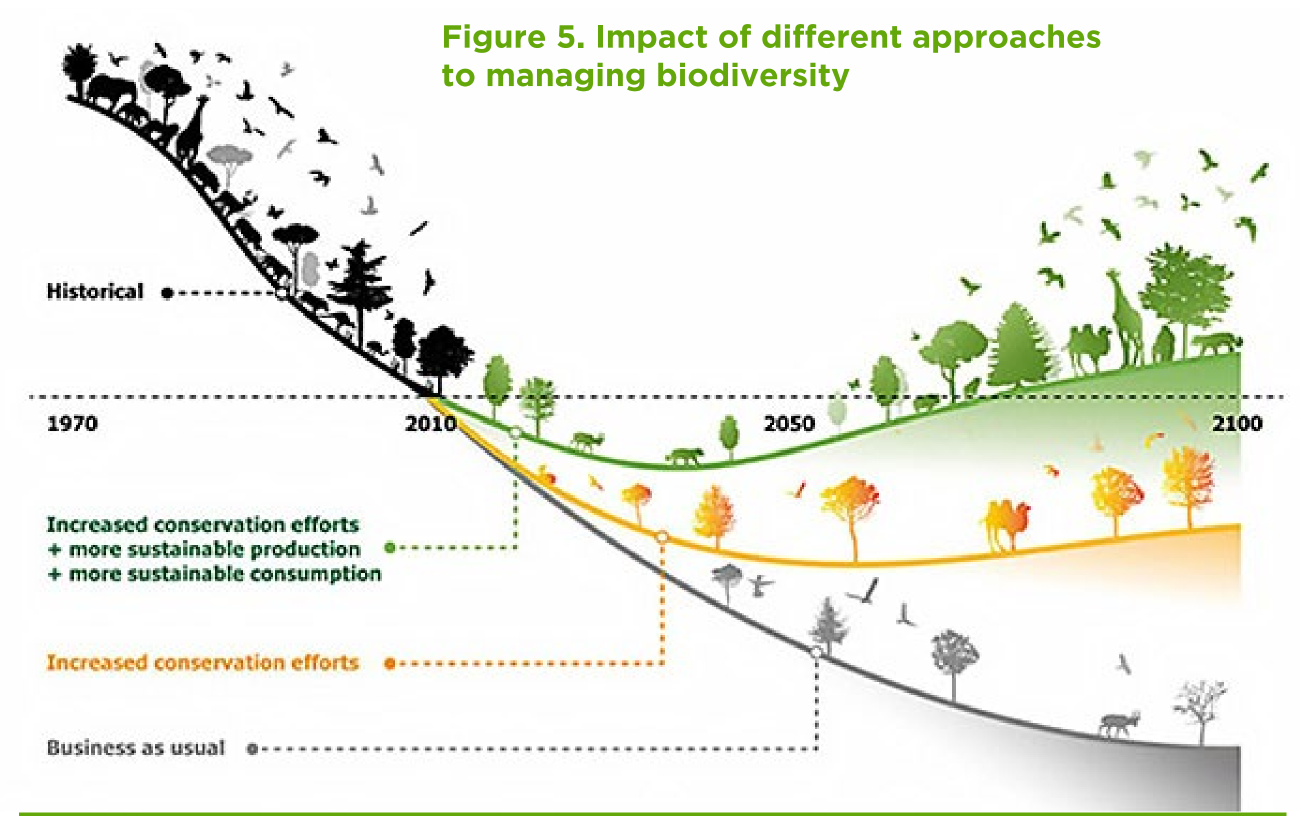
5. Enabling frameworks for the sustainable use and conservation of biodiversity for food and agriculture urgently need to be established or strengthened. Research on food and agricultural systems needs to become more multidisciplinary, more participatory and more focused on interactions between different components of biodiversity for food and agriculture. Improving the management of biodiversity for food and agriculture and enhancing its contributions to ecosystem services call for better multi-stakeholder, cross-sectoral and international cooperation.

A recent study published in the scientific journal *Nature*[307] shows the possibility of halting and reversing terrestrial biodiversity loss caused by land use change. The modeling shows the importance of more sustainable food production and consumption in addition to conservation efforts to achieve this aim. Six actions were identified:

- Sustainable increases in crop yields;
- Trade increases in agricultural goods with reduced trade barriers;
- Reduce waste of agricultural goods from field to fork by 50%;
- Cut the share of animal calories in human diets by 50%, except in regions where the share of animal products in diets is already estimated to be low (Middle East, sub-Saharan Africa, India, Southeast Asia, and other Pacific Islands);
- Increase protected area by up to 40% terrestrial coverage, covering important sites for biodiversity with improved management; and
- Increase restoration (on target to reach 8% of terrestrial areas by 2050) and landscape-level conservation planning that balances production and conservation objectives on all managed land.

