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GUIDELINES FOR THE DEVELOPMENT OF AN OECD FARMLAND HABITAT BIODIVERSITY INDICATOR

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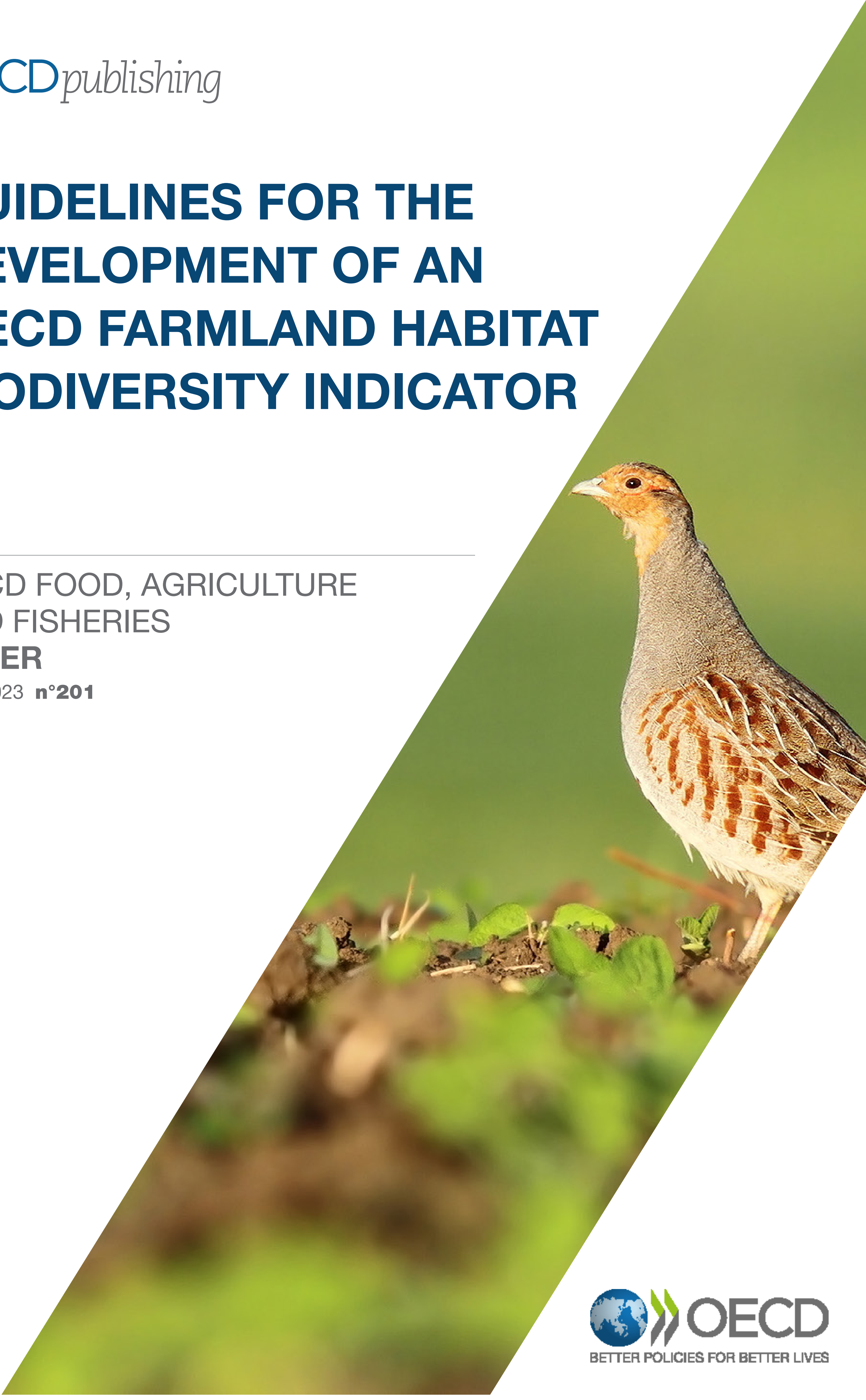

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Guidelines for the Development of an OECD Farmland Habitat Biodiversity Indicator

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With half of the world's habitable land being used for agriculture, monitoring the biodiversity on agricultural land is essential for meeting the objectives of the United Nations Convention on Biological Diversity (CBD). This paper seeks to advance the monitoring of farmland biodiversity in OECD countries by investigating current national initiatives and proposing guidelines for the development of an indicator based on habitat. The proposed approach provides a flexible and pragmatic framework to harmonise reporting from national programmes while accommodating cross-country diversity in contextual factors, including farming systems, climate, biophysical conditions and species pools. To facilitate implementation in the near term, the indicator includes a three-tiered approach to reporting based on data availability, which accommodates countries with limited data resources as well as those that currently have monitoring programmes in place.

Keywords: Agriculture, agri-environmental indicator, ecosystem services, land cover, monitoring

JEL codes: Q15, Q18, Q24, Q57

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Key messages

- This report presents an overview of the status of monitoring farmland biodiversity in the OECD countries, discusses international initiatives to monitor farmland biodiversity, explores methods of habitat-based monitoring and potential indicators, and proposes an OECD Farmland Habitat Biodiversity Indicator.
- To support the widespread commitment among OECD countries to maintain and improve conditions for biodiversity, it is essential that an indicator is developed to track trends in biodiversity over time in more detail than is presently possible with OECD agri-environmental indicators (AEIs), which remain limited to the farmland bird index for a subset of member countries.
- This paper seeks to advance biodiversity monitoring in agriculture by developing a complementary indicator based on habitat. Habitats are an important indicator of biodiversity because they describe the environment within which diverse plant and animals live and the resources available for their survival. In addition, monitoring habitats offers practical advantages, such as the ability to draw on remote sensing and aerial imagery to track changes in biodiversity over time at a landscape level.
- The proposed OECD Farmland Habitat Biodiversity Indicator is defined by four steps to be undertaken by each member country: 1) define the farmland habitat types to be monitored; 2) classify each habitat type according to its value for biodiversity; 3) calculate the proportion of farmland habitats in each value class; and 4) calculate an index value based on habitat shares in different value classes.
- The implementation of the proposed indicator is facilitated in the near term by a three-tiered approach that accounts for differences in data availability among countries. Tier III (limited data availability) relies on broad habitat definitions and rankings of biodiversity value, whereas Tier I (high data availability) includes finer-scaled definitions of habitat and field data analyses to classify habitats according to their biodiversity value.

Executive Summary

Given that half of the world’s habitable land is used for agriculture, it is critical to understand the relationships between agricultural production practices and biodiversity. Agricultural management practices influence biodiversity, while at the same time biodiversity supports agriculture by providing critical ecosystem services, such as pollination, pest control and soil fertility. The monitoring of biodiversity can help to uncover and explain changes in the provision of these services as well as provide insights into the effectiveness of agri-environmental measures to improve environmental outcomes.

The OECD agri-environmental indicators monitor the agriculture sector’s performance on a broad range of environmental and resource issues, yet the monitoring of biodiversity remains limited to the farmland bird index, which is tracked by only a subset of member states. The question of how to measure and track agricultural biodiversity across countries is fraught with challenges: OECD countries have diverse current and historical farming systems, land ownership, climate, biophysical conditions, and species pools, and there are wide cross-country differences in terms of data collection and biodiversity monitoring efforts to date.

This report seeks to advance biodiversity monitoring in agriculture by developing a complementary indicator based on habitat. Habitats are an important indicator of biodiversity in their own right because they describe the environment within which diverse plant and animals live and the resources available for their survival. Tracking biodiversity by monitoring habitats also offers practical advantages, such as the ability to draw on remote sensing and aerial imagery to examine changes over time at a landscape level. The value of tracking habitat to understand changes in biodiversity is recognised by numerous global and international initiatives, such as the Biodiversity Observation Network (GEO BON) and the European Monitoring of Biodiversity in Agricultural Landscapes (EMBAL) programme.

More specifically, this paper investigates current initiatives to monitor farmland biodiversity in OECD countries, identifies essential indicator design elements and proposes guidelines for the development of the OECD Farmland Habitat Biodiversity Indicator. A survey indicates that many OECD countries have implemented habitat-based monitoring on a national level. National programmes typically rely on field recording or a combination of remote sensing with field recording, alongside species recording to ensure that meaningful habitats and their quality are captured. Despite sharing similar objectives, these national programmes exhibit considerable differences in terms of habitat definitions, sampling strategies, and frequency of data collection.

It is essential that the proposed OECD Farmland Habitat Biodiversity Indicator provides a way to harmonise reporting from diverse national monitoring programmes, while also recognising that different biogeographical regions and agricultural systems have different species pools and baseline levels of biodiversity. The indicator should ideally be implementable in the relatively near term in order to facilitate the collection of baseline data where there currently are none, to begin evaluating biodiversity habitat trends and to support the analysis of policies that seek to maintain or improve farmland habitat. The indicator should also build on existing biodiversity monitoring programmes and reporting obligations already in place in order to avoid duplication of efforts and to alleviate the administrative and financial burden on member states of reporting.

The proposed OECD Farmland Habitat Biodiversity Indicator is defined by four steps to be undertaken by each member country: 1) define the farmland habitats to be monitored; 2) categorise each habitat type according to its value for biodiversity; 3) calculate the proportion of farmland habitats in each class; and 4) calculate an index value based on habitat shares and value classifications.

To facilitate implementation in the near term while acknowledging differences in data availability among countries, the indicator calculation follows a three-tiered approach based on data availability, where Tier III (limited data availability) relies on broad habitat definitions and rankings of biodiversity value, whereas Tier I (high data availability) includes finer-scaled definitions of habitat and field data analyses to classify habitats according to their biodiversity value. The indicator as proposed offers two means to track change within a country over time, one focused on habitat and the other on monitoring. Within a reporting tier, changes in farming practices that increase the share of farmland in habitat with high value for biodiversity elevate the index score. In addition, countries may progress from one reporting tier to another as they advance in data collection and monitoring.

1. Introduction

1.1. Why monitor farmland biodiversity?

The United Nations Convention on Biological Diversity (CBD) requires signatories to prepare a national biodiversity strategy and action plan and to integrate the conservation and sustainable use of biodiversity into relevant sectoral or cross-sectoral plans, programmes and policies. More specifically, the Convention requires countries to identify and monitor important components of biodiversity, as well as processes and activities that are likely to have adverse impacts on biodiversity.

Given that half of the world’s habitable land is used for agriculture (Ritchie, 2019[1]), it is important to understand the relationships between agricultural production practices and biodiversity. Intensive agriculture, which demands high inputs of fertilisers, pesticides, energy, and water, and which relies on mechanised cultivation and harvesting, is known to be harmful to biodiversity (Tsiafouli et al., 2015[2]; Díaz et al., 2019[3]; Benton et al., 2021[4]). There are many production systems worldwide that cannot, as such, be of high value for biodiversity even though they are of high value for crop yields and food security. In these cases, certain safeguards and abatement measures will be required for the resource base to be maintained, and for ecosystems and wildlife to survive in these landscapes. In contrast, extensive agricultural management, which uses relatively small amounts of labour and capital and produces a lower yield per unit of land than intensive farming, is essential for sustaining biodiversity in many countries (Bignal and McCracken, 2000[5]; Henle et al., 2008[6]; Takeuchi, 2010[7]; Pungar et al., 2021[8]; Mózner, Tabi and

Csutora, 2012[9]). There are many examples of agricultural management practices that lie between these two extremes and that seek to jointly support yields and provide benefits for biodiversity.

