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Land health monitoring framework

Towards a tool for assessing functional and habitat diversity in agroecosystems

P. Dussán López

Edited by J. Davies, L. Larbodière, M. Muñoz Cañas, J. Dalton

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The *IUCN Common Ground in Agriculture* series documents the importance of sustainable agriculture and food systems, feed the dialogue between agriculture and conservation actors, and help them balance human well-being, natural resources and life on Earth.

This first report focuses on land health monitoring in agriculture landscapes. The theme is highly relevant and timely given the considerable role agriculture can play in restoring land health, recognised by the 2022 Kunming-Montreal agreement and its post-2020 biodiversity framework agreement.

The *Common Ground in Agriculture* series ambitions to explore the complex relationships between nature, agriculture and agri-food systems to inform policies and better address food security, climate change and Nature conservation challenges.

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Executive summary

Biodiversity is context-specific, and there are no one-size-fits-all indicators or monitoring methodologies. Nevertheless, the lack of common metrics to measure and monitor biodiversity at different levels in agriculture poses a barrier to mobilizing actors, setting ambitious targets and assessing policy impact. This publication seeks to overcome that barrier through a flexible framework that uses existing tools to assess functional and habitat diversity by measuring diversity at various scales, including belowground, aboveground, habitat-level and national impact (impact on land-use change or downstream pollution).

To create this framework, the author conducted two exploratory assessments to analyze existing agrobiodiversity tools and individual agrobiodiversity indicators. The tools were analyzed first, to identify gaps, followed by a review of indicators that could fill those gaps. The research included:

- Analysis of 33 digital collections (DC) and 114 indicators that were organized according to five broad components of agrobiodiversity (biotic structure, ecosystem function, ecosystem services, farm management and human outcomes) and four scales of analysis (field, farm, landscape and national).
- Analysis of 14 existing tools, which vary according by definition of agrobiodiversity and scope. These existing tools tend to focus on the soil and farm levels and do not properly cover landscape and national levels. They also rely on available data sets and, as a result, tend to underestimate the 'biotic structure' dimension of agrobiodiversity, which requires direct collection to measure it.

The result of the review is the proposed land health monitoring framework, which includes a list of tools to assess biodiversity at different levels, and complementary indicators to assess the biotic structure based on available or new direct data collection.

The next step will be to test this framework in different pilot areas, based on iterative work with the selected landscapes. To make it easier to use, future development of the framework could include:

1. Setting a list of functional diversity indicators by ecosystem functions, to support the selection of relevant indicators at the local level;
2. Developing a methodology to estimate habitats per unit of farmland through remote sensing, to evaluate the agrobiodiversity potential in the landscape;
3. Comparing remote sensing and field assessment of representative samples of functional diversity, to validate the predictive value of remote sensing technologies; and
4. Listing functional diversity by agroecosystem functional groups (IUCN ecosystem typology), to support the choice of indicators locally and provide reference levels at the global level.

Why a land health monitoring framework

The lack of common metrics to measure and monitor biodiversity at different levels in agriculture (field, farm, landscape and national) is a barrier to mobilizing actors, setting ambitious targets and assessing policy impact. A framework for monitoring land health is needed to assess functional and habitat diversity.

Who is this report for

Policymakers, project managers and scientists working on monitoring biodiversity in agriculture

How this report is structured

This report is divided into four chapters:
Chapter 1 frames the work, while
Chapter 2 describes the methodology used to develop the proposed land health monitoring framework which is presented in Chapter 3.
Chapters 4 provide final remarks and next steps.

Main message

Land health monitoring is necessary to guide and assess policy making, and can be estimated through a limited set of indicators of biodiversity and habitat.

Acknowledgements

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The above-mentioned report and “the route for IUCN’s agrobiodiversity monitoring tool” by Pablo Dussán López, have been the raw materials for the present report.

Glossary of definitions

Agricultural biodiversity (Agrobiodiversity hereafter): 'All components of biological diversity of relevance to food and agriculture and that constitute an agroecosystem: the variety and variability of animals, plants and microorganisms, at the genetic, species and ecosystem levels, which are necessary to sustain key functions of the agroecosystem' (CBD, 2000).

Agricultural ecosystems (Agroecosystem hereafter): 'Communities of plants and animals interacting with their physical and chemical environments that have been modified by people to produce food, fiber, fuel and other products for human consumption and processing' (Altieri, 2002).

Associated biodiversity: Genetic variation of cultivars/livestock and wild plants/insects; species variation in crops/insects released for biocontrol and wild plants/insects; diversity of artificial and natural ecosystems.

Biological diversity (Biodiversity hereafter): At the global level, it is 'the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems' (UN, 1992).

Digital collections: Also known as a digital library. Any collection of files that has been digitally preserved and is accessible on the internet or through software.

Ecosystem services: 'The set of ecosystem functions that are useful to humans' (Kremen, 2005). According to the 2005 Millennium Ecosystem Assessment (MEA), ecosystem services can be divided into four categories: provisioning services like food, fiber and fuel; supporting services such as nutrient cycling, soil formation and habitat provision; regulating services including climate regulation, water, and disease and pest control; and cultural services such as aesthetic, spiritual or recreational experiences (MEA, 2005).

Essential biodiversity variables (EBV): A universal conceptual framework for organizing complex biodiversity data from diverse ecosystems and species in different parts of the world into a limited set of biological variables for documenting biodiversity change, namely: genetic composition, species populations, species traits, community composition, ecosystem structure and ecosystem function (Schmeller et al., 2018).

Functional biodiversity: The biodiversity providing ecosystem services to agricultural landscapes.

Land health: 'The capacity of land, relative to its potential, to sustain delivery of ecosystem services' (Shepherd et al., 2015).

Planned biodiversity: Biodiversity voluntarily introduced by the farmer.

1. Introduction

The concept of land health focuses on the diversity of life that is available to guarantee the long-term provision of ecosystem functions. However, it can be challenging to operationalize this concept, because of the lack of a common, accepted technique for comparing the local specificities of biodiversity at a global level.

1.1 Agriculture and biodiversity: an intricate relationship.

There is a scientific consensus that biodiversity in agriculture enhances ecosystem services and sustains agricultural yields and productivity (Dainese et al., 2019; Jeanneret et al., 2021; Larbodière et al., 2020; Zhang et al., 2007).

Scientists such as Erisman et al. (2016) claim that soil biodiversity, genetic biodiversity of crops and livestock, and on-farm habitat diversity contribute to sustaining agricultural productivity, while Wagg et al. (2014) identify soil community composition and biodiversity as essential to regulating the functioning of an ecosystem. Other studies have shown that increased functional biodiversity enhances ecosystem services such as pollination, pest control, nutrient cycling, soil fertility and water regulation without compromising crop yields (Tamburini et al., 2020); demonstrated that ecosystems with a diversity of habitats show higher levels of multiple ecosystem functions and services than ecosystems with low habitat diversity (Alsterberg, 2017); and concluded that rich biodiversity in agroecosystems contributes to the delivery of essential ecosystem services, mainly thanks to species diversity and the diversity of functions they carry out (IPES-Food, 2016).

It has been widely shown that the presence of biodiversity above and below ground on agricultural land not only provides ecosystem services, but also increases the resilience of agroecosystems. IPES Food highlights that crop diversity often plays a crucial role in the resilience of agricultural systems, 'acting as a buffer against environmental and economic risks and enabling adaptation to changing climate and land use conditions' (IPES Food, 2016, p. 32). This has been confirmed by many scientists, including Mijatović et al. (2013), who showed that agricultural biodiversity generally tends to strengthen the resilience of agroecosystems to climate change, and Renard and Tilman (2019), who claimed that the genetic diversity of crops is associated with increased temporal stability of total national harvest.