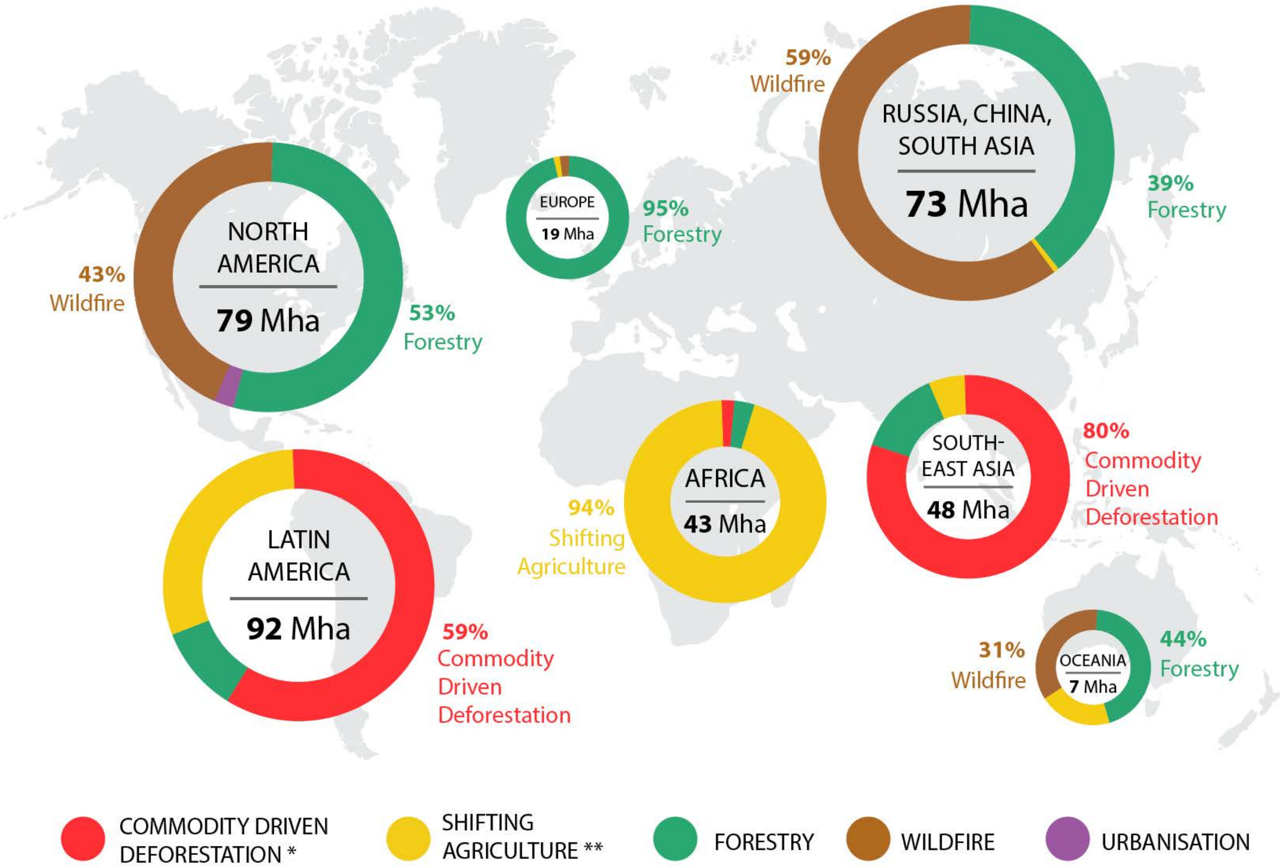
By combining the six actions above in an integrated strategy, modeling shows that it is possible to avoid more than two-thirds of future terrestrial biodiversity losses caused by land use change.

Figure 5. Impact of different approaches to managing biodiversity



Global Forest Watch[308] reports on the drivers of forest loss around the world. Data as of 3 March 2020, as reported by Hana Heineken of Rainforest Action Network at the "Nature for Life: Business and Finance Day" (September 2020),[309] show that nearly half of forest loss globally is linked to agriculture. In South East Asia, conversion of land for commodities like palm oil and pulp drive the loss, whereas in Latin America, the drivers are soy and cattle ranching.

Figure 6. Regional tree cover loss by driver 2001-18

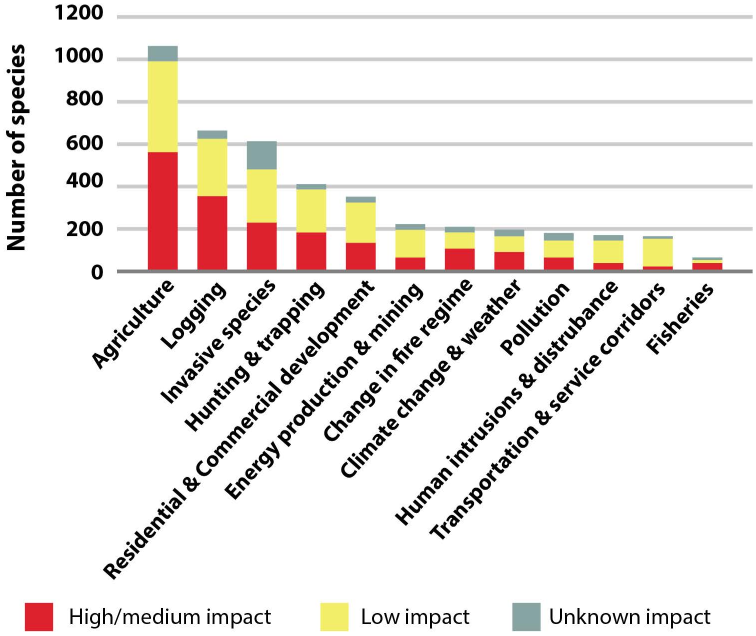


* Permanent deforestation
** May or may not lead to permanent deforestation

BirdLife International classifies the extinction risk of all the world's birds for the IUCN Red List. "The State of the World's Birds 2018"[310] reports that 13% of all existing species (10,966) are globally threatened with extinction (1,469 species). Foremost among the threats are agricultural expansion and intensification, which impacts 1,091 globally threatened birds (74%); logging, affecting 734 species (50%); invasive alien species, which threaten 578 (39%) species; and hunting and trapping, which puts 517 (35%) species at risk. Climate change represents an emerging and increasingly serious threat—currently affecting 33% of globally threatened species—and it often exacerbates existing threats.*

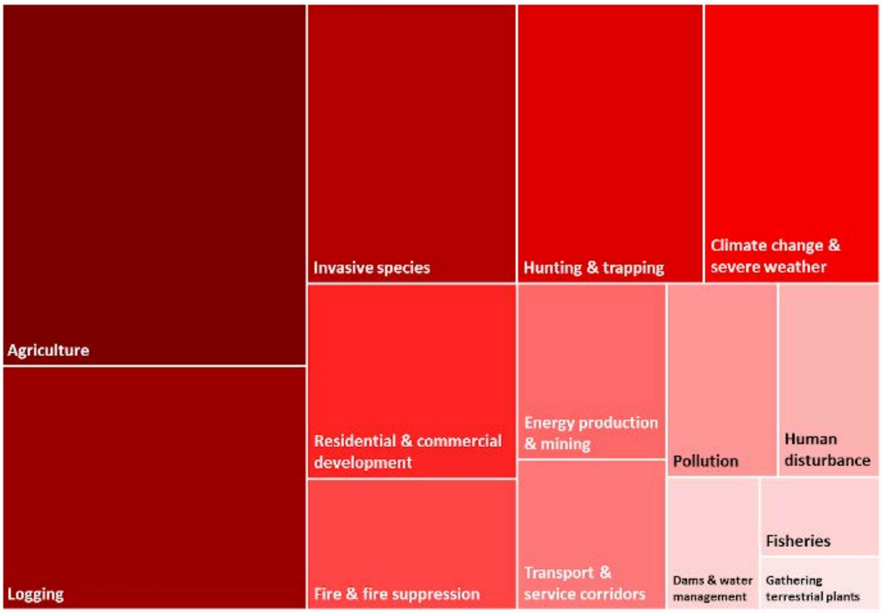
**Source: Butchart, S.H.M., Collar, N.J., Stattersfield, A.J. & Bennun, L.A. 2010. Conservation of the world's birds: The view from 2010. Foreword. In J. Del Hoyo, A. Elliott & D. Christie, eds. Handbook of the world's birds. Volume 15, pp. 13–60. Barcelona, Spain, Lynx Edicions.*

Figure 7. Threats to threatened bird species



The 2020 update of "The State of the World's Birds"[311] reviews the data in a different way, presenting 14 major factors impacting the world's threatened bird species. In this analysis, agriculture accounts for about 37% of the total threats compared to the next largest, logging, at 20% and 12 other important but less significant factors. There is no indication of whether the individual threats within each category are equally impactful (i.e., if all of the threats under the agriculture heading are equally impactful or whether some are relatively minor compared to others) or how much each impact varies across regions. Both factors are essential when planning to address the declines.