While agriculture impacts biodiversity, it is also true that biodiversity is important to agriculture because it supports critical ecosystem services, such as pollination, pest control and soil fertility (Dainese et al., 2019[10]; Hardelin and Lankoski, 2018[11]). Monitoring can help to uncover and explain changes in the provision of these ecosystem services that can affect agricultural yields. It can also provide insights into the policy drivers that potentially impede the provision of ecosystem services as well as the effectiveness of policy instruments that seek to improve environmental outcomes (Hardelin and Lankoski, 2018[11]). A meta-analysis of a wide variety of agroecosystems across the globe has shown that restoration efforts, for example, can be highly successful in increasing biodiversity and ecosystem service provision in agroecosystems (Barral et al., 2015[12]).[1] Similarly, government incentives to encourage planting of wildflowers to benefit pollinators has proven successful in augmenting pollinator abundance and species richness both in Europe and across North America (Williams et al., 2015[13]). In light of the potential for such programmes to improve biodiversity outcomes, it is important to monitor biodiversity on farmland and assess whether payments currently provided to the agricultural sector could be reformed and targeted to improve environmental sustainability (OECD, 2022[14]).

1.2. What is farmland biodiversity?

Farmland biodiversity includes all of the species, habitats and genetic diversity that occur in agricultural landscapes. One type of biodiversity, referred to as planned biodiversity, is purposefully included in the agroecosystem by the farmer, and includes the choice of species and varieties of crops planted, livestock breeds, honeybees, and any species introduced to support agriculture, such as bumblebees for pollination, or predators, parasitoids or pathogens for biological control of pests (Vandermeer and Perfecto, 1995[15]). Efforts to target planned biodiversity, as part of a broader biodiversity mandate, include the Commission on Genetic Resources for Food and Agriculture (~180 countries) and the International Treaty on Plant Genetic Resources for Food and Agriculture (~150 countries), which establish monitoring and reporting requirements for parties.

This report does not cover planned biodiversity, but rather focuses on associated biodiversity within the agricultural landscape.[2] Associated biodiversity consists of all non-harvested life forms that co-exist within the agricultural area and adjacent habitats on the farm, such as hedgerows, ponds, stonewalls, woodlots and unmanaged grassland. Associated biodiversity thus comprises species that are dependent on agriculture as well as wild relatives of domesticated species and includes organisms that are agriculturally beneficial as well as those that may be neutral or harmful (Vandermeer and Perfecto, 1995[15]).

1.3. What is farmland habitat?

Farmland is land used to cultivate crops or rear livestock. It includes cultivated land such as arable crops and rice paddies, land influenced by grazing animals such as pasture and rangeland, and land used to harvest human food or livestock fodder.

The term “habitat” has been used in many ways, as described in the review by Hall, Krausman and Morrison (1997[16]). The classical definition takes a single species as the starting point and makes explicit the connection between habitat and organisms. Habitat is defined as: “the resources and conditions present in an area that produce occupancy – including survival and reproduction – by a given organism. Habitat is organism-specific; it relates the presence of a species, population, or individual (animal or plant) to an area's physical and biological characteristics. Habitat implies more than vegetation or vegetation

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[1] Two examples of large-scale ecological restoration efforts cited by Barral et al. (2015[12]) are the Atlantic Forest Restoration Pact (AFRP), which has a goal of restoring 15 million hectares of degraded land in the Brazilian Atlantic Forest biome by 2050 (Calmon et al., 2011[112]), and the Sloping Land Conversion Program (SLCP) in China, which retired sloping and marginal land from agricultural production in an effort to reduce erosion and desertification (Yin and Zhao, 2012[113]).

[2] This report covers biodiversity on farmland only, i.e. it does not cover the implications of land-use change for biodiversity nor does it seek to develop a comprehensive profile of biodiversity within a country, which depends on biodiversity found in non-agricultural habitats, such as wilderness or wetlands.

structure; it is the sum of the specific resources that are needed by organisms. Wherever an organism is provided with resources that allow it to survive, that is habitat" (Hall, Krausman and Morrison, 1997[16]).

While a definition that preserves the linkage between species and habitat is appealing from a theoretical standpoint, it presents practical challenges in field mapping because the number of habitats as defined by Hall, Krausman and Morrison (1997[16]) is as great as the number of species. A more pragmatic approach to defining habitat follows from the principles of the Great Britain Countryside Survey in using the following definition of habitat: "An element of the land surface that can be consistently defined spatially in the field in order to define the principal environments in which organisms live" (Bunce et al., 2005[17]; Bunce et al., 2011[18]). Because agricultural land use typically alters the land surface in visible ways, this definition can work well for agricultural habitats. Each different type of agricultural land use, e.g. a cereal field, fruit orchard or rice paddy, can be interpreted as a potential habitat type, providing a specific set of environmental conditions.[3] This definition supports the use of aerial photographs and remote sensing data in habitat mapping, permits examination of habitat changes over time at a landscape level and facilitates linkages between habitat records and other biodiversity indicators (Bunce et al., 2013[19]).

In addition to areas used directly in food production, the term farmland habitat also encompasses other patches of land on the farm. Typically, these include various types of boundary features, or pockets of natural or semi-natural habitat that are surrounded by farmland. Thus, every piece of land on a farm is potentially a type of farmland habitat. The number and types of species supported by each habitat vary; some habitat types undoubtedly contain more species than others and some environments have more species than others.

1.4. Mapping farmland habitat and assessing habitat quality

In mapping farmland habitat, countries with quite similar agricultural systems may have subtle differences in the way they define categories of land use and land cover (Jansen and Gregorio, 2002[20]). Moreover, the categories used to generate any specific map are dependent upon the limitations of the data sources available (Glimskär and Skånes, 2015[21]). These challenges complicate comparisons of habitat maps across countries.

In addition, the definition of habitats as relatively homogeneous parcels of land may not necessarily reflect conditions as they are experienced by plants, animals, fungi and microorganisms. Each species has unique demands related to abiotic factors (e.g. temperature, air humidity, levels of sunlight) and biotic factors (e.g. competitors, predators, food sources). For example, an arable field may look homogeneous and easy to delineate from an aerial photograph, yet for many organisms, conditions at the field edge are more favourable than in the centre. Since small fields have comparatively more of the favourable edge conditions, biodiversity can decline as field size increases (Martin et al., 2019[22]; Clough, Kirchweger and Kantelhardt, 2020[23]). Whilst a very detailed map could pick out the edge as a specific habitat type, another approach is to consider that any habitat type may vary in "quality," where higher quality habitat supports more species, or more individuals of a species, than low quality habitat.[4]

Since land use/land cover classes may incorporate land parcels with a high degree of variation in habitat quality, other data are often used to provide information about conditions for biodiversity. For example, the same main type of land use (e.g. cropland) may be managed intensively (ploughed, sown, fertilised and sprayed with agro-chemicals) or less intensively (no-till, permanent crops, not fertilised, no chemicals). Some countries are developing data systems that can match management practices with specific land parcels. More commonly, signals of management intensity are interpreted from aerial photos or satellite images, e.g. by examining the smoothness of the surface, the colour or reflectance of the vegetation, or

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[3] The linkage between the land use and its value as a form of habitat is context-dependent; a particular agricultural land use may be more valuable as habitat than others as a function of the types of farming systems present, the historical path of agricultural development, climate, biophysical conditions, species pools, and the surrounding landscape.

[4] For a national-scale indicator, incorporating information about micro-habitat and habitat quality information is likely to be infeasible. For example, information at the scale of the individual patch may not be available, though information at the scale of the parent class would be available at sufficient resolution. In implementation, there are likely to be limitations in habitat monitoring related to data resolution.

the pattern of development of vegetation through the season. As technologies improve, these methods are becoming increasingly sophisticated.

While remote sensing can provide increasingly valuable data about habitats, there is nevertheless broad consensus that the best way to assess the habitat quality of land parcels is by collecting field-level observations, where the species present in the habitat are recorded. However, since species recording is time intensive, usually only a selection of species, often biased towards those that are easily observed and identified, can be recorded from a small sample of the farm area. Moreover, in habitats that have already suffered degradation, species that once relied upon the habitat may no longer be present.

2. State of the art in monitoring farmland biodiversity

2.1. Previous OECD work

For over 20 years, the OECD has been working to develop a set of agri-biodiversity indicators that are policy relevant, analytically sound, measurable and easy to interpret (OECD, 2001[24]). A key outcome of expert workshops held to date is the OECD Agri-Biodiversity Indicators Framework (Figure 2.1).

In 2001, the OECD recommended that the member countries should start collecting data on biodiversity within the context of agriculture as soon as possible (OECD, 2001[25]) and outlined methods and examples of good practice. Nevertheless, a review for the OECD (Karousakis, 2018[26]) found surprisingly little recording of studies that rigorously evaluated the impact of policies on biodiversity outcomes (e.g. species or habitats).

2.2. Ongoing national initiatives

Many OECD countries have some form of mapping and monitoring of biodiversity in place. Often the primary focus has been to monitor species and areas of special conservation concern or high national priority (Henle et al., 2013[27]). Nevertheless, some countries have also been monitoring agricultural landscapes for many years. The longest running national monitoring programme is the UKCEH Countryside Survey in Great Britain, which started in 1978. For many countries, monitoring of agricultural biodiversity is a more recent endeavour. Some countries have used available historical data to retrospectively assess conditions for biodiversity. For example, Canada has made use of census data to calculate an indicator of Wildlife Habitat Capacity on Farmland, constructing a time series going back to 1986 (Clearwater et al., 2016[28]).

For this report, a questionnaire on biodiversity monitoring, including questions on policy initiatives, data sources used, frequency of data collection, measurement units, and dissemination tools, was sent to contacts provided by 25 OECD countries, 16 of which responded.[5] Of the respondents, 13 have habitat-based monitoring on a national level. Most rely on field recording or a combination of remote sensing with field recording. The main categories of farmland habitats covered by the different programmes are shown in Table 2.1, including an assessment of whether each category is explicitly recognised in national policy. Farmland habitats are not necessarily monitored, even when recognised in national policy as being important for farmland biodiversity. This applies particularly to landscape structures (e.g. field boundaries and hedges).

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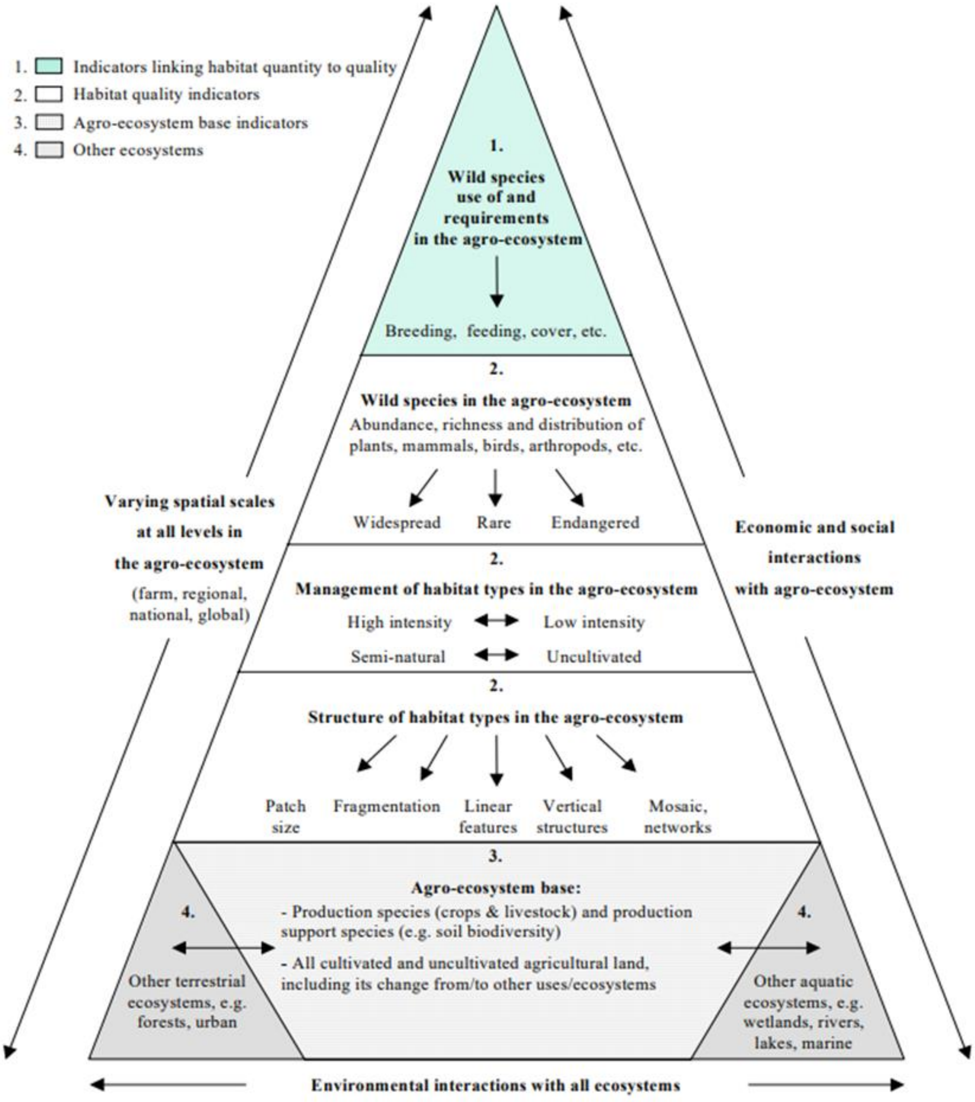
[5] In December of 2021, the OECD Secretariat called for participation of farmland biodiversity experts to be included in the group for the creation of these guidelines. The initial contact list for the survey was created based on the responses provided and extended/modified in view of revised or additional contact information.