In sum, while domestic agrobiodiversity provides food and other products such as fiber or wood, the non-harvested agrobiodiversity of agroecosystems sustains agricultural activities and yields by delivering ecosystem services, improving the resilience of agroecosystems and, in the long term, enhancing agricultural land health.

Nevertheless, widespread unsustainable agricultural practices are negatively affecting biodiversity today. Intensive agricultural practices, such as monocultures or the excessive use of pesticides and fertilizers, have been recognized as key drivers of biodiversity loss at the global level (IPBES, 2019). Across all aspects of agrobiodiversity (such as genetic diversity of crops and livestock, species diversity and soil biodiversity), 'the pressure on biodiversity rises with increasing farm management indicator values, which signify increased nutrient input to the farmland, progressive mechanization of farm operations, more frequent pesticide applications, or higher livestock densities on the farm' (Herzog et al., 2012, p. 71).

1.2 Public policy is a salient driver of agriculture for biodiversity

Political instruments are needed to guide action, gain public support and encourage adoption of good practices by the target population (Schumann, 2016, p. 13). Public management tools can strengthen accountability and transparency by clearly framing a problem and illustrating the progress made toward a solution, when subject to regular monitoring and evaluation (Neuhoff et al., 2009, p. 7). The quantification and simplification inherent in developing indicators render problems more manageable (Lehtonen, 2015) and increase the legitimacy and effectiveness of policy. Therefore, governments should use effective indicators to evaluate the desired outcome of farming practices, in order to improve the understanding of nature and promote a more practical discussion of sustainable agriculture. Agricultural policy indicators should provide information on the relationship between policy implementation, the change in farming activities and the effect on the biodiversity goal (Oñate et al., 2000), reflecting the on-farm practices and the actual, on-the-ground, biophysical state associated with the desired outcome (Reytar et al., 2014).

Since the 1950s, policy success has been measured with the yield by a unit of production indicator, as the public problem was considered to be insecure food provision and low productivity. Subsidies were used to encourage farmers' adoption of high-yield productive systems (including fertilizers, pesticides, mechanization, improved seeds and breeds, and irrigation) (Borlaug, 1972).

More recently, however, the United Nations has agreed on the Sustainable Development Goals (SDGs) (UN, 2015), which encourage agricultural policy to focus on sustainable intensification by increasing yields on existing farmland while conserving natural resources. Biodiversity loss is a public problem, and farming contributes to this problem. There is a need for state intervention to change farming practices, to ensure that fertilizers and pesticides are used as efficiently as possible in croplands and on-farm natural habitats are conserved. SDGs global agreement reoriented the social system towards the first level of the sustainable food systems transition (Gliessman, 2014), by including socio-environmental concerns and climate change adaptation among the public problems of agricultural policy.

1.3 Indicators for encouraging agriculture for biodiversity

The recent increase in research on and development of agrobiodiversity tools (many of the reviewed tools were developed in 2020 and 2021) shows a growing consensus on the importance of evaluating the state of biodiversity in agroecosystems on a larger scale.

A recent report by the Organisation for Economic Co-operation and Development (OECD) on agriculture in 54 economies (OECD, 2020) showed that only six economies applied environmental incentives (the European Union, Japan, Korea, Norway, Switzerland, United States). The OECD used only two indicators to assess the environmental performance of agriculture – nitrogen balance and agriculture's share of total greenhouse gas (GHG) emissions – demonstrating the limited extent to which agricultural impacts on the environment are measured.

Although there are worldwide agreed protocols for measuring carbon emissions, there are no similar, universal standards for measuring farmland biodiversity, because of the inherent heterogeneity and the lack of raw data. Still, the conservation community has made an enormous effort during the last decade on the operational implementation of the Essential Biodiversity Variables (EBVs) proposed by the Group of Earth Observations Biodiversity Observation Network (GEO BON) (Pereira et al., 2013).

1.4 Framing biodiversity in agriculture

This report uses the conceptual framework of ecosystem services delivery, developed by the Kellogg Biological Station Long-term Ecological Research program of Michigan State University (Hamilton et al., 2015), as the basis for framing biodiversity in agriculture. (Figure 1 presents this conceptual framework, with some examples.)

This framework claims that drivers of change influence both the social system and the disturbances related to agriculture. Drivers of change include, among others, climate shifts, commodity markets, demographics, technological change, and social and regulatory environments. In this last category, public policy is notable in that it is powerful in encouraging *agriculture for biodiversity* and can be influenced through political engagement.

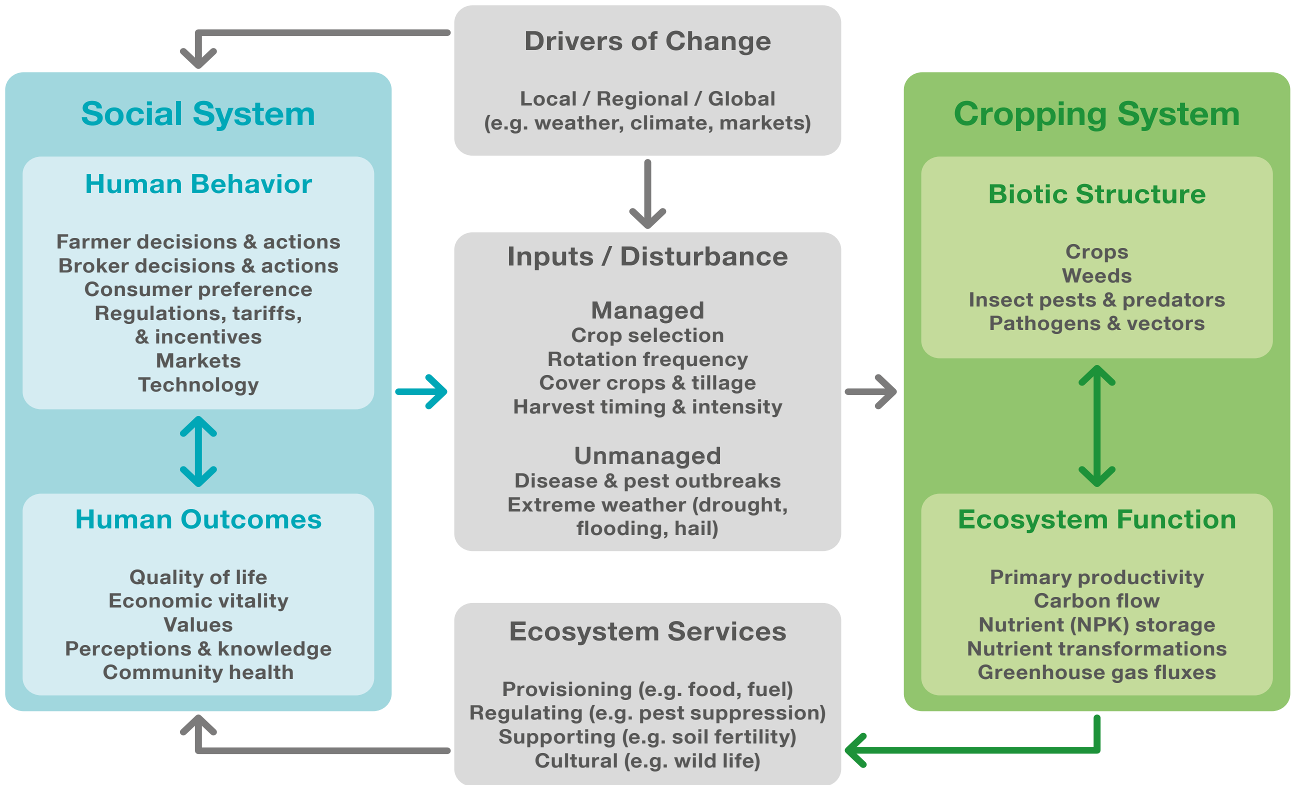

Figure 1. Conceptual model of ecosystem services delivery in agriculture.
Source: Hamilton et al., 2015, p. 6

Assuming all other variables remain equal, we focus the scope of our analysis on the relationship between public policies and farming practices. Figure 2 conjectures that public policies will influence farmers' behaviour and thus farming practices. In turn, these practices impact farmlands in both boxes, particularly the biotic structure in its three categories: level (genetic, species and ecosystems), type (planned and associated) and scale (soil, farm, landscape, national). Farmlands' biotic structure and ecosystem functions impact ecosystem (dis-) services affecting human outcomes and farming practices themselves (e.g. farming practices that enhance natural pest regulation would encourage a new set of biodiversity-friendly practices like crop diversification).