Figure 8. Relative importance of threats to globally threatened bird species based on number of species affected



Source: BirdLife International (2020). State of the World's Birds: 2020 Annual Update. Downloaded from http://www.birdlife.org[312] on 29 July 2020.

Birdlife International[312] analyses place a much greater focus on agriculture as a cause of biodiversity decline than the reports from the countries surveyed by the FAO, possibly because they do not take into account numerous other factors known to impact populations and biodiversity, including climate variability (as differentiated from climate change); medium and longer term cyclic population changes; migratory patterns and conditions during migration and in seasonal habitats; and diseases, including West Nile virus in North America, bird flu, avian malaria, trichomonas in western Europe and others.

The German National Strategy on Biological Diversity[313] concludes that the loss of habitats due to changes in land use is the major factor in the loss of biodiversity by significantly restricting the habitat for wild species. Agricultural activities are at least part of three of the 10 factors listed in the strategy.

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IBPES) 2019 report[314] concludes that "agriculture, including grazing, has immense impacts upon terrestrial ecosystems, with important differences depending upon an enterprise's intensity and size (well established). Agricultural systems remain quite varied, with plant- and animal-based systems, monocultures and mixed farming, plus newly emerging systems including organic, precision, and peri-urban approaches to production. Today, over a third of the world's land surface and – 3/4 of freshwater resources are devoted to agropastoral production. Grazing occurs on – 50% of agricultural lands and ~70% of drylands. About 25% of GHG emissions come from land clearing, crop production, and fertilization, with animal-based food contributing 75% of it. Intensive agriculture has led to increases in food production at a cost of multiple regulating and non-tangible contributions from nature and even overall decreases in well-being in cases. Small land holders (< 2 hectares) contribute – 30% of global crop production and ~30% of the global food supply − using 24% of agricultural land with the largest agrobiodiversity levels. Their diverse agricultural systems, developed over centuries, have reduced negative impacts on nature, providing a wide range of material and regulating and non-material contributions, while generating the basis for sustainable agriculture intensification, soil management and IPM. Organic agriculture has developed rapidly, with variable outcomes: In general, it has contributed to higher biodiversity, improved soil or water quality, and nutritional values, although often at the expense of lowering yields and/or raising consumer prices."

The IPBES "Transformative Change Assessment,[315]" part of the 2019-2030 work plan, is a thematic assessment of the underlying causes of biodiversity loss, determinants of transformative change and options for achieving the 2050 vision for biodiversity.

3. Addressing the threats to biodiversity

Agriculture is the dominant land use activity in much of the world. For example, in Europe, almost 50% of the land surface is used for agricultural production (European Commission, 2009). FAO 2019[316] and IBPES 2019[317] reports on biodiversity and agriculture concluded that changes in land use, which can be related to habitat availability, is the leading factor leading to biodiversity decline. In addition, the IPBES report emphasized the need for efficient farming practices to reduce the footprint on agriculture and thereby, provide land that can be used to support habitat for biodiversity. Extensive field data suggests that impacts on wildlife populations would be greatly reduced by boosting yields on existing farmland to spare remaining natural habitats (Balmford et al., 2018). This allows the opportunity to set aside land as refuges and reduce the depletion of biodiverse ecosystems.

The availability of habitats is thus key to support food webs and biodiversity. The creation of semi-natural habitats, especially in intensified landscapes, is a recommendation from IBPES to integrate biodiversity conservation on agricultural land. In addition to these habitats, the presence of networks of corridors across the landscape is especially important in intensively cropped areas to ensure sufficient connectivity between available habitat patches. Moreover, different species have different habitat requirements. Therefore, non-crop/semi-natural habitat creation measures should be adapted to the local situation.

Approaches to conserve biodiversity and promote species richness and abundance in agro-ecosystems should be focused at the landscape level and include cross-sectoral integrated management (European Commission, 2009). Achieving the right balance between agricultural practices and biodiversity requires aligned agriculture and nature conservation policies. However, it has been increasingly recognized that agricultural production and biodiversity conservation requires the minimization of trade-offs and the maximization of synergies (Millennium Ecosystem Assessment, 2005; Power, 2010). For example, ecosystem disservices, such as weed or pest occurrence, can likewise arise from biodiversity (Tschumi et al., 2018). These disservices can threaten the crop yield and quality and therefore, reduce land use efficiency. In turn, this reduced efficiency could result in increased pressure on converting natural habitats to agricultural use, resulting in trade-offs between different kinds of practices intended to promote biodiversity. Recent conclusions from the IPBES 2019 report on biodiversity and ecosystem services and stakeholder discussion within the EU's high-level Conference on Biodiversity and Ecosystem Services (23 May 2019, Brussels) have re-emphasized the need for implementing such synergies.

Especially in Europe and North America, agriculture has long been understood to be part of the solution to biodiversity conservation, particularly when combined with agri-environmental schemes and precision farming. The Common Agricultural Policy is an important tool to manage biodiversity in agro-ecosystems because many species and lands of conservation concern in Europe depend on the presence of healthy agro-ecosystems and their proper management (Batary et al., 2015). Agri-environmental schemes are often effective at enhancing species richness, however, as new research develops priorities for implementing agri-environmental schemes on more simplified landscapes (intensively managed cropland areas), they should contribute to more effective outcomes for biodiversity. Also, the focus of such measures to equally benefit crop production and biodiversity (i.e., mainstreaming biodiversity) should be considered when attempting to manage biodiversity at a landscape level.