While habitat monitoring can provide a useful indicator of biodiversity (Bunce et al., 2013[19]), the accuracy of the link between habitats and species is dependent upon the accuracy of habitat classification, as well as many other contextual variables, such as the composition and configuration of the surrounding landscape. Therefore, many countries include an aspect of species recording in their biodiversity monitoring. The species data can provide a control that meaningful habitats are being captured and can provide information about the quality of habitats.

Figure 2.1. OECD Agri-Biodiversity Indicators Framework



Note: The OECD Agri-Biodiversity Indicators Framework was developed following an expert meeting in Zurich in 2001.
Source: OECD (2001[25]).

Table 2.1. Overview of the farmland habitat types recognised in national policy (P) and monitored (M) in OECD countries

	Cropland		Cultivated/ improved pasture		Outfield grazing land/ rangelands		Landscape structures		Abandoned farmland		Semi-natural habitats		Unmanaged habitats	
Country	P	M	P	M	P	M	P	M	P	M	P	M	P	M
Austria	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Canada	✓	✓	✓	✓	✓	✓	✓	○	✓	✓	✓	✓	✓	✓
Czech Republic	○	-	○	-	○	-	○	-	○	-	✓	-	○	-
Denmark	○	○	✓	✓*	✓	✓*	✓	✓*	○	○	✓	✓*	✓*	✓*
Germany	✓	✓*	✓	✓*	✓	✓*	✓	✓*	✓	✓*	✓	✓*	✓*	✓*
Japan	✓	-	✓	-	✓	-	✓	-	✓	-	✓	-	✓	-
Latvia	✓	✓	✓	✓	✓	✓	✓	✓*	✓	✓	✓	✓	✓	✓
Lithuania	✓	✓	✓	✓	○	-	✓	✓*	✓	✓	✓	✓	✓	✓
Mexico	✓	✓	✓	✓	✓	○	✓	○	✓	○	○	○	✓	✓
New Zealand	○	○	○	○	○	○	✓*	✓*	-	-	✓*	✓*	✓*	✓*
Norway	✓	✓	✓	✓	✓	○	✓	✓	✓*	✓*	✓	✓	✓	✓
Slovak Republic	✓	✓	○	○	○	○	✓	✓	○	○	✓	✓	✓	✓
Slovenia	✓	✓	✓	○	✓	○	✓	✓*	✓	✓	✓	✓	✓	○
Sweden	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	✓
Switzerland	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓*	-
United Kingdom	✓	✓	✓	✓	✓	✓	✓	✓	○	○	✓	✓	✓	✓

Note: Legend: ✓ yes; ✓* yes, at least partially; ○ no; - no information. Table reflects only those OECD countries that responded to the survey (N = 16). "Landscape structures" include field boundaries and hedges; unmanaged habitats are those habitats on the farm that are not harvested, such as woods, ponds and wetlands.

Among the respondents that undertake species monitoring (Table 2.2), the most common group monitored is farmland birds (13), followed by butterflies (12), and farmland plants (7). Five countries monitor bumblebees (or are preparing to do so) and three monitor soil invertebrates. As part of the UK Countryside Survey's efforts toward soil monitoring, soil bacteria and chemical properties are also included (Black et al., 2003[29]).[6] France, Italy, Ireland, and the Netherlands did not reply to the survey, but have monitoring programmes of different taxa, including soil organisms/invertebrates (mainly earthworms) (Gardi et al., 2009[30]; Rutgers et al., 2019[31]; Van Leeuwen et al., 2017[32]). Germany and Austria also have national monitoring programmes involving soil invertebrates/earthworms (Van Leeuwen et al., 2017[32]).

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[6] Soil bacteria play a key role in maintaining the soil processes necessary for primary production and thus may serve as an indicator of soil health (Brussaard, 2021[114]).

Table 2.2. Species monitoring performed in OECD countries

Country	Farmland plants	Farmland birds	Bumblebees	Butterflies	Soil invertebrates	Others
Austria	3-4 years	Annual	3-4 years from 2023/24	3-4 years		Grasshoppers (3-4 years)
Canada						Domesticated animals, rare breeds (annual)
Czech Republic		Annual		Annual		
Denmark	6 years*	6 years*				
Germany		Annual		Annual		
Japan	Once a month	6x per year		2x per month spring to summer		
Latvia	6 years	1-5 years		1-3 years (3x per year)		
Lithuania		2-3 years		3 years		
Mexico						
New Zealand		Annual			Ongoing	
Norway	10 years	3 years	3x per year	3x per year		
Slovak Republic	Continuous	Annual	Continuous	Continuous		
Slovenia		Annual	Planned to start in 2023	Annual		Bear, wolf, lynx, amphibians, beetles, bats
Sweden		Annual		Annual		Pollinators (in planning)
Switzerland	5 years	Annual		5 years	5 years	
United Kingdom	Rolling	Programme limited to 3 years	Rolling	Rolling		Moths, bats, soil microbes

Note: Blank cells indicate species group is not monitored. Table reflects only those OECD countries that responded to the survey (N = 16). *Partial monitoring of farmland plants and birds without a dedicated monitoring programme.

There are considerable differences between countries in terms of the habitats monitored; the number, size and selection of samples; the frequency of recording; the indicators reported and the way in which the monitoring data are disseminated (Table 2.3). Even within the European Union, where Member States share the same habitat typology and policy requirements to monitor the conservation status of habitats under the Habitats Directive, the interpretation and application of monitoring differs significantly, preventing direct comparisons across countries (Ellwanger et al., 2018[33]).

With respect to data access, there are also large differences between OECD countries regarding whether information is shared publicly (Table 2.4). Most of the countries that took part in the survey replied that they offer access to some data from the monitoring programme. However, in most cases public access is limited to final reports that present aggregated results of the monitoring activities and indicators. Only a few member states provide direct access to raw data; others offer data access upon request. Several respondents indicated that limits to data access are mainly due to data protection concerns. In some countries, e.g. Norway, it is considered important to keep monitoring sites secret to avoid affecting management at these sites, which could influence the representativeness of the sampling squares. If monitoring led to positive changes in management, the sample would give an overly optimistic representation of the situation elsewhere in the country.

Table 2.3. Current habitat-based monitoring programmes in OECD countries

Country	Habitat-based monitoring	Name of programme	Data sources	Minimum mapping unit size	Number of habitat classes	Frequency of data collection
Austria	Yes	ÖBM Kulturlandschaft - Austrian Biodiversity Monitoring in cultural landscapes (Schindler et al., 2018[34])	Remote sensing, field mapping of habitats	100 sites 1km^2, habitat mapping: 625 x 625 m	401	3-4 years (but planned to change to rolling design)
		BINATS – Biodiversity survey in the Austrian agrarian landscapes based on habitat structures, vascular plants, grasshoppers, butterflies, and wild bees as representative indicators (Pascher et al., 2020[35])	Field mapping, recording of plant and animal species	100 test areas (625 x 625 m)	-	First re-survey after ten years, will be conducted together with ÖBM Kulturlandschaft in the future
Canada	Yes	Potential Wildlife Habitat Availability on Agricultural Land in Canada (Agri-Environmental Indicator) (Clearwater et al., 2016[28])	Earth observation (+ adjusted Canadian Census of Agriculture)	30 m	14	5 years
Czech Republic	Yes	Habitat mapping	Field recording	no limit	172	12 years
		Habitat monitoring	Field recording	5 x 5 m^2	157	6 years
Denmark	Yes	Novana (Svendsen and Norup, 2005[36]; Danish Nature Agency, 2016[37])	Field recording	10 m^2	Has varied	6 years (but varies)
		DanCover (Christensen and Brandt, 2016[38])	Remote sensing, field recording	10 m^2	9	5 years
Germany	Yes	High Nature Value Farmland Monitoring (Hüning and Benzler, 2017[39])				High Nature Value Farmland Monitoring (Hüning & Benzler 2017)
		Habitat monitoring under EU Habitats Directive	Field recording		16	6 years
Japan	Yes	Monitoring Sites 1000 Satoyama survey (Anon, 2012[40])	Field recording	Differs	Differs	Differs
Latvia	Yes	Natura 2000 monitoring	Field recording	0.1 ha	57	6 years
		Land accounting based on mapping of land cover types (remote sensing monitoring by Rural Support Service and State Forest Research Institute "Silava")	Remote sensing, field recording			Annual
Lithuania	Yes	Habitat monitoring under EU Habitats Directive	Field recording			4 years
		Land accounting based on mapping of land cover types	Remote sensing, field recording			Annual
Mexico	In preparation	SiPeCaM (Schmidt and Dirzo, 2019[41])				
New Zealand	Only at a regional council level					

Country	Habitat-based monitoring	Name of programme	Data sources	Minimum mapping unit size	Number of habitat classes	Frequency of data collection
Norway	Yes	3Q (Stokstad and Fjellstad, 2019[42])	Aerial photographs, field recording	-	Around 100 “land types”, but with different relevance as habitat	5 years (rolling)
Slovak Republic	Yes	Sectoral indicator reports				Sectoral indicator reports
		Complex informative and monitoring system	National inventory and monitoring of habitat and species	-	-	1-7 years
Slovenia	No					
Sweden	Yes	TUVA (Database from surveys of 85000 parcels of pasture and hay meadows)	Field recording	-	-	Irregularly
		Remiil: “Regional monitoring of small habitats, grasslands and wetlands” (Glimskär and Skånes, 2015[21])	Field recording, aerial photographs	-	> 20	Annual
Switzerland	Yes	ALL-EMA (Riedel et al., 2018[43])	Field recording, aerial photographs	10 m2	75	5 years (rolling)
United Kingdom	Yes	UKSCAPE/CS (UK)	Field recording	Plots	Broad and Priority Habitats	rolling programme since 2019
		LAndSpae	Field recording	No mapping		3-year baseline dataset
		GMEP and ERAMMP (Wales)	Field recording	20x20 m	Broad and Priority Habitats1	repeat of GMEP (2013-16)
		England (in planning)				
		NI (in planning)				
		Scotland (in planning)				

Note: Table reflects only those OECD countries that responded to the survey (N = 16).