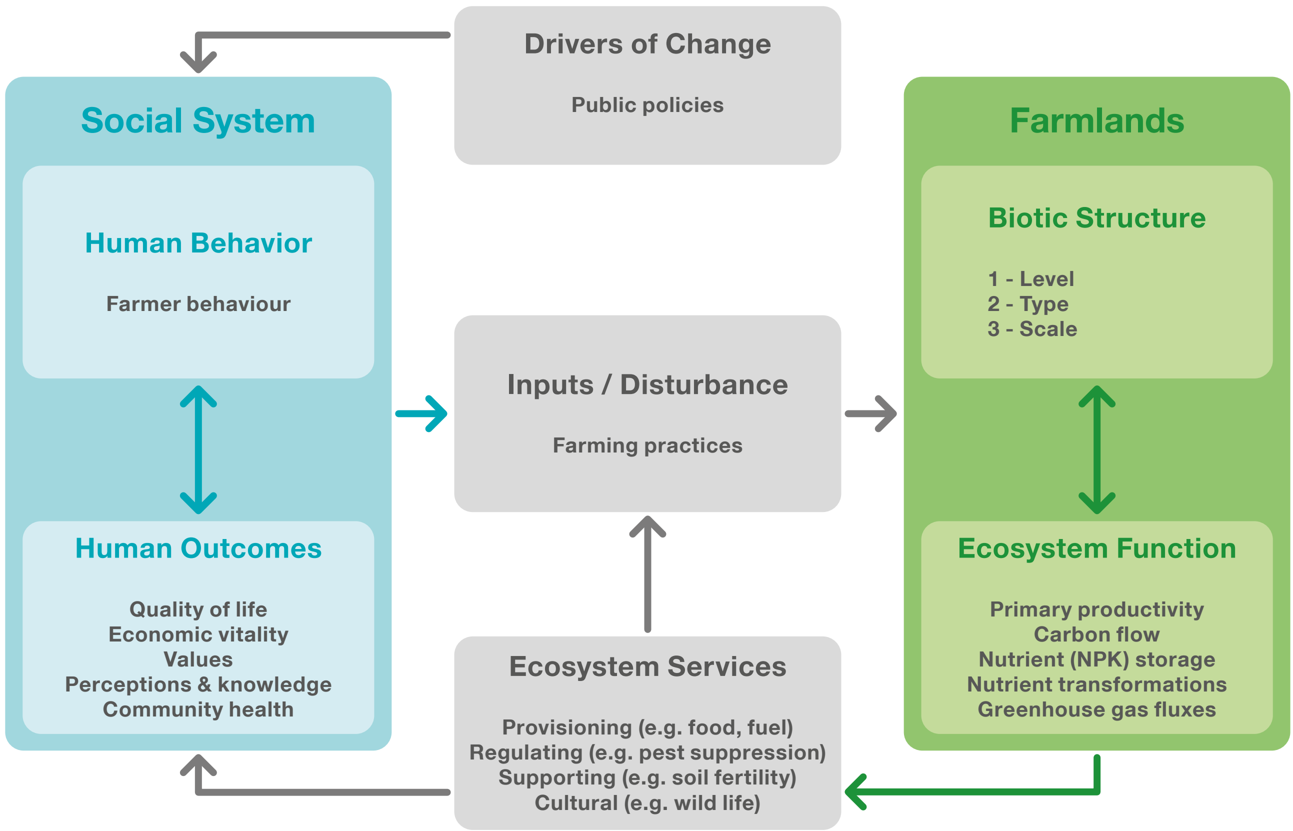

Figure 2. Agriculture for biodiversity framework
Source: Adapted from Hamilton et al., 2015

As the purpose of this report is to better understand and measure biodiversity in agroecosystems, the research focused on one of the two boxes inside the cropping system box in Figure 1: biotic structure. (In our framework, we use 'farmlands' in place of cropping system, as a more inclusive term) by defining the biotic structure though three categories.

The type (1) (planned or natural source of life) and the level (2) (genetic, species and ecosystem diversity), two of them operationalized by the CBD definition (CBD, 2000) proposed by Bàrberi (2013), and as an additional category, the observation scale (3) (soil, farm, landscape, and national).

In this last category:

1. **At soil level** we examine ***the soil biotic structure (field level)***, which includes the belowground biodiversity such us, all kingdoms of living nature that inhabit the soil, i.e., the underground parts of plants, vertebrate and invertebrate animals, algae and protozoans, fungi and bacteria (Glazovsky

& Zaitseva, 2009). Soil is used as an equivalent of field.

2. **At farm level** we examine how farming practices influence biodiversity, including farm ecosystem functions. Biodiversity can be conserved at the farm level through practices that explicitly promote biodiversity or minimise the negative impacts of agriculture. ***The farm biotic structure (farm level)***, includes the aboveground biodiversity such as domestic/wild animals and plants in an agricultural production unit and the surroundings.

3. **The landscape level** where critical ecosystem functions are maintained, including those that support agriculture and those that are enjoyed outside the farming landscape. Sustainable agricultural landscapes should maintain or strengthen the biological and economic productivity and complexity of the landscape, which can be measured through ecosystem services and functions. At the landscape scale, it is necessary also to consider trade-offs between land uses in order to maintain the desired balance of ecosystem functionality. ***The landscape biotic structure (landscape level)***, encompasses land heterogeneity and biodiversity not considered in the other two levels (farm and field) and the diversity of habitats in a predefined geographical area.

4. **The national level**, includes biodiversity and natural resources in the sum of landscapes encircled by an administrative border (e.g. Region, district, province, state, etc.). This scale includes the possible land-use spill overs within the country and between countries, as disturbances from farming practices impact the biotic structure beyond the farm itself and should be considered (e.g., biodiversity-friendly policies increase the habitat diversity in country A but encourage monoculture in country B). As mentioned before, this level does not constitute a formal scale to monitor but it is included as context to support with decision-making and to gain a better understanding of the spill-over effects from one productive landscape to another.

1.5 Conclusion

Monitoring biodiversity is the first step toward monitoring the ecosystem services that agricultural landscapes provide to society. Unfortunately, there is still a lack of authoritative tools and indicators for monitoring biodiversity.

Public policies influence farmer behaviour, and thus farming practices. In turn, these practices affect farmlands in the biotic structure in three categories: level (genetic, species, ecosystems), type (planned or associated) and scale (soil, farm, landscape, national).

Monitoring biodiversity is therefore crucial to measuring ecosystem services and ensuring the resilience of farming systems, and, in turn, understanding the impact of policies in driving the transition to more sustainable food systems.

This report aims to provide the framework for developing a tool that monitors the biotic structure in production landscapes, and indirectly assesses policies and projects impacting biodiversity through farming practices.

2. Two assessments: functional diversity and habitat diversity

2.1 Introduction

Seeking the most appropriate tools to inform the *agriculture for biodiversity model* described in Section 1.4, the author researched tools and indicators for measuring human outcomes, disturbances (farm management), biotic structure, ecosystem functions and ecosystem services.

- First, a gap analysis of tools and their agrobiodiversity measurements was performed, data and implementation processes, to understand what measurements are lacking for assessing an *agriculture for biodiversity framework*.
- Second, individual indicators were collected and analysed, to assess ways to close the identified gaps.
- Finally, additional data was collected to ensure proper coverage of the three-dimensional biotic structure (Figure 3).