Over 200 measures have been recommended in various EU studies to enhance biodiversity conservation at the landscape level. Most of them target the conservation of single or specific groups of species (farmland birds, pollinators) and recommend the establishment of very specific, often expensive actions to create habitats such as ponds or hedges. Other measures exist that can benefit multiple species and ecosystem services (e.g., water regulation, soil erosion regulation, pollination) at the same time. Most of the 200 measures are defined by numerous names (e.g., fallow land and ecological set aside mean the same thing) and vary in application forms and duration (areas, margins, strips, annual or longer, etc.). Their farm viability aspects in terms of profitability and costs (labor, time) involved are neglected. Thus, when identifying measures as to their broader applicability for use in arable field crops (orchard and perennial crops are different) win-wins for both crop production and biodiversity conservation should be aimed at increasing the motivation of application. When analyzing the measures in more details, their numbers can be reduced to a few groups, which contribute to habitat creations that are fit in terms of more generally recommendable compensatory measures: uncropped land (fallow areas, crop edges, headlands), managed margins (also bordering sensitive areas such forests and hedges), managed flower subfield areas or those cropped at reduced intensity. These measures could provide a low effort and cost-effective tool to support associated biodiversity in crop production and may benefit crop profitability if applied on less productive land. Creation of such habitat, in addition to applying traditional good agricultural practices, would provide an additional tool fundamental to efforts that enhance ecosystem services and other cropland-biodiversity, increase ecological resilience and sustainably intensify and improve crop production. Such in-field measures in simplified landscape types need to be complemented by broader landscape habitat provisioning efforts.

Crop Diversification Cluster318 members are working together to demonstrate the benefits of crop diversification to farmers and society, and to engage with stakeholders in the upstream and downstream value chains by transferring knowledge in:

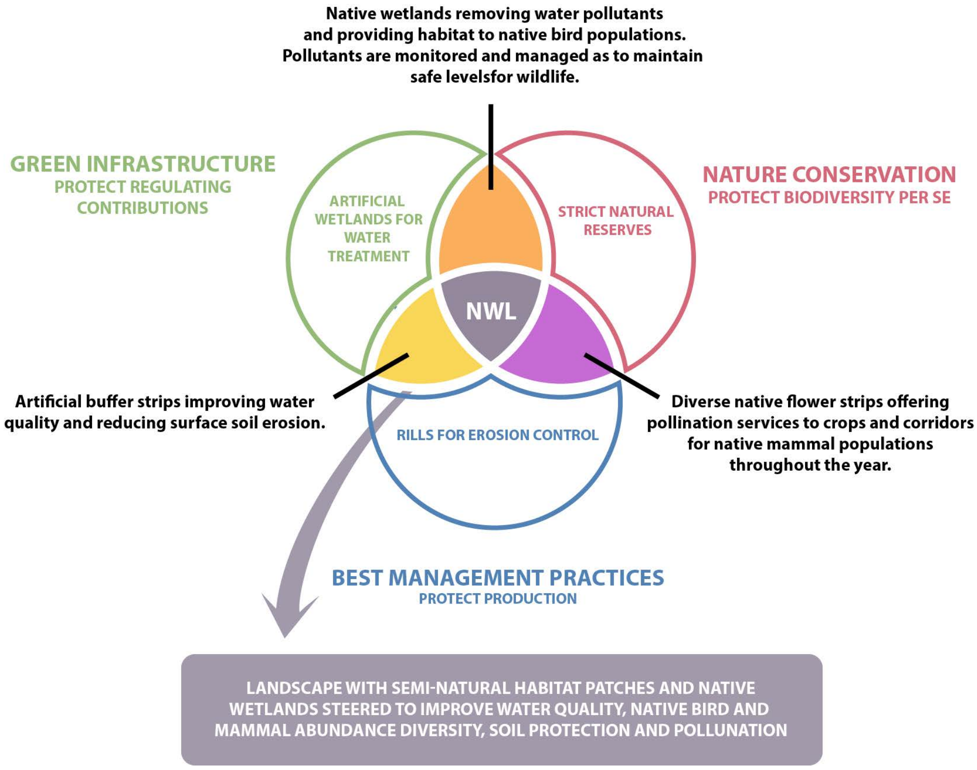
- Barriers to crop diversification and their solutions
- Innovative cropping methods, decision tools and new resources for crop diversification
- New end user-focused approaches and field demonstrations across pedoclimatic regions of Europe to share innovations and crop diversification experiences
- Multi-criteria assessment of system performance at field, farm, value chain and landscape levels
- Policy recommendations to facilitate uptake of crop diversification
- Communicating joint activities in the cluster and disseminating joint outputs

According to CropDiversification.eu, the diversification of crops through rotation, multiple cropping and species mixtures can allow farming systems to become more resource-efficient with fewer agronomic inputs. Diversified systems can help meet the needs of end users for food, feed and industrial products, simultaneously delivering other ecosystem services and public goods. The Crop Diversification Cluster brings together partner organizations from countries across Europe. Projects within the cluster are collaborating to increase the impact of crop diversification research and encourage sustained uptake of diversification measures by farmers in Europe through innovations across the agri-value chain.

A recent paper[319] by authors from institutes around the world proposes three streams of science-policy guidelines for managing working landscapes to protect production BMPs, biodiversity (nature conservation) or nature's contribution to people (green infrastructure or nature-based solutions). Multiple objectives pursued in any working landscape will entail both conflicts and synergies.

While BMPs have traditionally focused on the sustainability of mainstream production, they can overlap with green infrastructure initiatives when they simultaneously enhance other nature's contributions to people. BMPs may also benefit nature conservation when they include habitat restoration in working lands (e.g., native hedgerows). Finally, green infrastructure can overlap with nature conservation when native habitats that are used to provide regulating contributions also help preserve threatened native species. The concept of native habitat within working landscapes sits at the intersection of these three paradigms and seeks to enhance them simultaneously. Examples of synergistic interventions are given, considering a hypothetical agricultural region dominated by simplified, seasonal crop systems. These examples also exemplify conflicts among multiple objectives, such as when artificial buffer strips dominated by a few exotic plant species improve water quality and reduce surface soil erosion but have little value for nature conservation.