Table 2.4. Compendium of the available data from habitat monitoring programmes in OECD countries

Country	Habitat-based monitoring	Publicly-available data	Type of data	Links
Austria	Yes	Yes, but with delay and not entirely due to data protection issues	Results as reports	https://www.data.gv.at/katalog/dataset/cef715f3-9232-4fee-9687-40b86f4b81d0 https://boku.ac.at/dib/zoology/arbeitsgruppen/ag-pascher/binats
Canada	Yes	Yes	Results for Agri-Environmental Indicators	https://open.canada.ca/data/en/dataset/e996d9be-6a3b-4059-9afc-17dc68385f05
Czech Republic	Yes	Yes	Species data and habitat types	https://portal.nature.cz/publik_syst/ctihtmlpage.php?what=1013&nabidka=nadmodul
Denmark	Yes	Yes	Results as reports	https://novana.au.dk/

Country	Habitat-based monitoring	Publicly-available data	Type of data	Links
Germany	Yes	Not yet	Results as reports, data on request	
Japan	Yes	Yes (aggregated)	Results as reports	https://www.biodic.go.jp/moni1000/findings/newsflash/
Latvia	Yes	Yes (aggregated)	Reports, raw data on request	https://www.daba.gov.lv/lv/biologiskas-daudzveidibas-monitorings
Lithuania	Yes	Yes (aggregated)	Reports, thematic maps	https://zis.lt/en/
Mexico	In prep.	Not yet		
New Zealand	Yes	No		
Norway	Yes	Yes (aggregated)	Results as reports	https://www.nibio.no/en/about-eng/our-divisions/division-of-survey-and-statistics/landscape-monitoring?locationfilter=true
Slovak Republic	Yes	Yes	Statistics, habitat types, plot data	https://www.biomonitoring.sk/Home/Monitoring
Slovenia	No			
Sweden	Yes	On request		https://jordbruksverket.se/e-tjanster-databaser-och-appar/e-tjanster-och-databaser-stod/tuva https://www.slu.se/institutioner/ekologi/foma1/jordbruk/regional-landskapsovervakning/
Switzerland	Yes	On request	Results as reports	https://www.agroscope.admin.ch/agroscope/en/home/topics/environment-resources/monitoring-analytics/monitoring-programm-all-ema.html
United Kingdom	Yes	In aggregated form	Plant species presence and abundance	https://doi.org/10.5285/fd6ae272-aeb5-4573-8e8a-7ccfae64f506

Note: Table reflects only those OECD countries that responded to the survey (N = 16).

2.3. Ongoing international initiatives to monitor farmland biodiversity

Numerous international initiatives set a policy background for monitoring farmland biodiversity in the sense that they require reliable data that is comparable over time in order to assess progress towards internationally agreed goals. Among these are efforts to establish goals and commitments relevant to biodiversity, such as the UN 2030 Agenda for Sustainable Development and Sustainable Development Goals (SDGs); the 2050 Vision for Biodiversity of the CBD, the UN Leaders' Pledge for Nature of 28 September 2020: "United to Reverse Biodiversity Loss by 2030 for Sustainable Development"; the Global Coalition of the Willing on Pollinators; the FAO's Framework For Action on Biodiversity for Food and Agriculture; and for European countries, the EU Biodiversity Strategy for 2030, the Common Agricultural Policy (CAP) and the Habitats Directive. There are also a number of international initiatives established to provide evidence on trends or progress towards international goals, such as the Global Assessment Report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) of 31 May 2019 on Biodiversity and Ecosystem Services; and the Global Biodiversity Outlook of the CBD.

Following the 15th Conference of Parties to the UN Convention on Biological Diversity, the adoption of the Kunming-Montreal Global Biodiversity Framework establishes four goals and 23 targets for biodiversity preservation. Target 10 directly addresses the need for biodiversity conservation in agricultural systems, providing further justification for monitoring farmland biodiversity. Specifically, the target seeks to "Ensure that areas under agriculture, aquaculture, fisheries and forestry are managed sustainably, in particular through the sustainable use of biodiversity, including through a substantial increase of the application of biodiversity friendly practices, such as sustainable intensification, agroecological and other innovative approaches contributing to the resilience and long-term efficiency and productivity of these production systems and to food security, conserving and restoring biodiversity and maintaining nature's contributions to people, including ecosystem functions and services" (UN CBD, 2022[44]).

2.3.1. Global initiatives

With respect to initiatives that are active on a global scale, the International Union for Conservation of Nature (IUCN) is the world's largest organisation in the field of nature conservation. While the programme's focus for a long time was on the conservation of species and their natural habitats, the IUCN has recently increased its focus on farmland habitats and sustainable agriculture (Larbodière et al., 2020[45]). The organisation is particularly known for The IUCN Red List of Threatened Species which serves today as a basis for many national and international indicators on biodiversity.

The Global Biodiversity Information Facility (GBIF) is an intergovernmental network for the coordination of biodiversity information. GBIF provides an open-access database for biological data that are published by governments, institutions and organisations worldwide. GBIF administers four different types of datasets: resources metadata, checklist data, occurrence data, and sampling-event data, which includes monitoring data. The use of data standards ensures interoperability and makes it easier to combine the information from different sources.

Another global initiative is The Biodiversity Observation Network (GEO BON) which is part of the Group on Earth Observation. The aim of GEO BON is to harmonise biodiversity monitoring systems on a global scale. Changes in global biodiversity are to be measured based on Essential Biodiversity Variables (EBVs) (Pereira et al., 2013[46]; Jetz et al., 2019[47]) which comprise six main classes: (i) genetic composition; (ii) species populations; (iii) species traits; (iv) community composition; (v) ecosystem functioning; and (vi) ecosystem structure. Each class has multiple subclasses, resulting in a total of 20 EBVs. Based on those EBVs, different indices are calculated for certain aspects of biodiversity. With respect to habitats, the most relevant is the Biodiversity Habitat Index.[7] The BHI is based on remote sensing data on land cover and land-use change on a global 1 km grid scale in combination with habitat-condition scores retrieved by a PREDICTS (Projecting Responses of Ecological Diversity In Changing Terrestrial Systems) meta-analysis (Purvis et al., 2018[48]; Newbold et al., 2015[49]).

The United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC), in collaboration with the Luc Hoffman Institute (LHI) and other stakeholders, is in the process of developing and testing a Multidimensional Biodiversity Index (MBI) that approaches biodiversity from a pluralistic perspective rather than relying on unidimensional indicators that capture different aspects of biodiversity (Soto-Navarro et al., 2021[50]). The proposed MBI consists of a nested structure built around two sub-indices that capture key biodiversity dimensions describing biodiversity as part of nature (diversity, abundance, function) and the contributions of biodiversity to people (regulation, materials and assistance, non-material). Each biodiversity dimension nests public biodiversity health objectives (e.g. genetic diversity, community composition, climate change mitigation, food provision), and the indicators and metrics used to measure those objectives. The structure of the MBI is designed to allow for interoperability among countries and aligns with the CBD's post-2020 global biodiversity framework (GBF) and the SDGs.

2.3.2. European initiatives

Harmonisation of monitoring activities across countries has advanced the farthest among members of the European Union, frequently extending to the United Kingdom (as a former member) and members of the European Economic Area (EEA). In 2017, the European Commission launched the European Monitoring of Biodiversity in Agricultural Landscapes (EMBAL), which is intended to contribute to multiple EU environmental policies such as the EU Biodiversity Strategy for 2030, the EU Common Agricultural Policy and the EU Pollinators Initiative. EMBAL aims to provide data on land use, biodiversity and ecological value of agricultural landscapes that is comparable between regions and over time. It uses field surveys of 500 x 500 m sample squares, from a regular 2 x 2 km grid across all 27 EU Member States. The programme will include an area survey, which records parameters on agricultural parcels and landscape elements, a vegetation survey based on transect walks, and photo documentation (Oppermann et al., 2021[51]; EFTAS, IFAB and EAA, 2021[52]). EMBAL is aligned with the Land Use/Cover Area Survey (LUCAS) to ensure that the methodology of both programmes can be harmonised. In 2020/2021, a pilot survey was conducted in four EU Member States. Based on this pilot, the programme is currently being rolled out EU-wide (beginning in 2022 and continuing into 2023).

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[7] https://geobon.org/ebvs/indicators/biodiversity-habitat-index/.

A European Pollinator Monitoring Scheme (EU-PoMS), which uses the same sampling framework, is also under testing and is planned for integration with both LUCAS and EMBAL. A pilot is being carried out through the Strengthening pollinator recovery through indicators and monitoring (SPRING) project in seven EU Member States piloting a Minimum Viable Scheme (MVS) and testing complementary and additional modules for other taxa. The report proposes a general EU indicator as well as a Common Agricultural Policy specific indicator to evaluate the impacts of the CAP, and the agri-environmental measures implemented within CAP, on pollinators and pollination (Potts et al., 2021[53]).

The EU has developed a framework of 28 agri-environmental indicators (AEIs) to monitor how environmental concerns are integrated in the CAP in individual EU Member States (EC, 2006[54]). With respect to biodiversity, these indicators include genetic diversity, High Nature Value farmland (HNVf), and population trends of farmland birds, where the latter is also an OECD agri-environmental indicator. The indicators for genetic diversity and HNVf are not fully implemented at this time (European Union, 2023[55]).

The Streamlining European Biodiversity Indicators (SEBI) process was initiated in 2005 by the European Commission with the aim of harmonising the many different biodiversity indicators that are used by EU Member States (EEA, 2012[56]). Among an initial collection of over 140 biodiversity indicators, a final set of 26 indicators was selected. The selected indicators cover diverse topics, such as species, water quality, nitrogen levels in agriculture, protected areas, and selected ecosystems and habitats (Hicks et al., 2010[57]).

2.4. Emerging monitoring techniques and technologies

Several techniques and technologies are enabling new and improved methods of monitoring, which are likely to become more widely used for monitoring farmland biodiversity. For example, technological developments in the field of genetics offer new opportunities for the efficient monitoring of a large number of species. In particular, metabarcoding approaches are promising in delivering species lists and, potentially, estimations of abundance and biomass (Ruppert, Kline and Rahman, 2019[58]).[8] In aquatic habitats, metabarcoding of environmental DNA samples (eDNA) of soil, water, and air is already implemented in monitoring routines (Deiner et al., 2015[59]). With respect to insect monitoring programmes, metabarcoding can increase sample sizes, cover larger areas, and provide reliable identification, although uptake has been comparatively slow.

Remote sensing is becoming increasingly useful as both the spatial resolution and frequency of images improves. Pixel-based analysis within a growth season can now provide more reliable interpretation of land cover than was previously possible and improvements in computing capacity and techniques are enabling better handling of large amounts of remote-sensed data (Ni et al., 2021[60]). In recent years, the use of new sampling and machine learning techniques have made it possible to obtain very high resolution (VHR) satellite imagery from non-commercial platforms like Sentinel or Landsat (Oriani, McCabe and Mariethoz, 2021[61]).

With progressive improvements in spatial and temporal resolution, satellite imagery may soon partly replace aerial photography in monitoring due to better coverage and lower costs. A forerunner in the use of satellite data for monitoring is the Copernicus Land Monitoring Service, which provides maps of land use/land cover change, as well as more specialised products, such as mapping water and wetness or their map of “Small Woody Features” (SWF). The SWF product specifically aims to detect potential habitat in agricultural landscapes across the 38 EEA countries plus the United Kingdom, and captures changes from 2015-2018 (CLMS, 2021[62]). The reliability of this data remains to be verified in the different countries and biogeographic regions, a limitation that CLMS recognises. Moreover, the very high resolution data are still of insufficient spatial resolution (>2 m) for detecting small landscape elements that are important for habitat, and there are problems with geographical misregistration between monitoring cycles (CLMS, 2021[62]).