It is important to highlight that this report only focuses on the biodiversity dimension of sustainability, the biotic structure, as the major gaps in knowledge relate to this dimension. Work on social and economic indicators and linkages with the environmental dimension will be completed at a later stage.

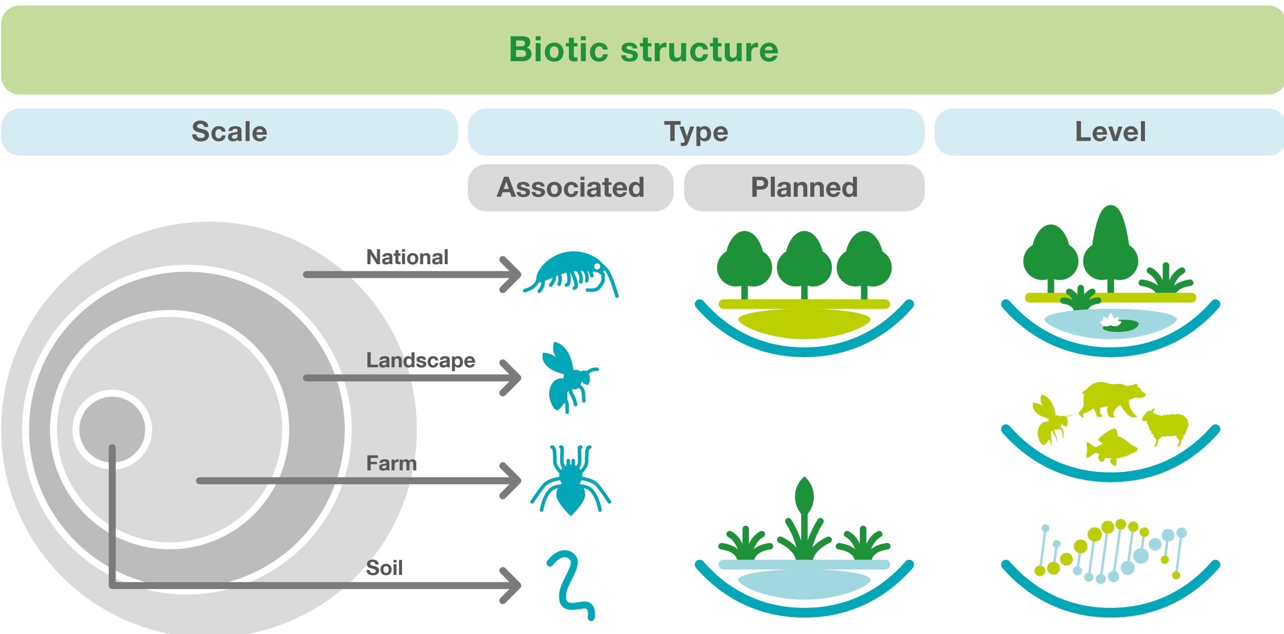

Figure 3 Three dimensions of the biotic structure: scale, type and level.
Source: Dussán P. Own production

2.2 Measuring (indirectly) agriculture and biodiversity: analysis of available tools

IUCN conducted two exploratory research analyses during the second and third trimesters of 2021, to identify the available tools and indicators for measuring biodiversity and to identify which parts of the boxes of the *agriculture for biodiversity framework* (Section 1.4) were already effectively monitored and where there were gaps in information.

Agrobiodiversity tools

The exploratory research on existing tools focused on how these tools measure *agrobiodiversity*. The research identified 14 tools with the "agrobiodiversity index" keyword in digital collections (Annex I). Next, the tools' objectives and methodologies were analysed, to understand how they conceptualize agrobiodiversity. Finally, barriers identified during the formulation and implementation of the tools were investigated through semi-structured interviews.

Agrobiodiversity indicators

The exploratory research on agrobiodiversity collected 114 indicators (Annex II) through the 'snowball technique', which involved identifying digital collections of indicators (33 were found) and tracing their sources and networks to find new indicators. This technique is exhausted when each new indicator's added value is near zero (because of redundancies).

2.3 Tools for assessing functional diversity

Figure 4 presents the set of 33 digital collections that measure the main variables in our framework, namely *disturbances* (farming practices), *farmlands* (biotic structure, ecosystem functions) and *ecosystem services*. We do not include measurements for the variables *drivers* and *social system*. The collections cover all variables, in some cases measuring both pressure (*disturbances/farmlands*) and state (*biotic structure/ecosystem services*), and in others assessing one variable as a proxy for others (i.e., farming practices or farmland vegetative biomass as a proxy of biotic structure and ecosystem services).

As the objective of this study is to understand how biodiversity is measured in agricultural landscapes, we focused exclusively on the biodiversity structure, and therefore extracted only the available digital collections describing that structure (Figure 5). The results were organized into a three-dimensional matrix, in which each box represents an intersection between the level, type and scale of the biotic structure.

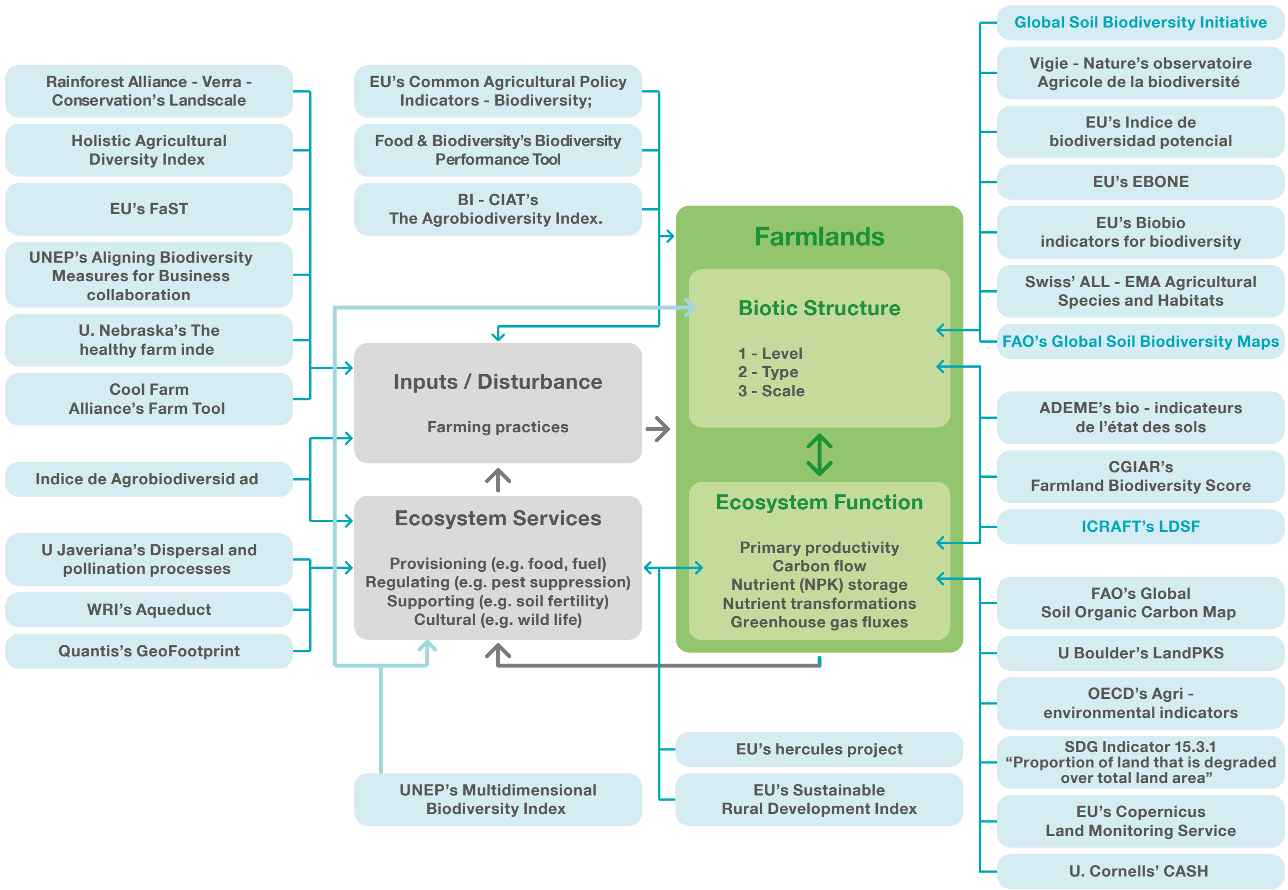

Figure 4. Digital collections that measure variables of the agriculture for biodiversity framework.