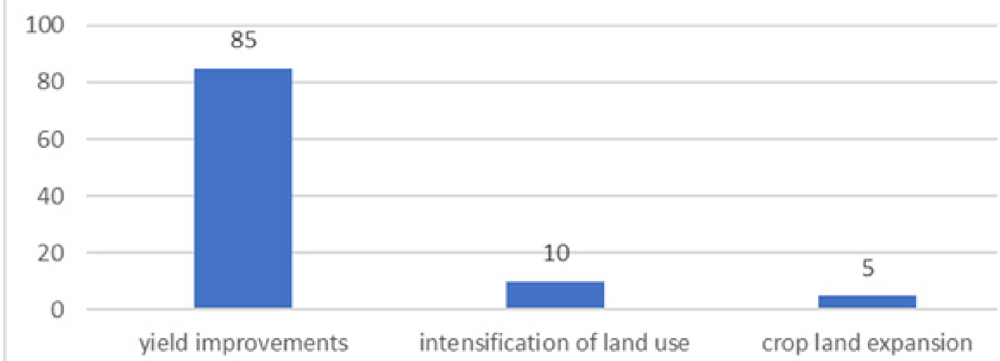
Figure 9. Streams of science-policy guidelines for managing landscapes to protect production, biodiversity and nature's contribution to people



4. Current status of agricultural output in relation to biodiversity

The OECD-FAO Agricultural Outlook 2020-29[320] shows that most of the growth in agricultural output in the next 10 years is expected to be from yield improvements and recognizes the assumption that "output growth" through the intensification of crop production (i.e., higher output per unit of land) is assumed to be more economically efficient than through large expansion of agricultural land given the prevailing policy and economic conditions."

Figure 10. Percentage contribution to expected global crop output 2020-29



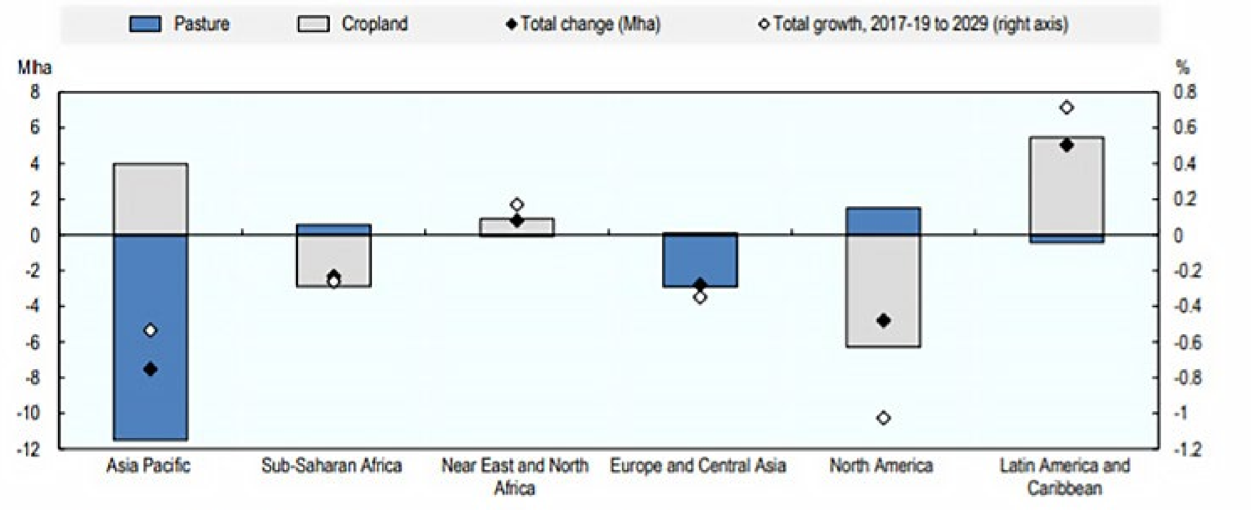
Source: OECD-FAO Agricultural Outlook 2020-29

However, the OECD-FAO report warns that "the intensification of agricultural practices (e.g., drainage, tillage), and in particular, the more intensive use of fertilizers and pesticides, can exacerbate some environmental problems and threaten sustainability." The benefits of gains from the adoption of more advanced technologies (e.g., precision farming) or the implementation of better management practices would allow a greater output to be produced without an increase or with a less-than-proportional increase, in the use of inputs, including natural resources and chemical inputs. The report considers the balance between conventional, high-input systems and alternative crop production systems: "By reducing or eliminating the use of chemical inputs or shorting supply chains, some of these approaches aim to reduce the environmental footprint of commercial agriculture. Organic agriculture, for instance, achieves better environmental impact per unit of land used, although it produces less food per unit of agricultural land. Studies have showed that organic yields are at least 20% lower than yields in conventional agriculture, which implies that it requires much more land to produce the same output. This raises a number of concerns given the limited availability of land suitable for agriculture, and the negative environmental impacts associated with agricultural land expansion." Greater efforts are needed to reduce the pressure exerted by some agricultural practices on biodiversity while enhancing agriculture's positive contributions to the environment. Agriculture is dependent on ecosystems services for its continuing development.

The OECD-FAO report also notes that agricultural expansion through clearing or conversion of forest, shrub land, savannah and grassland has been responsible for substantial CO2 emissions from the loss of above- and below-ground carbon sinks and is associated with negative effects on biodiversity: "When taking into account those indirect effects of agriculture on land use change, agriculture's contribution to global GHG emissions increases from 11% to 24%."

Agriculture currently uses 40% of the world's land, 70% of which is pastureland. Globally, agricultural land use is expected to remain at current levels during the coming decade as an increase in cropland offsets a decrease in pasture in line with historic trends. However, trends in land use and their underlying determinants differ around the world. In Latin America, cropland use is expected to expand by about 5.5 million hectates over the next 10 years while pastureland will decline by only 0.4 million hectares, resulting in a total increase in agricultural land of 5 million hectares (0.7%). Large-scale commercial farms in the region are expected to remain profitable and invest in the clearing and cultivation of new land, including previous pastureland, for soybean and maize production. A significant increase in cropland is also expected in the Asia Pacific region (4 million hectares), but this is projected to be more than counterbalanced by a decline in pasture land (more than 11 million hectares), which will be enabled by further intensification of pasture and ruminant production. More limited land use changes are expected in other world regions (Figure 11). Despite substantial land availability in Sub-Saharan Africa, for instance, total agricultural land use is projected to slightly decline (-0.3%) over the next 10 years. Farmland expansion will be mainly constrained by the prevailing smallholder structure, presence of conflict in land-abundant countries and loss of agricultural land to other uses such as mining and urban sprawl. The change in agricultural land use is summarized here:

Figure 11. Change in agricultural land 2017-19 to 2029



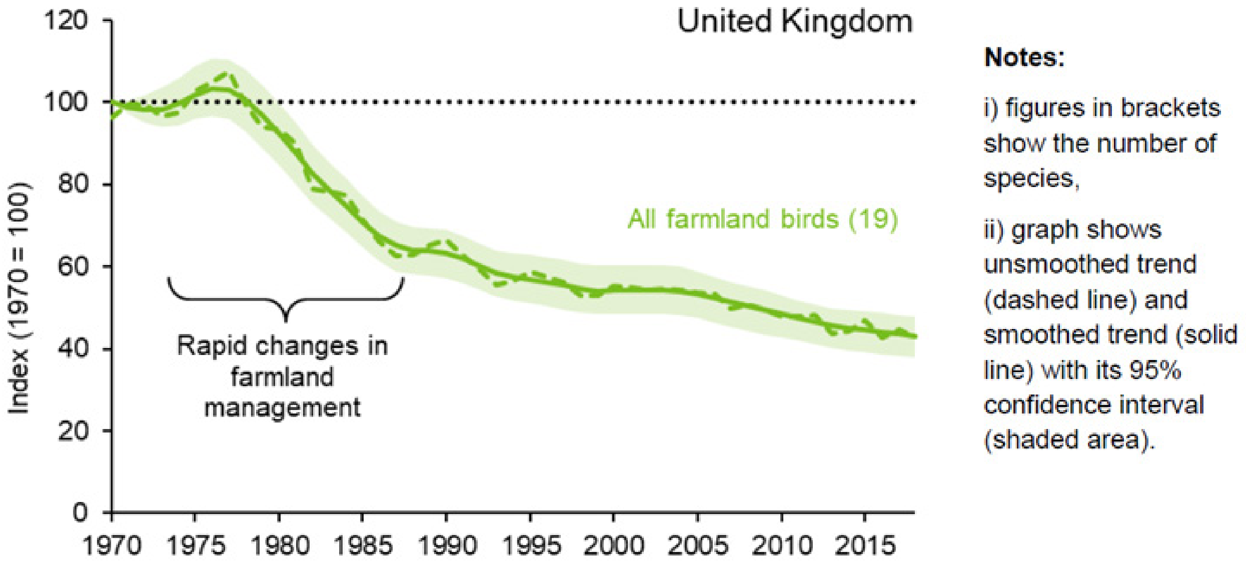
Source: OECD/FAO (2020), "OECD-FAO Agricultural Outlook", OECD Agriculture statistics (database), http://dx.doi.org/10.1787/agr-outl-data-en.

4.1 Example of farmland birds

The UK "State of Nature 2019"[321] report shows that the impact of agriculture on biodiversity is not only a phenomenon of the last few years as its effects intensified in the second half of the 20th century. A wide range of changes in agricultural management in recent decades has led to greater food production but it has also had a dramatic impact on farmland biodiversity. For example, populations of farmland birds have more than halved on average since 1970, and similar declines have been seen in many other taxonomic groups. Targeted wildlife-friendly farming, supported by government-funded agri-environmental schemes, can halt and reverse these declines, but to date, the only successes have been for rare and localized species. The area of land receiving effective agri-environment measures helped slow the decline in nature after 1990 but has been insufficient to halt and reverse the trend.

The most recent "Wild Bird Populations in the UK"[322] report was published in November 2019. The large historical declines in the abundance of many farmland birds have several known and potential causes. “For a large part, declines have been caused by the changes in farming practices that have taken place since the 1950s and 1960s, such as the loss of mixed farming, a move from spring to autumn sowing of arable crops, change in grassland management (e.g., a switch from hay to silage production), increased pesticide and fertilizer use, and the removal of non-cropped features such as hedgerows. The rate of these changes, which resulted in the loss of suitable nesting and suitable feeding habitats and a reduction in available food, was greatest during the late 1970s and early 1980s, the period during which many farmland bird populations declined most rapidly. However, some generalist species such as woodpigeon have benefited from increased availability of their food throughout the winter owing to the autumn sowing of crops.”

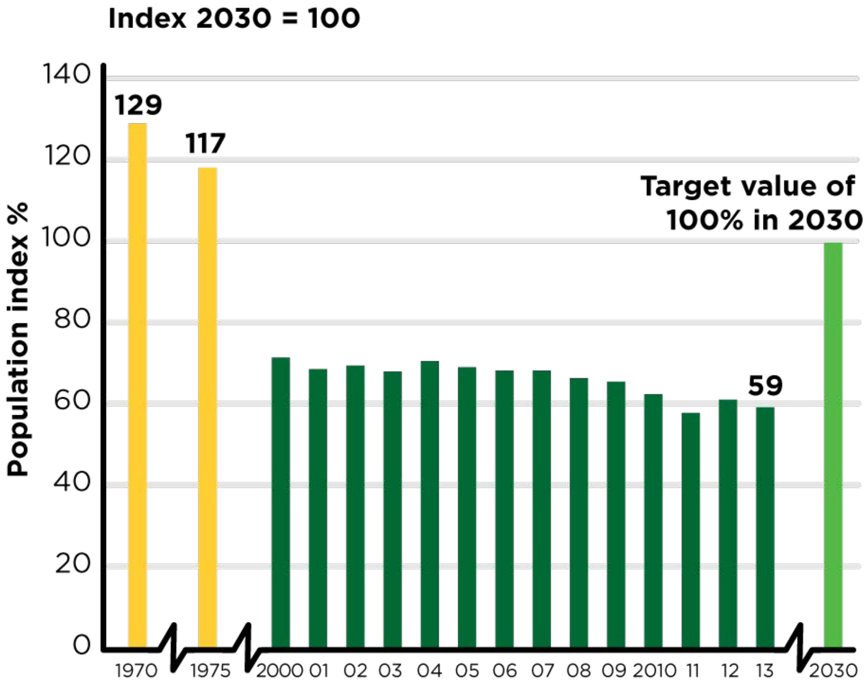
Figure 12. Breeding farmland birds in UK 1970-2018



Farmland birds are an important measure of UK biodiversity and one of the government’s sustainable development indicators. Birds such as yellowhammer, corn bunting, grey partridge and skylark depend on arable farmland for food and habitat. Changes in farmland management can affect populations and the use of pesticides can have indirect effects such as removing food sources. These effects can be reduced by using pesticides responsibly and creating and maintaining suitable habitats. For example, management techniques for birds and pollinators in the UK include: https://voluntaryinitiative.org.uk/environment/birds/[323] and https://voluntaryinitiative.org.uk/environment/pollinators.[324] Similar results are apparent in other European countries, for example in Germany.[325]

However, it is important to distinguish between trends in different world areas. In the central United States, a study[326] suggests that there is no broad trend for greater decline of birds in crop-intensive areas. While these results do not rule out potential agricultural effects, such as toxicity resulting from pesticide exposure, which may have species-specific or localized effects, a variety of factors related to habitat are likely the most significant contributor overall. Abundance differed for many species as the proportion of cropland changed, a result that would be expected with any major habitat change, which benefits some bird species and disadvantages others. However, trends in counts suggest that the majority of bird species tested have the same or greater abundance trends in high proportions of cropland as in low proportions. This lack of general effect across species suggests that influences related to agricultural intensification are not causing the observed declines for most species. Rather, the declines in species such as Western Meadowlark, Horned Lark and Grasshopper Sparrow are just as likely due to species-specific effects related to habitat loss or degradation.