Applications used in citizen science-based monitoring programmes can be helpful tools in the collection of structured, semi-structured, and unstructured data. For example, in breeding bird monitoring programmes,

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[8] Metabarcoding is a system that uses DNA sequences as “taxon ‘barcodes’” to identify taxa, i.e. a group of one or more populations of an organism or organisms that form a unit (Hebert et al., 2003[110]). Barcoding seeks to identify a specific organism, whereas metabarcoding seeks to determine multiple taxa within a sample.

apps can be used to record species observations directly in the field (a form of structured data collection), offering a time-saving approach to data collection. The use of apps by naturalists and people who enjoy spending time in nature can complement structured monitoring data with semi- or unstructured data to augment the sample size of monitoring programmes and thus contribute to an improved understanding of species distributions. Even people without knowledge of a species can contribute to unstructured data collection efforts by using apps that contain modules based on artificial intelligence for species identification. Promising results have already been achieved for the monitoring of butterflies.

3. Methods of habitat-based monitoring

3.1. From data collection to habitat mapping

To monitor habitats, they must first be mapped, yet there are many approaches to habitat mapping. Generally, the choice of method involves a compromise between the level of detail at which habitats are defined, the area that can be covered, the frequency that maps are updated, and the cost of data collection. Data sources include field recording, aerial photos, satellite data, or a combination. The data source(s) influence the definitions of habitat that can be used. When mapping in the field, different species can be observed, which provides information about the conditions of the habitat and about habitat quality. When mapping by satellite, it may not be possible to distinguish between a species-rich or species-poor version of the same broad habitat type.

In general, satellite data are less precise than field recording data because of the spatial resolution of the satellite image pixels. If an image pixel is 10 x 10 m, it may include areas that are quite different from one another. If a portion of the pixel is covered by trees, for example, it could influence the spectral signal of the entire pixel, making it appear different from neighbouring pixels, when in fact it is simply on a boundary between two habitat types.

As an alternative, aerial photographs are often used for detailed mapping of habitats. Although they still provide less information about biodiversity than field recording, aerial photographs provide pixel resolutions of below 1 m which makes it possible to distinguish even small landscape elements. These may be important habitat patches in agricultural landscapes. Examples include ponds, piles of stones, or small islands of uncultivated land within agricultural fields, as well as linear features, such as narrow streams, ditches, fence lines, stone walls, margins along waterways, and herbaceous strips or lines of bushes or trees along field edges, including classical hedgerows (Bunce et al., 2020[63]). Their importance as habitat is related to the species in question, whether it be a badger looking for food or an insect looking for a place to nest.

As the resolution of satellite imagery improves, more of these smaller landscape elements may be captured by remote sensing. However, even a harmonised mapping of landscape elements, for example small woody features, does not necessarily translate into monitoring of biodiversity because it reflects only vegetation structure and provides no information about the species present. Nevertheless, earth observation data, if combined with species data, holds promise for the future of biodiversity monitoring.

3.2. From mapping to monitoring

Principles of good monitoring require that any changes in a habitat map should reflect changes on the ground, and not differences in how or by whom the mapping was carried out. The methods must be repeatable and as person-independent as possible. Comparability over time is generally best if the operator can see the previous map while making the new one. This enables them to consider carefully whether any changes in the map are real, or whether they could be due to different interpretations.

Maps derived from satellite imagery using automated mapping rules may seem to remove the aspect of person-dependence. However, different environmental conditions, such as soil moisture level, may affect the spectral signal in ways that are not yet feasible to detect using algorithms. In the future, these methods can be improved, for example by using data from in situ sensors. However, these technical solutions are not yet in operation, and some level of human interpretation is still needed. Currently, the best globally harmonised satellite-derived maps are at 30 m spatial resolution (Liu et al., 2021[64]; Friedl et al., 2022[65]).

At this resolution, few pixels are uniform in their land use/land cover and the number of classes that can be distinguished is limited.

Current monitoring initiatives differ in their frequency of recording (Table 2.3). The chosen interval between monitoring cycles is often determined by funding and practical considerations. For example, the United Kingdom's Countryside Survey had irregular intervals during early years: 1978, 1984, 1990, 1998 and 2007 (Wood et al., 2018[66]). However, since 2019 the monitoring has changed to an annual rolling programme that will repeat approximately every five years. Rolling programmes have the advantage that they are not unduly influenced by extreme weather events, such as droughts or floods that might affect a single season. They also allow maintenance of a trained and experienced workforce, which increases the consistency and reliability of the data.

There are likely complementarities between the use of aerial photography and satellite imagery. Photo plans for programmes relying on aerial photography are easily disrupted by adverse weather conditions, which suggests a need for some flexibility in the time interval. In addition, campaigns for capturing aerial photographs differ between countries and high-resolution aerial photographs are not accessible for all. Satellite imagery, on the other hand, is generally a less expensive option and time intervals between repeat scenes are much shorter, often with many repeats during a single season. However, these advantages bring associated challenges related to the technological infrastructure and competency needed to manage such large amounts of data.

3.3. Sampling

Although habitat mapping in the field is generally considered to provide the most valuable data, it is time consuming and costly. Satellite data are comparatively inexpensive to acquire for large areas but do not provide the detail necessary to capture changes in habitat quality. Therefore, many countries have chosen a solution using statistical sampling, in which detailed maps are created for a representative sample and used to extrapolate to unmapped areas. Various sampling strategies have been used, with different number and sizes of sample units and different methods to select the sample units from the population. Generally, some form of random sampling is used, with stratified random sampling being particularly common, to ensure representation of different sub-populations (strata) within the country (De Blust et al., 2013[67]; Stokstad and Fjellstad, 2019[42]). Whilst a stratified random sample is a cost-effective design, other practical and cost considerations may mean that less-than-ideal samples are used, for example when relying on citizen science or building opportunistically on existing data. In such cases, statistical methods are available to help compensate for biases in samples (Van Turnhout et al., 2008[68]; Van Strien, Van Swaay and Termaat, 2013[69]).

3.4. Frequency of data capture and reporting

The frequency of data collection and reporting also differs between countries (Table 2.3). Often this is closely linked to the budget available. One strategy is to use a rolling monitoring cycle, whereby a portion of the sample units are mapped each year and full coverage of the country is progressively achieved over time. This strategy can ensure that staff are continually engaged in monitoring and are well-trained in the methods being used. The alternative is to put in a large effort to cover the entire sample in one year, then wait several years before repeating the survey. This is more demanding in terms of recruiting and training staff each time a monitoring cycle is to be carried out, but may be the only option if long-term funding is not available.

Different types of biodiversity can be described across spatial scales using the concepts of alpha, beta, and gamma diversity, as defined by Whittaker (1972[70]). Alpha diversity is a measure of diversity within one particular ecosystem; beta diversity applies to diversity between two ecosystems; and gamma diversity refers to the diversity for all of the different ecosystems within a region. For example, if the interest is in measuring species diversity, alpha diversity could be measured as the number of different species (i.e. species richness) within an open field. Beta diversity could be measured as the difference in the number of species within an open field versus another habitat type (e.g. a riparian buffer or hedgerow). Gamma diversity would represent the total number of species found in the open field and all other habitat types.

4. Types of analysis and indicators

4.1. Genetic diversity

Genetic diversity is a central component of both planned and associated biodiversity and refers to the diversity of inherited traits within a species.[9] Genetic variation ensures that species and populations have a higher ability to resist and adapt to changes in environmental conditions, pests, and diseases (Frankham et al., 2002[71]). High genetic diversity is essential for maintaining high species diversity and functions as the motor for evolutionary processes such as adaptation to changing environmental conditions.

Despite its importance, genetic diversity is often neglected in national monitoring and reporting, especially within the context of associated biodiversity. In an extensive analysis, Hoban et al. (2021[72]) evaluated 114 national reports on genetic diversity from countries that have signed the Convention on Biological Diversity (CBD). Findings showed that most national actions are limited to measuring genetic diversity *ex situ* (e.g. seed banks), while in situ measurements are rare. Moreover, the researchers found the indicators proposed by the CBD to be insufficient in measuring genetic diversity, particularly in capturing the genetic diversity of wild species. Instead, Hoban et al. (2021[72]) propose using the following indicators:

- the number of populations with effective population size (Ne) above *versus* below 500
- the proportion of populations (or geographic range) maintained within species
- the number of species and populations in which genetic diversity is monitored using DNA-based methods

4.2. Species diversity

Species diversity is a commonly used indicator of biodiversity at the national level. It is also widely used to describe the biodiversity richness of habitats. It should be noted that some habitats are naturally species poor, however the species living there may be unique and not able to survive in other habitats. Therefore, these habitats are also important to maintain biodiversity at regional and national scales.

Direct comparisons of species diversity across countries are difficult because different countries naturally have different species pools, driven by bio-geographical factors (especially climate), rather than by present or past land-management practices. For example, countries farther north generally have lower species diversity than countries nearer the equator. A study of farmland biodiversity on 88 farms across six European regions found that geographic location alone had a dominant effect on both plant and animal communities (Lüscher et al., 2015[73]).

Nevertheless, for some of the most commonly monitored species groups, harmonised indicators are available or are being developed across a large number of countries, namely for farmland birds (Gregory et al., 2005[74]; Kirk et al., 2020[75]), bats (Van der Meij et al., 2015[76]) and butterflies (Van Swaay et al., 2015[77]; Van Strien, Van Swaay and Termaat, 2013[69]). Birds were the first group for which global status was available (BirdLife International, 2023[78]). For butterflies, there also exist global guidelines for monitoring, which recommend standard methodologies to produce indicators that are comparable across different ecosystems, biogeographic regions, and climatic zones (Van Swaay et al., 2015[77]).

4.3. Functional diversity

Variation in functional attributes is also an important component of biodiversity and is included in some definitions (IPBES, n.d.[79]). Functional traits are characteristics of a species that affect their ecological roles. Examples for plants include the timing and duration of flowering, which are related to specific reproductive strategies; the height of the plant, which affects how well the plant can compete for light; or

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[9] Genetic diversity within the context of planned biodiversity can be found in the agronomic practice of planting genetically diverse crop cultivars within a single field in an effort to increase yield by minimising damage by pests and pathogens (Hughes et al., 2008[111]). A similar idea holds for associated biodiversity, which is of primary concern in this report.

the size and spacing of leaves, which affects competition for space. Functional traits are important in determining how different species are affected by agricultural management such as mowing, grazing, and fertilisation. Functional diversity makes a community of species more resilient to changes, such as those due to management or climate change. Since species pools differ from country to country, this approach may be useful to make comparisons across countries. However, patterns of functional diversity and species diversity are not correlated. Therefore, these measures are complementary, meaning that both are relevant to conservation and management decisions (Mandle and Ticktin, 2015[80]).

4.4. Habitat diversity

Variation in habitats is a component of biodiversity in its own right, as well as an indicator of other forms of biodiversity. While habitat diversity may be a headline indicator, there are many measures related to habitat number, type, and spatial arrangement that can be useful for understanding and monitoring different aspects of biodiversity. Agricultural landscapes have been the focus of countless studies within the field of landscape ecology, since they conform to a clear "patch-matrix" model, where patches of habitat are separated by a relatively inhospitable matrix of crop fields (Forman and Godron, 1986[81]). These conditions have allowed researchers to examine not just how the amount and quality of habitats affect species and communities of plants and animals, but also how the spatial configuration of habitat patches in the landscape affects the movements of individuals and the success of populations (e.g. reproductive success, gene flow, extinction and recolonisation of patches). Many landscape metrics have been developed to measure various aspects of landscape content and configuration (Forman and Godron, 1986[81]; Turner, Garner and O'Neill, 2001[82]) and computer programmes are available to assist with calculating the metrics from maps (McGarigal et al., 2002[83]). The challenge, when considering habitat indicators for international reporting, is to find a minimum set of useful indicators that are appropriate to the spatial scale at which habitats are defined using the data available (Bailey et al., 2007[84]). Another challenge is that while arable landscapes are characterised by clear field boundaries, this does not apply to grassland landscapes or rangelands, where there are gradual changes between different habitat types and qualities.