Source: Dussán P. Own production

At first glance, there appear to be enough tools and indicators to assess biodiversity in soil and farms at all three levels (genetic, species and ecosystem). However, when biodiversity is divided between planned and associated, it becomes apparent that, while there are sufficient tools for measuring associated biodiversity, tools to measure planned biodiversity at the three levels exist only at the farm level, and not at the soil or the landscape level. This gap is interesting, because, although interventions to create planned ecological infrastructures at the landscape level are well-known, the reviewed tools make no distinction from associated biodiversity. As for the soil level, this does not mean that farmers are not artificially improving their soil, but rather that the reviewed tools are not differentiating these actions.

By contrast, associated biodiversity at the species and ecosystem level is covered at the soil, farm, landscape and national level.

None of the reviewed tools cover genetic diversity at the landscape or national level, for either associated or planned biodiversity. This gap points to a need for new technologies that are not part of any reviewed tool, such as total eDNA. For example, IUCN's recently developed eBioAtlas project can determine total biodiversity in a landscape by collecting water samples from the rivers that comprise a river basin. A similar atlas could be developed for soil biodiversity in agricultural landscapes.

Table 1. Digital collections that measure the biotic structure.

Source: Dussán P. Own production

Planned / Assoc.	Genetic	Species	Ecosystems
Soil	Planned: – Assoc.: Vigie-Nature's OAB; Global Soil Biodiversity Initiative.	Planned: – Assoc.: Biobio; ADEME's bio- indicateurs; Vigie-Nature's OAB; Global Soil Biodiversity In.	Planned: – Assoc.: EBONE; FAO's Global Soil Biodiversity Maps
Farm	Planned: Biobio; CIAT's AI Assoc.: Biobio	Planned: Biobio; CIAT's AI Assoc.: Biobio; ALL-EMA; Vigie-Nature's OAB	Planned: Biobio; CIAT's AI; Biodiversity Performance Tool Assoc.: Biobio; ICRAFT's LDSF; ALL-EMA; CGIAR's FBS; Biodiversidad potencial
Landscape	Planned: – Assoc.: –	Planned: – Assoc.: ALL-EMA	Planned: – Assoc.: ALL-EMA; CGIAR's FBS; ICRAFT's LDSF; Biodiversity Performance Tool
National	Planned: – Assoc.: –	Planned: – Assoc.: ALL-EMA; CAP-Biodiversity	Planned: CAP-Biodiversity Assoc.: ALL-EMA; UNEP's MBI

2.4 Indicators for assessing functional diversity

Apart from this visual assessment of gaps, the author used this vast collection of digital resources to identify the combination of indicators that can provide the best information on agrobiodiversity with the lowest effort. A three-step approach was used to identify this combination:

1. Indicator collection and classification

The 114 identified agrobiodiversity indicators were classified into types and subtypes, based on the information they provide on the biodiversity structure of the *agriculture for biodiversity model* (Section 1.4).

From the review, it is clear that the tools prioritize indicators that measure phenomena that are observable with the naked eye. More than half of the indicators describe a biotic element, and a fifth describe farm practices, but only a small portion describe ecosystem services.

We also added a variable related to the difficulty of measurement, divided into two categories: 1) *field*, which includes self-assessments by farmers or field surveys by agronomists or biologists, and 2) *lab and remote sensing*, which includes assessments that require laboratory analysis, data analytics models that use satellite imagery and aerial photography, and statistical models used to predict species abundance and distribution.

The review showed that 80 percent of 'fauna' indicators and 74 percent of 'habitat' indicators are assessed in the *field,* while nearly 87 percent of 'ecosystem functions' and 'ecosystem services' are assessed through *lab and remote sensing.*

2. Indicator richness

Once collected, indicators were ranked by the number of parameters they could potentially inform; the more information the indicator provides, the higher the indicator richness. Indicator richness was assessed through a literature review in Google Scholar linking the phenomena measured by the indicator with ecosystem functions and services. The titles and abstracts were reviewed as supporting evidence.

As an example, we found scientific literature showing that the indicator 'abundance of earthworms' provides additional information on five different ecosystem functions. Earthworms 1) decompose organic matter (Knollenberg et al., 1985; Raw, 1962; Satchell, 1983; Schon et al., 2020), 2) increase nutrient availability (Hodge et al., 2000; Ruz Jerez et al., 1988; Sharpley et al., 1979; Simek & Pizl, 1989), 3) improve soil structure and soil hydrological processes (Joschko et al., 1989; Shipitalo & Protz, 1989; Stewart et al., 1988), 4) increase plant growth (Schon & Dominati, 2020) and 5) provide a food source for aboveground species (Scheu, 2001). As those functions are part of the provisioning, regulating and supporting ecosystem services (Blouin et al., 2013; Boyer & Wratten, 2010; Schon & Dominati, 2020), the five ecosystem functions plus the three ecosystem services give the indicator 'abundance of earthworms' a richness of 8.

3. Indicator selection

To optimize the results, indicators were divided into the following three main groups (Table 1):

- **Belowground diversity**: For example, using 'abundance of earthworms' to assess healthy soils.
- **Aboveground diversity**: Indicators related to aboveground species, such as vascular plants, bees, butterflies, spiders, birds and bats.
- **Habitat diversity**: Diversity, quality, number and composition of semi-natural habitats.

The *lab and remote sensing* group of indicators was not prioritized, because the resource and expertise required makes wide use difficult (compared to the field indicators).

Table 2. Final group of selected indicators. (Biodiversity richness by indicator, scale from 1 to 10.)
Source: Dussán P. Own production

Indicator	Richness	
Number of species of earthworms per farm (BioBio)	8	Belowground diversity
Participatory Earthworm Observatory (ARB idF)	8	
Earthworms protocol (Vigie Nature)	8	
Les Indices Vers de Terre (L'ADEME and EcoBioSoil).	8	
Species Diversity (ALL-EMA Switzerland)	6	Aboveground diversity
Species Quality (ALL-EMA Switzerland)	6	
Diversity and Quality of Species and Habitats in BPAs (ALL-EMA CH)	5	
Invertebrates protocol (Vigie Nature)	5	
Number of species of wild bees and bumblebees per farm (BioBio)	5	
Bees protocol (Vigie Nature)	5	
Number of species of spiders per farm (BioBio)	4	
Bats protocol (Vigie Nature)	4	
Butterflies protocol (Vigie Nature)	4	
Number of species of vascular plants per farm (BioBio)	4	
Habitat diversity indicators (BioBio)	4	Habitat diversity
Habitat Quality (ALL-EMA Switzerland)	4	
Habitat Diversity (ALL-EMA Switzerland)	4	
Potential Biodiversity Index (Biorgest)	4	
Landscape diversity (Biodiversity Performance Tool)	4	
Quality of Semi-Natural Habitat - Management (BPT)	4	
Ecosystem Restoration (Landscale)	4	
Quality of Semi-Natural Habitat - Composition (BPT)	4	
Natural Ecosystem Protection (Landscale)	4	
Natural ecosystem connectivity (Landscale)	4	

2.5 Three groups of complementary indicators: soil, species and habitats

In the sections above, we explained how we collected 114 agrobiodiversity indicators, which were ultimately classified into three main groups that provide complementary information about related phenomena: belowground, aboveground and habitat diversity.