Figure 13: Biodiversity and landscape quality – sub-indicator agricultural land: index of representative bird species in farmland



5. Biodiversity mitigation and resilience

Developments in farm practices over the years have contributed to biodiversity while supporting the resilience of agriculture. CropLife America includes several of them on its website,[327] for example:

- Farmers have adopted measures that reduce energy use and soil erosion with no-till methods and that increase soil organic matter with these methods and the consistent use of cover crops – all of which benefit soil health and reduce CO2 emissions.

- Treating seeds with chemical products and/or micro-organisms prior to sowing to suppress, control or repel pathogens, insects and other pests that attack seeds, seedlings or growing plants. Seed treatment offers an increasingly precise mode of applying products in the field, using much less pesticide, and provides a high level of protection against insects and disease while reducing potential exposure of humans and the environment to crop protection products.

- GPS systems facilitate farm planning, field mapping and sampling, crop scouting for weeds and pests, and yield mapping. Sensor technology on tractors or drones allows data to be gathered on soil conditions (water availability, compaction, fertility, etc.), the crop (leaf temperature, leaf area index, plant water status, pest and weed infestation, etc.) and local climate data. Having this information available allows the farmer to vary inputs to different parts of the farm and within fields to increase efficiency, optimize and minimize inputs, and address biodiversity issues such as endangered species, pollinators, etc.

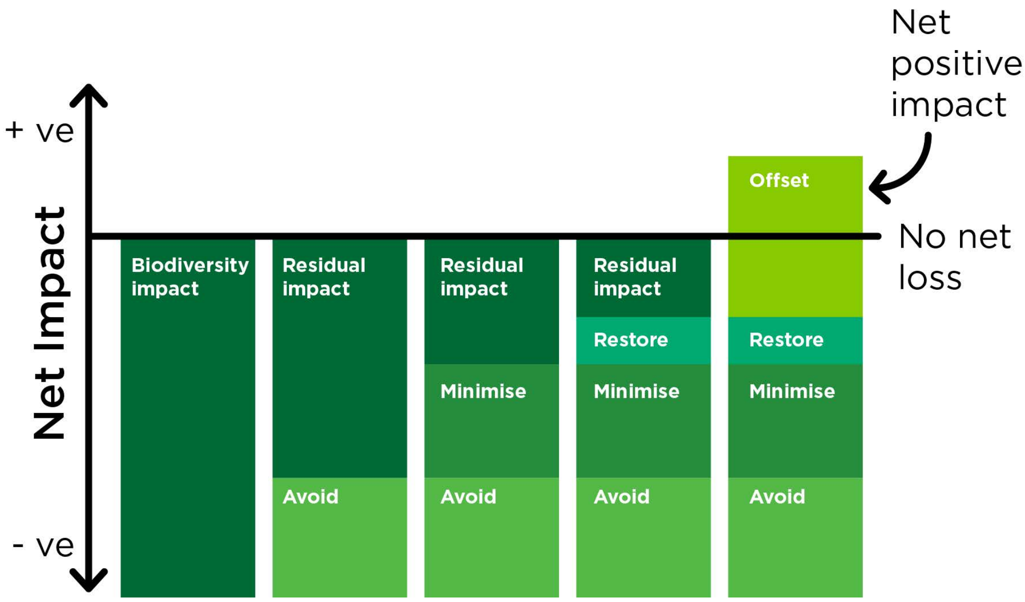
The concept of ecosystem services attempts to provide a framework to identify what to protect and which mitigations may be required to achieve a balance between agricultural production and biodiversity protection, and to support informed decision-making on what, where and at which scale to protect. It also facilitates measurement of the benefits. Even when an objective is to enhance general biodiversity, approaches may be made at different scales. A regional approach will incorporate actions for different landscapes, such as river catchments, within which the biodiversity associated with agriculture may be addressed at the farm level and within individual fields or plots. Although, ideally, it is desirable to protect all ecosystem services, it may not be essential to protect them all at the same time in the same place.

For example, it was considered practical by the European Food Safety Authority328 to make a distinction between in-crop and off-crop risk assessments because of differences in the socio-economic and ecological functions of in-crop and off-crop areas.

CropLife Europe has produced a glossary to clarify biodiversity and ecosystem services terminology relevant to agriculture. The latest version is available on its website.[329]

The biodiversity mitigation hierarchy is a tool that provides a sequenced approach to addressing foreseeable impacts on biodiversity. As shown in Figure 2, it consists of various elements that mitigate biodiversity loss if a residual adverse impact arises from a project, including avoidance, minimization and restoration. Balancing negative impacts on biodiversity against a baseline is called a no-net-loss approach;[330, 331] outweighing negative impacts by conservation gains is a net positive impact.

Figure 14: Sequential steps of mitigation hierarchy
Adapted from ICMM and IUCN, 2012



Biodiversity offsets[332] are measurable conservation outcomes, resulting from additional actions designed to compensate for significant, residual, adverse biodiversity impacts after applying appropriate prevention and mitigation measures. Biodiversity offsetting aims for a net positive impact or gain in species composition, habitat structure, ecosystem function, societal use and cultural values associated with biodiversity.

Trade-offs may be necessary. A trade-off in general is “a giving or taking of one thing of value in return for another.” More specifically, “ecosystem service trade-offs arise from management choices made by humans, which can change the type, magnitude, and relative mix of services provided by eco-systems” (Rodriguez et al., 2005[333]) as a side-effect and characteristic rather than an active goal. The decision-making process is complex. Conflicting needs must be balanced. The consequences of trade-off decisions should be understood in relation to the objectives and local conditions. For example, biodiversity trade-offs vary as agricultural expansion transforms landscapes and are thus a moving target, particularly in tropical and subtropical deforestation frontiers which are changing rapidly (Macchi et al., 2020[334]).

Resilience is the capacity of a system to withstand unpredictable events resulting from natural or human-driven causes. At the heart of managing for resilience is the idea that human beings are an integral part of ecological systems. General resilience is usually demonstrated when a suite of functioning ecosystem services are maintained over time and scale in response to various pressures. Specified resilience means coping with and tolerating a single change occurring in a system.

Since the 1990s, resilience has been used commonly in the context of agriculture and climate change. It refers to the need of agriculture to adapt to climate change (e.g., resulting in extreme weather events like droughts and floods) and to maintain its productivity over time. The close link between humans and nature has been recognized in the concept of a social-ecological system, which is considered central to resilience-thinking.