In spite of the complexities and challenges, there are also some simple "take-home messages" from the research on habitats in agricultural landscapes, namely that diversity of habitats and connectivity between habitats is generally favourable for biodiversity (Frey-Ehrenbold et al., 2013[85]; Borges et al., 2017[86]; Pedersen and Krøgli, 2017[87]; Sirami et al., 2019[88]; Vilella-Arnizaut, Nottebrock and Fenster, 2021[89]) and for the provision of ecosystem services (Dainese et al., 2019[10]; Stiles et al., 2021[90]).

An important indicator in the European Union, which has been under development for some time, is the concept of High Nature Value farmland (HNVf) (Paracchini et al., 2008[91]). This is farmland that has a high contribution to biodiversity conservation at the European level. To be categorised as HNVf, the area should fulfil one or more of the following criteria:

- farmland with a high proportion of semi-natural vegetation
- farmland with a mosaic of low intensity agriculture and natural and structural elements, such as field margins, hedgerows, stone walls, patches of woodland or scrub, or small rivers
- farmland that supports rare species or a high proportion of European or World populations

Notably, the method for identifying HNVf differs across countries because farming systems, farm typologies, land classification, and data availability vary greatly between nations (Lomba et al., 2014[92]). Some studies suggest that a common methodology for identifying HNVf is inappropriate (Zomeni et al., 2018[93]). However, as harmonised data for Europe have increasingly become available, there have also been attempts to increase standardisation, while still allowing national inventories of agricultural habitats to improve the classification where these are available, e.g. in the Czech Republic, Sweden, Estonia, Lithuania, and England (Paracchini et al., 2008[91]). This is considered important in Nordic countries, where small semi-natural areas within forests are not sufficiently captured due to the resolution of standard map data.

Work remains to verify links between the map classifications of HNVf and biodiversity. For example, in Finland the HNVf concept provides a good representation of the distribution of butterflies in agricultural landscapes but does not reflect the diversity patterns of farmland birds as well (Mäkeläinen et al., 2019[94]).

In Japan, high habitat diversity is also considered a defining characteristic of HNVf, namely the satoyama landscapes (Ito and Sugiura, 2021[95]). Satoyama comprises a mosaic of different land use/land cover, including mixed forests, rice paddy fields, dry rice fields, grasslands, streams, ponds, and reservoirs for irrigation. As with HNVf in Europe, high habitat diversity was created and maintained by a variety of traditional management practices and harvesting of different types of resources from the landscape.

While HNVf is an important indicator of biodiversity, land classified as HNVf covers only one-third of the agricultural landscape in Europe. Limiting attention to tracking biodiversity on HNVf lands misses an opportunity to target improved ecosystem functioning on the remaining two-thirds of the land base, on which management practices can exert an important influence on biodiversity. For example, a large decline in insect populations on protected lands in Germany is believed to have been driven by agricultural intensification on surrounding, unprotected lands (Hallmann et al., 2017[96]). It is potentially easier to achieve improvements in biodiversity on non-HNVf lands while at the same providing benefits to farmers, for example by enhancing populations of pollinators and natural enemies of pests.

4.5. Essential Biodiversity Variables

The concept of Essential Biodiversity Variables (EBVs) is specifically designed to address the challenge that current monitoring activities are not directly comparable. EBVs are intended to be a minimum set of essential measurements that capture the major dimensions of biodiversity change and are complementary to one another and to other environmental change observation initiatives (Pereira et al., 2017[97]). Although a preliminary list of suggested EBVs is publicly available, work continues to reach agreement on a finalised list (Geijzendorffer et al., 2016[98]; Pereira et al., 2017[97]).[10] The EBVs most relevant to habitat are ecosystem composition by functional type; habitat structure (the three-dimensional organisation of the ecosystem, including the height, density and patchiness of the ecosystem); and ecosystem extent and fragmentation.[11]

4.6. A composite index

This overview has shown that there are many alternative approaches and potential indicators that can be useful to monitor farmland habitats. Many of these have been presented in earlier OECD workshops and publications, and many are currently in use in individual countries. Where farmland habitat monitoring programmes exist, they usually collect a range of data and report multiple indicators. This is done in recognition of the fact that the concept of biodiversity is too multi-faceted to capture in a single number. One solution is to calculate a composite index, based on summing scores across multiple indicators.

A good example of a composite index is the City Biodiversity Index (Kohsaka et al., 2013[99]; Chan et al., 2021[100]). This index has been developed in consultation with hundreds of experts and has been endorsed by the CBD. The index is comprised of 28 indicators and covers three components: native biodiversity, ecosystem services, and governance and management. Each indicator is given a score from zero to four points. The index is the sum of the scores, with a maximum of 112 points. It is recommended that the index value be updated every 3-5 years. The City Biodiversity Index is designed to be a self-assessment tool for each city to monitor progress against its own individual baselines.

The main goal of the Index is to measure progress, and not to compare values across cities. It thus allows different definitions, scales of measurement, and data sources between cities. This pragmatic choice makes the index easier for cities to calculate, since they can use data that are readily available. And while data quality may vary from city to city, the index nevertheless provides a basis to learn more about city biodiversity.

The theoretical foundation of the City Biodiversity Index could be translated directly into the context of an Agricultural Biodiversity Index, and could serve as a useful model moving forward. However, it is important to note that work on the City Biodiversity Index was a long-term process that began in 2008 and concluded with the publication of the manual for its calculation in 2021. A similar effort to develop an Agricultural

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[10] https://geobon.org/ebvs/what-are-ebvs/

[11] https://www.cbd.int/doc/meetings/sbstta/sbstta-17/information/sbstta-17-inf-07-en.pdf.

Biodiversity Index would without doubt require time and numerous discussions to reach consensus on which indicators to include, how to calculate them, and how they should be scored and weighted.

Composite indicators are useful in policy analysis and in communicating to general audiences. However, their construction depends upon the selection of indicators as well as a weighting scheme, both of which affect the conclusions and policy messages gleaned from the composite (OECD, 2008[101]). Challenges may arise when indicators included in the composite are closely correlated, as may be the case for field size, length of edge, and landscape heterogeneity. In this case, the choice of weights for each is relatively unimportant, but the composite provides little new information. When the indicators included in the composite are uncorrelated, the value of the composite may be determined by strategically choosing a set of weights.

Another issue is the complexity of interpreting changes in a composite index, which generally involves decomposing the index and analysing the component indicators. In many ways a composite index is a policy tool that summarises complicated information in a simple format. The true usefulness is the data that lie behind the index, which can be analysed to understand how different aspects of habitats and landscapes affect species or groups of species.

While a composite index might be a long-term goal, the “perfect can be the enemy of the good.” To make progress toward implementing a biodiversity habitat indicator across OECD countries in the medium run, it is important to agree on a practical measure that can be implemented and sufficiently capture variation in farmland habitat across time and space. This measure can serve as the basis for, and help to build momentum toward, further development over time.

5. A proposed OECD Farmland Habitat Biodiversity Indicator

Based on the review of ongoing monitoring activities in OECD countries, it is clear that many member countries are using considerable resources to fulfil national and international reporting obligations related to farmland biodiversity. Given a widespread commitment among members to maintaining and improving conditions for biodiversity, developing a mechanism to track trends in biodiversity over time is essential. Such a mechanism offers the opportunity to assess policy measures for improving farmland biodiversity and enables integration with other OECD indicators, such as those related to agricultural production and farm management.

At present, OECD monitoring of biodiversity is limited to the farmland bird index, which is reported by 23 of the 38 OECD countries. Birds are often used as an indicator of agricultural biodiversity, but relying on a single taxon to represent the state of nature can be problematic if the taxon serves as an imperfect proxy for biodiversity (Eglington, Noble and Fuller, 2012[102]). The use of a habitat-based indicator is intuitively appealing because habitats describe the environment within which diverse taxa live and the resources available for their survival. Moreover, there are practical advantages to tracking biodiversity by monitoring habitats, such as the ability to draw on remote sensing and aerial imagery to examine changes over time at a landscape level.

While an indicator spanning the full OECD membership is valuable, there are important differences between members that must be taken into account in its development. Examples include differences in the types of farming systems present (current and historical), climate, biophysical conditions and species pools. Moreover, countries differ broadly in terms of data availability and the development stage of biodiversity and landscape monitoring conditions. The indicator should provide a way to harmonise reporting from existing monitoring programmes, while also recognising that different biogeographical regions and agricultural systems have different species pools and baseline levels of biodiversity. This diversity poses an additional challenge in interpreting the indicator. For example, it could be misleading to compare biodiversity levels across countries that use different definitions of farmland.

The indicator should make use of knowledge about the connections between habitats and biodiversity. While it might be tempting to focus on High Nature Value farmland, along the lines of the European HNVf indicator, these areas cover a minority of agricultural landscapes. The OECDs Farmland Habitat Biodiversity Indicator should provide information about the state of all agricultural landscapes within a country, both the ordinary as well as those that are most valuable for biodiversity. Many species of concern on today’s farmland were common one hundred years ago, and there is great potential for improvement in biodiversity on ordinary landscapes. Research indicates that this is important for ecosystem functioning, on agricultural land (e.g. for pollinators and natural enemies of pests), as well as for other ecosystems that are surrounded by ordinary agricultural landscapes (Hallmann et al., 2017[96]).

The OECD Farmland Habitat Biodiversity Indicator should be implementable in the relatively near term to facilitate the collection of baseline data in countries without current monitoring programmes. Because changes take time to detect, it is important to start recording as soon as possible so that trends can be evaluated within a few years' time. One of the goals of developing an indicator is to support policy analysis and to determine whether agri-environmental policies that target maintaining or improving biodiversity in agricultural landscapes are meeting their objectives. A delay in starting to record also delays the opportunity to conduct such assessments.

The indicator must strike a balance in terms of flexibility and harmonisation. An approach that maximises flexibility allows countries with differing conditions, resources, and monitoring programmes to begin measurement and tracking sooner. While this approach supports faster implementation and the evaluation of trends in time for individual countries, its disadvantage is that it cannot support meaningful cross-country comparisons. An approach that prioritises harmonisation requires addressing differences between members prior to beginning measurement and tracking. This approach could ultimately facilitate more meaningful cross-country comparisons, but at the cost of delaying data collection.

The indicator should build on efforts undertaken by other projects, including the MBI, the AEIs of the Common Agricultural Policy (CAP), and established and nascent national programmes.[12] The chosen approach should avoid duplication of efforts and alleviate the administrative and financial burden on member states of reporting. To the extent that data are collected to meet other reporting requirements, those data should also be leveraged in calculation of the OECD Farmland Habitat Biodiversity Indicator.

The indicator should accommodate the full range of OECD countries, including mega-diverse countries for which species monitoring is prohibitively costly. In some cases it may be more appropriate to apply integrated prediction models and to use population-level surveys only to periodically validate predicted outcomes or to monitor changes in specific cases. The indicator should integrate consideration of scale, including defining key concepts at the level of the landscape, ecotope, and population or community.

5.1. A pragmatic indicator that is achievable in the short term

The proposal of this paper is to monitor farmland habitat in OECD countries with a single indicator, the OECD Farmland Habitat Biodiversity Indicator. The calculation of the OECD indicator by each member state is defined by the following steps:

- Define the farmland habitats to be monitored
- Categorise each habitat type according to its value for biodiversity using the following ratings: Very low, Low, Moderate, High, Very high
- Calculate the proportion of farmland habitats in each class
- Calculate the index: *(% Very low x 0) + (% Low x 0.25) + (% Moderate x 0.5)+ (% High x 0.75) + (% Very high x 1)*

This formula is a means to include all five classes in one index bounded between 0 and 100, where a score of 0 indicates that all farmland habitat is in the worst class and a score of 100 indicates that all land is in the best class.