Unfortunately, one of those three main groups cannot inform the other two because, even though there is a correlation between habitat heterogeneity/diversity and animal species diversity (Tews et al., 2004), there is no clear connection between belowground and aboveground diversity (Hooper et al., 2000). Despite the fact that there are some complementarities (e.g., habitats can measure potential aboveground biodiversity), the state of aboveground and belowground diversity demands direct assessments. Some insights into how scientists are addressing these three groups are described below.

Belowground diversity

There have been several studies of belowground diversity. The Global Soil Biodiversity Initiative compiled globally available assessments of soil biota. Scholars have amassed global distribution data on bacteria, plants, fungi, mycorrhizae, nematodes, earthworms, isopods and insects using several thousand samples and lab analyses. Furthermore, an exciting international collaborative scheme directly measures ecosystem services globally through the Global Soil Organic Carbon Map. Nonetheless, except for indicators of earthworms, these indicators are difficult to replicate, because of the required expertise and lab analysis. Earthworms are an easily observed indicator and can measure various vital ecosystem functions for agroecosystems, as discussed in Section 2.4.

Aboveground diversity

Almost all indicators related to direct aboveground biodiversity require field assessment, which means there is a direct trade-off between the level of collection effort and the richness of the information. Fortunately, there is an enormous range of knowledge, experience and collection protocols. Furthermore, widespread academic collaboration (particularly in Europe) has resulted in a robust set of aboveground diversity indicators, indicators that have survived various elimination steps from literature reviews, expert and stakeholder focus groups, and finally, field testing.

Two criteria are key for selecting species indicators (Herzog et al., 2012, p. 52):

1. Indicators that represent diversity at the farm and landscape level; and
2. Indicators that represent the trophic levels of organisms.

Based on the analysis of available information, it would be valuable to further explore the following species indicators:

- **Vascular plants**: Plant diversity has a positive domino effect on biological pest control at the field scale, with spill over effects at the landscape scale (Gurr et al., 2003).

- **Wild bees**: Bee diversity (Bees' global distribution) is associated with provisioning ecosystem services (Matias et al., 2017), especially effective pollination (Garibaldi et al., 2013; Rader et al., 2016; Roubik, 1995) and influence on improving yields (Garibaldi et al., 2014; Klein et al., 2003).

- **Spiders**: Spiders (Global data set on arachnids) are particularly relevant, as they are essential invertebrate predators (De Young & Wilgers, 2016).

- **Butterflies**: Butterflies (European grassland butterflies indicator), in addition to providing food for other organisms, carry pollen to be shared across plants that are far apart, contributing to genetic variation in plants species and increasing their chance of survival against different diseases (Ghazanfar et al., 2016).

- **Birds**: Birds (Wild Bird Index) play many roles, including predators, pollinators, scavengers, seed dispersers, seed predators and ecosystem engineers (Pejchar et al., 2018; Philpott et al., 2009; Sekercioglu et al., 2016; Whelan et al., 2008).

- **Bats**: Bats play an essential role in arthropod suppression, seed dispersal and pollination (Kunz et al., 2011), enhancing quality and yield in crops (Tremlett et al., 2020).

Habitat diversity

If the effort/information trade-off is the main challenge of species diversity indicators, definition is the main challenge of habitat diversity indicators, because the definition depends on the assessment technique. In our research, we found that the most comprehensive definition is found in the General Habitat Categories developed by the European Biodiversity Observation Network (EBONE project).

There is an overarching consensus that habitat diversity affects species diversity. Plants, spiders, earthworms and bees were positively correlated with the number of habitats per farm (Herzog et al., 2012) and crop diversity is positively associated with the species richness of arthropods such as bees, carabids and bugs (Billeter et al., 2008). Other studies showed that mosaic-like landscapes are particularly important (Villemey et al., 2015), with smaller fields and more field edges (Fahrig et al., 2015). This is because of the limited mobility of species (Boller et al., 2004) between feeding spots (inside cultivated areas) and shelter areas (in semi-natural habitats). Most species do not range more than 30 meters, and the maximum is 150 meters between feeding spots and shelter areas (Solagro, 2002).

It is possible to evaluate the potential agrobiodiversity of any farm by measuring habitats through aerial photos and manual designs, followed by the use of sophisticated sampling models that select the minimum statistical samples (unit of farmlands) to collect direct data on the functional diversity that can reveal the state of agrobiodiversity at the selected level. The state of agrobiodiversity and land health can only be validated through field assessment.

A global framework to assess functional and habitat diversity in agroecosystems (*Land health monitoring framework*) would need to combine both approaches in a model that analyses the state of agrobiodiversity, minimizing the number of sampling sites. It is conceivable that remote sensing technologies and robust algorithms can evaluate habitats per unit of farmlands. Current detection methods are promising, but more work is needed (Hazeu et al., 2014). Indeed, remote sensing technologies exist to potentially measure habitats (Demattê, 2017), particularly in Europe (Copernicus Programme, 2022), but sophisticated data analyses are missing.

2.6 Conclusion

Understanding of what agrobiodiversity is varies significantly across existing tools. This range of understanding has produced gaps regarding the *agriculture for biodiversity framework*, primarily because of the lack of inclusion of landscape and national scales in agrobiodiversity monitoring and the lack of representation of the ecosystem component of agrobiodiversity.

As each tool addresses different aspects of biodiversity, there is no single, comprehensive tool. For example, several tools define agrobiodiversity as a proxy of biodiversity-friendly farming practices (*Healthy farm index, Cool Farm Tool, FaST Platform* and *SALCA*), corporate actions (*geoFootprint*) or even public policies (IRENA). Others focus on human outcomes, such as nutritional, material and spiritual needs (*Indice de agrobiodiversidad*), socio-economic factors underlying biodiversity-friendly practices (*Sustainable Rural Development Index*), the impacts of crop and genetic diversity – and thus food diversity – on human health (*Agrobiodiversity Index*), and farmer food security (Holistic Agricultural Diversity Index). Some tools relate to the biodiversity around the farm, but not directly associated with agriculture (*Multidimensional Biodiversity Index*), while others look at biodiversity directly associated with the farm (*Biobio*) or exclusively in the soil (*SIREN*). Others define agrobiodiversity from the ecosystem services (*agroecosystemic resilience index*). Therefore, although the Convention on Biological Diversity provides an internationally agreed-upon definition of agrobiodiversity, the 14 reviewed tools show a significant range of understanding and operationalization of agrobiodiversity on the ground.

The reviewed tools rely on data from international organizations such as the FAO or the European Commission. However, data is limited to what countries report. Not only does the quality of data collected in each country differ, but also each country collects different data on agrobiodiversity, posing obstacles to data comparability. Furthermore, national data is not always disaggregated to regional levels, constraining more detailed analyses (Jones et al., 2021). Still, it is suggested that the many already existing data sets could be used more efficiently through sophisticated analysis/assessment tools, although these data solutions are mainly suitable for indirect agrobiodiversity indicators.

Our exploratory research did not find easily observable species to monitor ecosystem functions according to the type of ecosystems. Even though our research was based on a heuristic technique, it is improbable that we missed such a tool. More plausible is that the field of research on agrobiodiversity indicators is growing in some ecosystems (e.g., Europe) and just beginning at a global level. Another explanation can be that the growing literature on soil biodiversity is relatively recent (Guerra et al., 2020), and despite recent efforts, still, there are significant global gaps in soil biodiversity data (Cameron et al., 2018).