- Depending on the farmland and its context, crop management applies to a range of practices, technologies and tools that may contribute to enhancing the flow of agro-ecosystem services, for example, within arable field crops such as cereals, oilseed rape, sunflower and maize. Crop rotation, including planting of cover crops, and crop diversification can benefit soil fertility through the provision of organic matter. Similarly, low and no tillage (reduced plowing) or retention of stubble on fields after harvesting benefits organic matter provision and water regulation.

Managing different areas or applying different measures within fields supports the enhancement of agro-ecosystem services for the benefits of farming and biodiversity. These are often referred to as field margins, strips or patches. Examples include:

- Less productive or water-logged areas, where machine operations are difficult or around environmental structures (e.g., trees, hedges);

- Extensively rather than intensively cropped areas and strips to regulate water and soil erosion;

- Specific flower areas to support pollination in insect pollinated crops (e.g., sunflowers, oilseed rape); or

- Uncropped areas, such as fallow land to regulate water, build-up of organic matter and contribute to soil erosion prevention. All these measures applied within fields in addition to agricultural land in general can contribute to habitat connectivity needed to enhance total biodiversity at broader landscape level scale and to provide semi-natural habitats in fields.

5.1 Integrated production: Agroecology, ICM and IPM

"Agroecology" was defined by Francis et al. (2003)[335] as the ecology of food systems, connecting disciplines in production agriculture and beyond into the rural landscape and community. Fields of sociology, anthropology, environmental sciences, ethics and economics are crucial to the mix. The design of individual farms using principles of ecology is expanded to the levels of landscape, community and bioregion, with emphasis on uniqueness of place and the people and other species that inhabit that place in contrast to a narrow focus on crop-soil interactions. This is summariszed in the CropLife International infographic “What is Agroecology”[336] and related documents.[337] Using agro-ecological knowledge, farmers, scientists and researchers can select appropriate technologies and systems to create a sustainable food system. Many of the practices promoted as “agro-ecological farming” are existing best practices, such as crop rotation, cover crops or soil quality management, which can be applied in a variety of contexts and farming systems.

Integrated Production (IP)[338] is a concept of sustainable agriculture based on agroecology and a system approach that aims at contributing to sustainable, resilient, and profitable farming systems. It is:

- An agroecology approach that considers a farm as an agro-ecosystem and

- A system approach, taking the farming system as a basic unit in which all interactions between different elements of farming are utilized.

A closely related concept is Integrated Crop Management (ICM),[339] which essentially integrates the management of individual crops to benefit from the interactions between them. Integrating crop production strategies also provides benefits such as pest control, maintain soil fertility, etc. It is an ancient technique practiced widely by farmers around the world but also takes advantage of modern technology to improve on the system. It uses agroecology principles and includes IPM as an integral component of the strategy. Emphasis is placed on a holistic system approach involving the entire farm as a basic unit, the central role of agro-ecosystems, balanced nutrient cycles and the welfare of all species in animal husbandry. The preservation and improvement of soil fertility and a diversified environment are essential components. Biological, technical and chemical methods are balanced carefully, accounting for the protection of the environment, profitability and social requirements.

IPM is the part of IP and ICM using agroecology principles to manage pests, pathogens and weeds. The OECD[340] defines it simply as “the study of the relation of agricultural crops and environment.” The FAO[341] provides a broader definition: “IPM means the careful consideration of all available pest control techniques and subsequent integration of appropriate measures that discourage the development of pest populations and keep pesticides and other interventions to levels that are economically justified and reduce or minimize risks to human health and the environment. IPM emphasizes the growth of a healthy crop with the least possible disruption to soil and encourages natural pest control mechanisms.” IPM is an ecosystem approach to crop production and protection that combines different management strategies and practices to grow healthy crops and minimize the use of pesticides. The FAO promotes IPM as the preferred approach to crop protection and regards it as a pillar of both sustainable intensification of crop production and pesticide risk reduction. As such, IPM is being mainstreamed in FAO activities involving crop production and protection. The FAO IPM program currently comprises three regional programs (Asia, Near East and West Africa) and several stand-alone national projects. Under these programs and projects, the FAO assists with capacity-building and policy reform and facilitates collaboration among ongoing, national IPM programs.

CropLife International strongly supports IPM[17] and the rational use of agro-ecological principles, provides training materials[342] for anyone to use and actively trains trainers and farmers as in the examples on its website.[343]

5.1 Example of anti-intensive agriculture campaign

There are numerous campaigns and movements that attack the concept and practice of "intensive agriculture." Although the term "agroecology" has long been used in science to describe the ecological principles behind agricultural systems and growing crops, it is now commonly used to refer to a social movement around sustainable agriculture. Certain groups advocate agroecology as “the” exclusive alternative to current agricultural systems, particular directed against what is termed “industrial agriculture.” While CropLife International and its members do not oppose agroecology *per se,* they believe that there are a variety of approaches and different agricultural systems available in support of more sustainable food systems worldwide. There is no single “fix all” approach suited to the variety of crops, different growing conditions (favorable versus less favorable), climate-dependent difference of pest pressures (tropical versus moderate zones) and farm structure (small or large) to name a few parameters. All of these factors need consideration when defining more sustainable food systems for a growing human population and resolving the associate triple challenge of food security, climate change and biodiversity loss.

Unfortunately, agroecology campaigners frequently use vague concepts that are difficult not to agree with (while the crux is in the detail) and bold, unsupported allegations that engage emotional reactions. The following infographic is presented as an example published in July 2020 on the BirdLife International website.[343]

1. What is "nature friendly"? Difficult to say we disagree!

2. Doesn’t agriculture, by its purpose, alter biodiversity and cultivate specific ecosystems?

3. We all want to protect our ability to produce food in the future!

Annex III: List of Sources

1 https://croplife.org/news-views/2019-annual-report/

2 https://www.iucn.org/

3 https://www.wbcsd.org/

4 https://www.cbd.int/

5 https://www.cbd.int/convention/articles/?a=cbd-02

6 http://www.fao.org/3/CA3129EN/CA3129EN.pdf

7 https://royalsocietypublishing.org/doi/10.1098/rspb.2015.0813

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9 https://www.cbd.int/gbo/gbo5/publication/gbo-5-en.pdf

10 http://www.fao.org/3/CA3129EN/CA3129EN.pdf

11 http://www.ifab-mannheim.de/EFA-Photo-brochure-feb2013.pdf

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16 https://croplife.org/crop-protection/stewardship/

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