Box 5.1 illustrates a simplified example of the calculation of the index for a case in which land currently in habitat that is of very low or moderate value for biodiversity is displaced by habitat that is of high value for biodiversity. An example might be the case in which the installation of a riparian buffer displaces land

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[12] Specifically, 28 AEIs were developed by the European Commission in collaboration with members pursuant to the commission communication of 2006. The AEIs, which include for example area under organic farming, farming intensity, and soil erosion, were developed to "track the integration of environmental concerns into the Common Agricultural Policy (CAP) at EU, national and regional levels" (European Union, 2023[55]).

currently in crop or livestock production. The installation of the buffer drives an increase in the index value from 25 to 32.5.

Tracking changes in the index value as a function of changes in the share of land in habitats of differing quality provides a mechanism to track temporal trends in habitat biodiversity. Members should report both the final index value as well as the quantity of land by habitat type and the ranking of each habitat type in terms of its value for biodiversity.

Box 5.1. Example: index calculation

Scenario (i): 100 hectares of farmland bordering a stream are allocated such that 50 hectares are in habitat type A and 50 hectares are in habitat type B, where habitat type A is categorised as Very low value for biodiversity and habitat type B is categorised as Moderate value for biodiversity.

Scenario (ii): a riparian buffer, habitat type C, is installed on 20 hectares of land, displacing 5 hectares from habitat type A and 15 hectares from habitat type B. Habitat type C is categorised as High value for biodiversity.

	Scenario (i)	Scenario (ii)	Value for biodiversity
Habitat type A	50 ha	45 ha	Very low
Habitat type B	50 ha	35 ha	Moderate
Habitat type C	0 ha	20 ha	High

The index value for scenario (i) is: *(50 x 0) + (0 x 0.25) + (50 x 0.5)+ (0 x 0.75) + (0 x 1) = 25*. The index value for scenario (ii) is: *(45 x 0) + (0 x 0.25) + (35 x 0.5)+ (0 x 0.75) + (20 x 1) = 32.5*. The installation of the riparian buffer thus increases the index value by 7.5 points.

5.2. Definitions and best practices for index calculation

To measure changes over time, all indicators require consistency in methods and adherence to “best practices” for monitoring. Reaching agreement on these items is challenging given the diversity of contexts and existing programmes within member countries. Therefore, allowing countries to use their own definitions and data sources, within agreed-upon bounds, could facilitate and expedite implementation. It is essential that countries document the definitions and methods chosen and apply these consistently in future rounds of monitoring so that any change is due to real changes on the ground and not changes in how the index is calculated.

Each country must define total farmland area for the indicator, which involves making a decision about whether to include or exclude certain land uses, e.g. outfields and rangelands. Countries should strive to attain spatially explicit data (maps), and not rely solely on statistical information. The development of metadata standards and transparency in reporting is critical, particularly in making clear that cross-country comparisons may not be valid.

Each country needs to categorise its habitats according to their value for biodiversity. In some cases, regional differences within a country may mean that the same broad habitat type is given different value in different regions. For example, landscape features are commonly highly valued in Europe. However, in some regions cereal steppes are characterised by a lack of landscape features, yet support many bird species of high conservation value (Delgado and Moreira, 2000[103]). The biodiversity value of habitats also derives not only from properties on the measured site, but also from the surrounding landscape (e.g. landscape heterogeneity, habitat continuity). As such, the value assignment will depend upon the local context.[13]

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[13] To ensure that the indicator is useful, and to avoid duplication, it is important to consider how the biodiversity values assigned to land under different management practices correspond to the “biodiversity friendly practices” referenced under objective 10 of the Kunming-Montreal Global Biodiversity Framework.

In categorising habitats based on their value for biodiversity, it is necessary to define whether the assessed value for biodiversity takes into account the current quality of the habitat, namely whether it is based on the potential value of the habitat (e.g. how many species could live there) or whether it is based on the actual value of the habitat (e.g. how many species currently live there). Actual habitat value can be more accurately assessed with better monitoring data and has the intuitive appeal that it reflects the linkages between management practices (current and historical) and the value of habitat for biodiversity.

The ultimate goal is to achieve standardisation in valuing habitats. Reaching international agreement on such detail is likely to be challenging. For example, one issue that is open for discussion between EU Member States is whether Ecological Focus Areas automatically qualify as "high value", even if they are just planted with legumes (Zinngrebe et al., 2017[104]). Rather than waiting until the standardisation is complete, it is suggested that some constraints be developed to reasonably bound the classification of management practices in terms of their value for biodiversity. Countries can then begin to develop the first version of the indicator themselves, making decisions grounded in their specific context and data availability or limitations. The responsiveness of the calculated index value to changes in the amount of land in different value categories should be evaluated to ensure that the indicator adequately captures improvements in biodiversity habitat.

These decisions can then provide a foundation for further discussion in which specific issues are addressed. The more dialogue is undertaken between countries at an early stage, the more stable will be the first versions of the indicator. Lessons may be learned from the European HNV indicator and work beyond Europe to identify HNVf, e.g. in the United States (Blann, 2006[105]) and the People's Republic of China (hereafter "China") (Fang et al., 2022[106]).

A flexible approach to the initial calculations of the OECD Farmland Habitat Biodiversity Indicator, steered by the individual member countries, is a necessary step to highlight that the indicator is a work in progress. However, the results of such an approach should be interpreted with care, particularly taking into account that the index value depends on contextual factors and that the availability of monitoring data influences the degree of certainty in assessing habitat extent and value. The indicator is thus most appropriate for interpreting changes over time for individual countries rather than comparisons across countries. Care must therefore be taken in interpreting the output.

5.3. A tiered system to reflect data availability

In order to achieve near-term implementation of the OECD Farmland Habitat Biodiversity Indicator, while acknowledging the large differences in data availability between countries (Table 2.3), an evolving three-tiered approach based on data availability is suggested, as follows. This approach is designed to accommodate members that currently have limited data availability (Tier III) as well as members that currently have programmes in place to monitor farmland biodiversity (Tier I).

Tier III (limited data availability): Habitat definitions under Tier III may be broad categories that have been defined for other reporting purposes. An example might be the classes used in census reporting (e.g. cereals, other land). At this level of reporting, some land types and landscape features that are important for biodiversity will be missed, and it will not be possible to determine whether a specific parcel of land is of real value for biodiversity or not. Nevertheless, by ranking existing categories of land in relation to one another, a coarse indicator of *potential* habitat can be calculated. Broad habitat classes may also be derived relatively quickly from remote sensing imagery.[14] Expert opinion may then be used to rank the broad habitat types according to their "most probable value" in terms of their ability to support biodiversity.

Tier II (moderate data availability): Tier II adds an additional level of detail to the habitat definitions and/or the assessment of the value of each habitat for biodiversity. For the habitat definitions, classes may be identified from analysis of very high-resolution remote sensing and map analysis (e.g. large cereal fields,

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[14] It is possible that in using remote sensing data, biodiversity could be monitored within a country without their involvement in the process. It is essential that remote sensing data be combined with local expertise to ensure that meaningful habitats are captured by land-use classifications and that the value of habitats for biodiversity is captured by the indicator.

small cereal fields in heterogenous landscape, woodlots, hedges). The value of habitats for biodiversity may be calculated based on an analysis of species distribution maps and known habitat associations.[15]

Tier I (high data availability): Tier I defines the most detailed level of habitat assessment. At the outset, countries reporting at the Tier I level will be those that already have a programme in place for monitoring farmland biodiversity. For these programmes, important landscape features and habitat types have already been defined, and data have been compiled from field recording of habitats or species. Field data and analyses will provide an empirical basis to classify habitats according to their biodiversity value.

Each member should report at one tier, though it is possible that regional differences in current biodiversity and habitat monitoring activities may mean that there is within-country variation in data availability. The tier at which each country reports its biodiversity habitat indicator should be flagged to make evident the quality of the assessments, and thus the reliability of the reported results. Uncertainty is likely to be greatest for Tier III and least for Tier I. Efforts should be made to quantify and report the level of uncertainty in the estimated habitat shares, biodiversity values, and the index value.

5.4. Changes in data and methods over time

As monitoring progresses and data availability increases, countries may wish to refine their definitions, methods, or the tier at which they report. This creates a dilemma in monitoring as care must be taken to ensure consistency over time and comparability with earlier results.

Ensuring comparability of results over time can be achieved, for example, if newer, more detailed categories of information can be nested within less detailed, older categories.[16] Scope for such potential future adjustments should be considered when deciding the first definitions and methods.

Once the habitat classifications and the assignment to a category of value for biodiversity have been made, they should remain consistent over time, so that changes in the indicator value cannot be produced by re-labelling habitat types. Initial agreement is needed to bound to a reasonable degree the values assigned to different habitats that result, for example, from differing land management practices. If new knowledge shows that re-labelling is appropriate, earlier indicator values should be recalculated to reflect the correct classification and valuation. If a specific habitat type has genuinely become of greater value for biodiversity, evidence of that change should be shared and publicised, and the agreed-upon value classifications revised. This will require careful data management and documentation over time.

As data availability increases, countries can move from Tier III to Tier II to Tier I. This can be tracked over time and can, in and of itself, form a useful indicator of the degree to which habitat for biodiversity is being monitored.

5.5. Hierarchical classification of farmland habitat

Allowing countries to define their own farmland habitats is a pragmatic solution that can enable implementation of the indicator, avoiding delays over long-term discussions about harmonisation. At the same time, the goal is for a level of global consistency that makes the indicator comparable between countries. It may be helpful to draw on the lessons and successes learned from similar exercises, such as the intercalibration of the European Water Framework Directive (WFD) to harmonise national classifications of good ecological status (Ritterbusch et al., 2018[107]).

A first step in harmonising farmland habitat definitions is to assess the suitability of a global land cover classification in order to determine whether it is practical to redefine national equivalents. A system developed to address this issue, and a potential starting point for the OECD indicator, is the Land Cover

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[15] Available species distribution models are limited and may be biased towards certain types of organisms. Details about how to determine value classes in Tier II should be addressed in the proposed workshop and pilot programme.

[16] Another way to address this issue would be to update past years when a new method or data are available, but this is only possible if data exist for earlier periods. Work by Canada to retrospectively construct an indicator of biodiversity using earlier remote sensing imagery provides an example of using this approach successfully (Clearwater et al., 2016[28]).

Classification System of the UN Food and Agriculture Organisation (Di Gregorio, 2016[108]).[17] Existing classification systems can potentially be "translated" to the LCCS.

The LCCS defines eight major land cover types: (1) Cultivated and Managed Terrestrial Areas, (2) Natural and Semi-Natural Terrestrial Vegetation, (3) Cultivated Aquatic or Regularly Flooded Areas, (4) Natural and Semi-Natural Aquatic or Regularly Flooded Vegetation, (5) Artificial Surfaces and Associated Areas, (6) Bare Areas, (7) Artificial Waterbodies, Snow and Ice, and (8) Natural Waterbodies, Snow and Ice. Following this first level of definition, more detailed land cover classes are created by the combination of sets of pre-defined classifiers, which are different for each of the eight major land cover types. For example, common classifiers used for cultivated and managed terrestrial areas are life form of the main crop, spatial aspect (field size and field distribution), crop combination and water supply. Common classifiers for natural and semi-natural terrestrial vegetation are life form of the main strata, cover, height and spatial distribution/macropattern (continuous, fragmented or patchy). For aquatic or regularly flooded areas, water seasonality is an additional important classifier. If the land-use categories are too broadly defined to be of value in monitoring habitat, they can be refined to develop a list of potential habitat types that is both meaningful for biodiversity and harmonised across countries.