Species are unevenly distributed around the world. For example, the global distribution of earthworms (Phillips et al., 2019) shows that their abundance is a robust indicator of land health in several ecosystems, but is useless in the drylands of the Sahel or Mexico. Other species, such as ants and termites, play the role of earthworms in decomposing organic matter or maintaining soil structure in these agroecosystems (Evans et al., 2011). It is important to note that our snowball technique for collecting indicators has a European bias, and the individual indicators (e.g., earthworms) we referred to cannot be used globally for assessing agrobiodiversity. However, we conjecture that by standardizing the three groups of indicators (belowground, aboveground and habitat diversity) into functional diversity lists, we can measure agroecosystems around the globe.

Thus, after reviewing the results, it is recommended to focus on ecosystem functions. These are assessed through the list of functional diversity indicators by types of ecosystem, using the Breure hypothesis, which states that 'the threat to vital (ecosystem functions) can be expressed by comparing the number of species in functional groups in a certain area with its reference (undisturbed locations)' (Breure, 2004).

3. Land health monitoring framework and tool

3.1 Introduction

Creating a tool requires making choices not just about the definition of agrobiodiversity but also the type of data that the indicators rely on. Considerations in choosing indicators include the directness of indicators, data time lags, data availability and global applicability. These considerations are interrelated, as they all point to the same trade-offs between reach, ease of application, ease of data collection, data availability and resource efficiency on the one hand, and accuracy, local representability and quality on the other. Time lags between the data collection and assessment, or initial data collection and updates, pose further significant constraints. Often, the data that the tools rely on are static, and, although fields change over the seasons, farmers' adaptations cannot be considered.

Indirect indicators can be cost-effective (compared to direct indicators), but their accuracy varies greatly. Indirect indicators of on-farm practices, for instance, mainly rely on information from farmers, which is often difficult to obtain, and their accuracy cannot be assured. There is great value in measuring biodiversity through direct indicators of biotic structure that support ecosystem processes and functions (e.g., assessing relevant organisms like earthworms or termites). However, the most common direct indicators – species indicators – are labour intensive and costly to assess. Some of the potential sources for data on agrobiodiversity include direct collection in collaboration with farmers, government reporting or specialized start-ups. Collecting agrobiodiversity data from the start is an enormous effort, but relying on existing datasets also poses constraints on data quality. Farmers are often uncomfortable about collecting and sharing large amounts of data, which requires time and effort. Furthermore, they often lack such information themselves.

Combining direct (e.g., diversity and abundance of species within a certain area of land) and indirect (e.g., land cover) indicators of biodiversity provides advantages, most importantly by facilitating connections between management practices or policies and their relationship with biodiversity. The accuracy and scope of the indicators have to be balanced by considerations of the availability of data that the indicators rely on. The main trade-offs are between data coverage (related to collection efforts and accessibility of data across localities) and data quality (scope, accuracy and representation of agrobiodiversity).

3.2 Functional agrobiodiversity: a proposal to go beyond local specificities

The concept of functional diversity can support species selection. Moreover, 'species are not all equal with respect to function; in general, ecosystems contain keystone species whose role is best defined as those species whose removal causes a significant change in function' (Jones & Bradford, 2001). Bàrberi (2013) explores the concept of functional agrobiodiversity, including both planned (i.e., voluntarily introduced by the farmer) and associated biodiversity at the three levels (genetic variation of cultivars/livestock and wild plants/insects; species variation in crops/insects released for biocontrol and wild plants/insects; diversity of artificial and natural ecosystems).

A functional agrobiodiversity list evaluates ecosystem functions through the keystone (belowground and aboveground) species that support these functions. We conjecture that, by prioritizing some ecosystem functions, we can identify keystone species. Then, the smallest set of easy-to-assess and best-informing keystone species indicators can be developed, using species representative of the scale of spatial distribution, range of activity and trophic level (Herzog et al., 2012).

Without neglecting the insurance effects – the 'long-term effects of biodiversity that contribute to maintain or enhance ecosystem functioning in the face of environmental fluctuations' (Yachi & Loreau, 1999) – we believe that keystone species can reveal how well an agroecosystem functions. Therefore, although species differ across agroecosystems, keystone species can be compared in terms of the processes they sustain, such as decomposition of organic matter, maintenance of soil structure and regulation of soil hydrological processes, nutrient cycling, plant growth control, seed dispersion, pollination, predation, and pest and disease control.

The *IUCN Global Ecosystem Typology* (Keith et al., 2020) can help define the scale that keystone species can inform. This typology starts with five realms, representing all parts of the biosphere, and includes 25 biomes, 108 Ecosystem Functional Groups (EFGs), and three additional lower levels.

We identified the 12 main EFGs that support, in various degrees, agricultural activities (Annex III); we call these the Agroecosystem Functional Groups (AFGs). The next challenge was to identify a group of keystone species that provide salient ecosystem functions in one or several of these AFGs. The higher the number of AFGs a species can inform, the better the keystone species is as an indicator.

For example, we defined one AFG as *Annual Croplands* and chose one salient ecosystem function, *decomposition of organic matter*. Then, we combined the global map of the AFG *Annual Croplands* with the global abundance of both earthworms (Phillip, 2019) and nematodes (Van Den Hoogen et al., 2019). In Figure 6, blue circles represent the annual croplands in which abundance of earthworms is close to the highest (150 individuals per m^2) and the green circles where abundance of nematodes is more than the medium level (1.615 nematodes per 100 g of dry soil). Hence, using the abundance of both earthworms and nematodes and, as a reference, a standardized target (e.g., one standard deviation above/below the regional average), we can assess one crucial ecosystem function for agriculture: decomposition of organic matter in all circles.

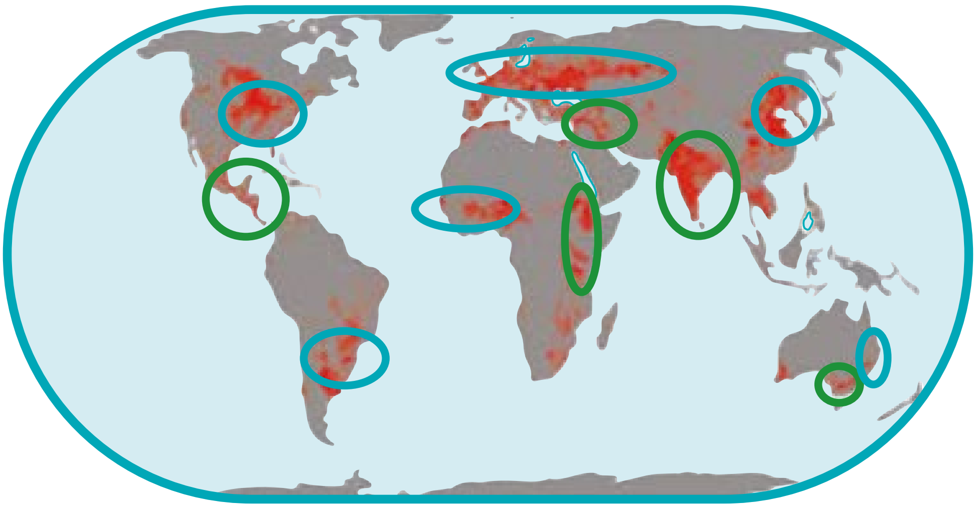

Figure 5 Measuring decomposition of organic matter through earthworm abundance (blue circles) and nematode abundance (green circles) in annual croplands.

Source: Keith et al. 2020. Blue circles adapted from Phillips H. et al., 2019; green circles adapted from Van den Hoogen et al. l, 2019.

Once the functional diversity list by study area is developed, three critical challenges have to be solved to enable a worldwide census of habitats per unit of farmland:

1. Overcoming the technological challenges of assessing habitats per unit of farmland;
2. Using this information to feed the sampling models and set up the agrobiodiversity monitoring program: sampling frequency, spatial setup, selection of the monitoring sites, sampling techniques and statistical techniques to interpret the monitoring data (Breure, 2004); and
3. Coordinating all monitoring partners.