LCCS is a hierarchical system: the more classifiers used, the greater the detail of the defined land cover class. This fits well with the idea of a tiered indicator. However, the levels of detail reported from countries many not fit neatly into three tiers. In some countries, for example, where water is scarce, information on the water supply used on agricultural land is likely to be readily available even at the coarsest level of reporting. In a country with plentiful rainfall, however, this attribute may not be recorded, even if irrigation does occur in some small regions. Nevertheless, attributes that are important in a country are likely to be captured and the LCCS can therefore meaningfully reflect the large biogeographic variations that can be seen across OECD countries. A global landcover dataset has been created using the LCCS system (Bartholomé and Belward, 2005[109]).

5.6. A proposed way forward

This report presents an overview of the status of monitoring work in the OECD countries and an initial proposal for the OECD Farmland Habitat Biodiversity Indicator. Nevertheless, much of the work to implement the indicator remains.

To begin, the OECD seeks agreement on the value of developing the OECD Farmland Habitat Biodiversity Indicator as a complement to the only other measure of biodiversity available within the set of current OECD agri-environmental indicators, the farmland bird index.

The OECD also seeks agreement on the foundational elements of the proposed OECD Farmland Habitat Biodiversity Indicator. These consist of: i) the proposed index, which combines the shares of habitat types with a value ranking; and ii) the three-tiered system for reporting based on the data available to quantify habitat type and assess biodiversity value. The calculation of the index within a tier forms the basis for capturing changes over time in biodiversity habitat, while movements between tiers constitute an indicator of progress toward monitoring biodiversity habitat within member states.

To achieve progress in implementing the indicator in the near-term, the OECD proposes a pragmatic solution that allows the flexibility for countries to move forward with their own definitions and data sources. This is a pragmatic solution that can enable tracking to begin without delays over long-term discussions about harmonisation. Even so, it is necessary to agree upon basic bounding principles when assessing habitat type and value, and to strategically choose classification systems that support the comparability of values over time as data and methods are refined. To do so, the OECD recommends a workshop involving stakeholder participation to advance OECD-wide agreement on the following items:

- the adoption of a common classification system, such as the Land Cover Classification System (LCCS), as a starting point for defining potential farmland habitat types as well as consideration of the interaction between farmland and the broader landscape

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[17] https://www.fao.org/3/x0596e/x0596e00.htm.

- including habitat quality when assessing biodiversity habitat value, i.e. evaluating actual versus potential value
- developing guidelines on valuing habitat for biodiversity (e.g. types of biodiversity, species targeted, distinctions between value categories) as well as reasonable constraints on the classification of agricultural management practices in terms of their value for biodiversity
- reporting standards, such as the definition of spatial reporting units, spatial precision of remote sensing data by tier, frequency of measurements, and metadata standards for transparency in reporting.

Subsequent to this discussion, the OECD seeks to move forward with a pilot, or proof of concept. Due to the large differences between countries in data availability, it will not be possible for all OECD countries to report the indicator immediately. A pilot programme should involve any member wishing to participate and would ideally involve participation by countries that anticipate reporting across the three tiers of data availability. The pilot should involve parallel processes for countries with existing programmes and those without, as follows:

- Countries that already have suitable datasets or existing monitoring programmes can be encouraged to calculate the indicator as a pilot, or proof of concept, at the Tier I level. Testing the OECD Farmland Habitat Biodiversity Indicator for these countries will involve re-analysing existing national data to test the feasibility of a common indicator that adheres to agreed-upon definitions and valuation of habitats.
- For those countries that have not yet engaged in farmland biodiversity monitoring, but are willing to do so, there may be opportunities to learn from the monitoring approaches developed by other members. It is particularly important to consider heterogeneity across countries in attempting to adapt definitions and methods from established programmes to new regions. For example, methods currently used to collect field observations of individual species may not be viable in mega-diverse countries. It is essential to discuss reasonable definitions, data sources and methods within differing regional contexts to ensure that the guidelines developed for the indicator are sufficiently flexible to accommodate the diversity among member states.

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Annex A. Summary of the OECD workshop held 24-25 August 2022

The OECD invited OECD delegates and technical experts on biodiversity to a joint two-day workshop to discuss the development of a national farmland habitat indicator and to gather feedback on the proposed guidelines. Around 60 participants took part in the workshop.

Invitation

As part of the 2021-22 PWB project on enhancing the use of agri-environmental indicators and analytical tools, this workshop focused on developing an agricultural biodiversity habitat indicator using a combination of in-situ monitoring and earth observations. Biodiversity indicators based on landscape features and habitats can potentially be measured under diverse country conditions and complement the farmland bird index, at present the only biodiversity indicator available in the OECD agri-environmental database. The objective of this workshop was to elicit feedback from delegates and technical experts on proposed indicator guidelines that were then discussed at the JWPAE meeting in November 2022.

Agenda

Table A.1. Agenda for the Biodiversity Habitat Indicator Workshop

24-25 August 2022, from 12:00-15:00 each day in a virtual setting

	Time	Activity and presenters
Day 1, 24 August 2022		
	12:00-12:20	**Welcome and opening remarks** Kelly Cobourn and Jussi Lankoski, OECD Trade and Agriculture Directorate
	12:20 – 12:40	**Getting ready** *All attendees, please write the following 3 bullet points on a "sticky note" and add to the Miroboard: Your name, country, institute and interests*
	12:40 – 13:00	**Setting the scene** *This session will present an overview of existing farmland biodiversity monitoring in OECD countries based on a recent survey of member countries. Please add questions or comments on the Miroboard at any time.* Ulrike Bayr, Norwegian Institute of Bioeconomy Research (NIBIO)
	13:00-13:15	**Break**
	13:15-13:35	**Conceptual framework: A proposed tiered approach to developing an OECD farmland biodiversity indicator based on habitats** Wendy Fjellstad, Norwegian Institute of Bioeconomy Research (NIBIO)
	13:35-13:55	**Questions, comments and discussion**
	13:55-14:10	**Break**
	14:10-14:30	**Potential wildlife habitat availability on agricultural land in Canada** Steve Javorek, Sustainability Metrics, Agriculture and Agri-Food Canada
	14:30-14:50	**Land Use/Cover Area Frame Survey (LUCAS) and European Monitoring of Biodiversity in Agricultural Landscapes (EMBAL)** Carsten Haub, EFTAS, Germany
	14:50-15:00	**Close of Day 1** *The Miroboard will remain available. Please continue to add questions, comments and suggestions. We will revisit your additions on day 2.*
Day 2, 25 August 2022		
	12:00-12:15	**Recap of the previous day**
	12:15-12:35	**Presentation of high nature value (HNV) farmland** Jan Erik Petersen, Spatial Assessment Team, European Environment Agency, Copenhagen
	12:35-12:55	**The Farm Bird Index** Richard Gregory, Royal Society for the Protection of Birds, Centre for Conservation Science, UK

	12:55-13:30	**Gathering feedback on an OECD farmland biodiversity indicator based on habitats: Breakout groups** With your groups, please add “sticky notes” to the Miroboard on advantages and disadvantages of potential approaches, as well as considerations related to existing information in your own country. Questions for discussion (each breakout group will start with a different question): 1. What are the most important elements for farmland biodiversity in your country and are data available about these? 2. Do we need to reconcile differences across countries in the definitions of land-use categories to support comparisons in absolute terms? What would be required to develop internationally standardised definitions? 3. Is it important to capture both HNV farmland and biodiversity in everyday agricultural landscapes? And if so, could the HNV approach could be directly applied in your country? 4. How could we implement a tiered indicator, to allow countries to report according to the best data they have available (remote sensing/field data)?
	13:30-14:00	**Break**
	14:00-14:30	**Report from the breakout groups and general discussion**
	14:30-14:45	**Summing up the meeting: Important points moving forward** Felix Herzog, Agroscope, Switzerland
	14:45-15:00	**Next steps and close of the workshop** Kelly Cobourn and Jussi Lankoski, OECD Trade and Agriculture Directorate

Short summary of main discussion points

Single indicator vs. composite index

One of the main issues that was discussed during the meeting is whether a single indicator is sufficient to capture farmland biodiversity. Several participants expressed concerns that a single indicator might not be capable of capturing all aspects of such a complex topic. Other participants see a single indicator as a good starting point as it can be implemented relatively quickly and help to set farmland biodiversity on the political agenda. In this regard, it was mentioned that drawing attention to the importance of monitoring farmland biodiversity over time should be given a higher priority than monitoring biodiversity perfectly and in great detail at the OECD-level. Improvements to the indicator(s) can still be made over time. As an alternative, it was also suggested that the use of a composite indicator or index based on a set of primary indicators might be more suitable to capture multiple aspects of biodiversity.

Country-specific definitions for farmland habitats

One critical issue discussed at the workshop was the large variation in how farmland habitats are defined in the different member countries. As the OECD encompasses countries from five continents, land use is very different and thus also the definitions of farmland habitats. Opinions on this issue were divided. On the one hand, the preservation of different definitions seems to be important to reflect the reality in each country and to account for the reality that habitats are very different. On the other hand, common definitions are seen as a prerequisite to assess policy impacts and if international comparability is the aim. As a possible solution it was suggested that definitions should be common at the broadest hierarchical level in the habitat classification system (e.g. biogeographical regions), while member states can define the lower levels more freely based on what is relevant for the respective country. It was also mentioned that land use and land cover should be handled differently. Land cover can be extracted objectively using remote sensing methods, while land use is more difficult to capture from remote sensing data.

Data quality and resolution

Varying data quality and resolution (both spatial and temporal) pose a main challenge for the development of a comparable farmland habitat indicator. The survey that was conducted amongst OECD countries showed that data sources as well as the recording frequencies vary to a large degree.

During the workshop, it was discussed that remote sensing (particularly satellite imagery) is essential for the large-scale mapping of farmland habitats. The use of global data sets with the same resolution was mentioned as a possibility to ensure comparability. At the same time, the spatial resolution of remote sensing is limited and for some regions might be no better than 30 m. Even with 10 m resolution, smaller landscape features that contribute to biodiversity at the local scale are not captured. It was mentioned that the methodology should be inclusive for countries that have less infrastructure and less resources available. As a solution to this, it was suggested to include data resolution into the tier system, where the lower tiers are based on lower resolution data (satellite remote sensing) and higher tiers on higher spatial resolutions (aerial photography and field recording).

Important elements for farmland biodiversity

Regarding the question of which elements are seen as the most important ones for farmland biodiversity, landscape heterogeneity and habitat diversity were named by most participants. Many countries already use the landscape mosaic as a proxy for biodiversity, e.g. by applying landscape metrics for connectivity, land type diversity and spatial heterogeneity. It was also emphasised that the positive effects of landscape diversity on biodiversity is strongly supported by the current research literature.

With respect to specific elements, participants mentioned in particular small landscape features like field boundaries, ponds and ditches, semi-natural grasslands and grazed rangelands in mountainous areas and in some cases also grasslands in extensively farmed areas (but with varying species richness). In this regard, it was stressed that not only the presence of elements is relevant, but also their quality as habitats.

Implementation of a tiered indicator

In general, the participants were receptive to a tiered indicator as it would take into account the fact that data availability, data quality and resolution vary between countries. With a tiered system, countries with less infrastructure and poorer data availability can still contribute on the first tier, while countries that have more detailed data (e.g. field records) can report on a higher tier. In this regard, it was stressed that with each tier, certainty increases and thus, it should be considered if a measure for uncertainty should be included in the tier approach. Also, the resolution of remote sensing data can be integrated, as already mentioned.

Despite the positive response to a tiered indicator, it was also emphasised that there are important issues that need careful consideration, in particular with respect to data comparability over time, potential biases, data interpretation and the classification system.

In general, there was broad consensus that an indicator of biodiversity in everyday farmland habitats is important and meaningful in addition to already established indicators like the High Nature Value (HNV) farmland and the Farm Bird Index.

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Comments are welcome and can be sent to tad.contact@oecd.org.