3.3 The framework

As a first step, and based on the results of this analysis and conclusions of the research, IUCN has developed a *land health monitoring framework* (Figure 7) to measure biodiversity at four levels: soil, farm, landscape and national/global. Each level includes a set of indicators to assess biodiversity and the biotic structure, based on available or new direct data collection. The IUCN *land heatlh monitoring framework* explicitly emphasizes the environmental pillar of sustainability and does not currently provide guidance on social and economic dimensions, to first ensure a complete accounting of the impact on biodiversity where most gaps have been found. This framework can then be used to better understand how to integrate environmental monitoring with social and economic criteria.

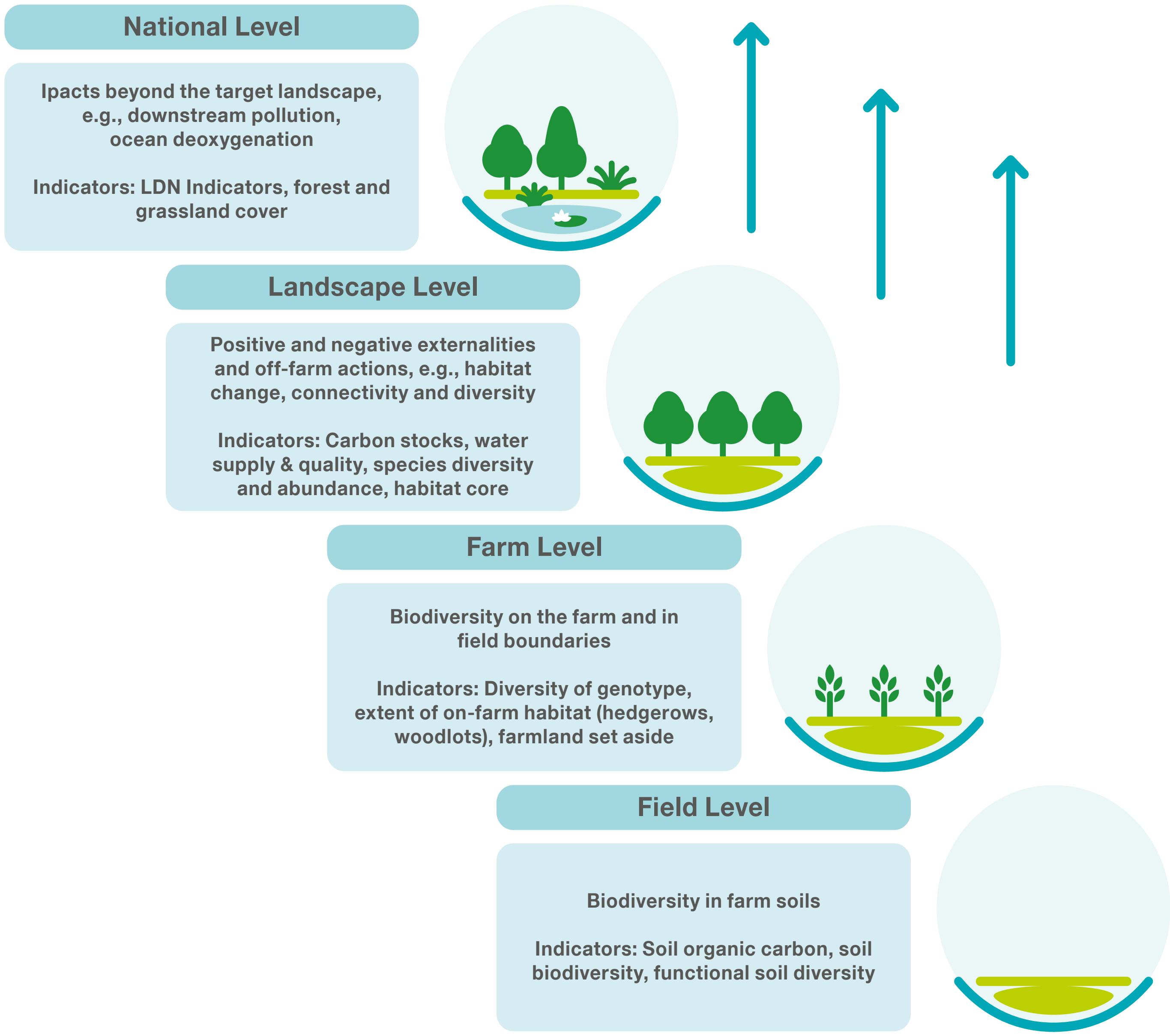

Figure 6. IUCN land health monitoring framework.
Source: Dussán P. Own production

3.4 Towards a tool

After reviewing all the available information and defining the *land health monitoring framework*, the next step is to create a tool for measuring the biotic structure, to provide the data in a standardized manner.

As discussed above, the tool must include three dimensions (genetic, species and ecosystems) and four levels (soil, farm, landscape and national). This could be achieved using a combination of existing tools (eDNA and Cool Farm Tool) and new tools developed by IUCN (functional diversity lists by agroecosystem and computer vision model). More detail on the dimensions and levels and which tools might be applicable is presented below.

Dimensions

Genetic: The total eDNA recently developed by IUCN's eBioAtlas project could be replicated for agricultural landscape biodiversity using soil samples, crop/livestock diversity and the Cool Farm Tool (variety/breed diversity).

Species: Depending on the dimension of measurement, it is recommended to use eDNA (for soil species) or the Cool Farm Tool (for certain types of biodiversity and biomes). For all four levels, new measurements are also needed. With the development of **functional agrobiodiversity lists,** a set of belowground and aboveground species indicators, species could be represented at the scale of spatial distribution, range of activity and trophic level in selected agroecosystems. *Agroecosystems*, *ecosystem function,* and the *keystone species* need to be defined in an iterative process, combining experts and workshops with key stakeholders with field testing pilots.

Ecosystems: To improve the knowledge on **habitat diversity and composition**, IUCN could create a tool that combines direct data collection with remote sensing to assess habitat diversity and species diversity. The final development of a **computer vision model** will represent the results visually.

Levels

The field, farm and landscape levels have already been described above, and the tools to be used are similar to those noted under dimensions, above (eDNA, Cool Farm Tool, etc). To measure the **biotic structure** at the final level, **national/international,** the functional agrobiodiversity lists will be used in combination with the computer vision model (the model informing sampling sites) and linking it to the related policies at the national and international level.

Creating this tool to measure biotic structure will require the development of two main inputs:

1. Functional agrobiodiversity lists by agroecosystems; and
2. Data analytics.

The *IUCN guidelines for planning and monitoring corporate biodiversity performance* (Stephenson & Carbone, 2021) differentiate between global and local biodiversity indicators. For global indicators, the guidelines focus on the abundance and diversity of soil invertebrates, bees, fish and freshwater insects, and for local indicators, threatened birds, butterflies and native tree species. It is important for local indicators to focus primarily on keystone species, while threatened species diversity and abundance could measure quality.

Table 3. Tools to measure the biotic structure
Source: Dussán P. Own production

Planned / Assoc.	Genetic	Species	Ecosystems
Soil	Planned: eDNA Assoc.: Func. Diversity List	Planned: eDNA Assoc.: Func. Diversity List	
Farm	Planned: Cool Farm Tool Assoc.: Func. Diversity List	Planned: Cool Farm Tool Assoc.: Func. Diversity List	Planned: Cool Farm Tool Assoc.: Cool Farm Tool
Landscape	Planned: eDNA Assoc.: eDNA	Planned: Cool Farm Tool Assoc.: Func. Diversity List	Planned: Comp. vision model Assoc.: Comp. vision model
National	Planned: eDNA Assoc.: eDNA	Planned: Cool Farm Tool Assoc.: Func. Diversity List	Planned: Comp. vision model Assoc.: Comp. vision model

Using the same example as in Section 3.2, the Agroecosystem Functional Group (AFG) (Annex III) of *Annual Croplands in Europe,* we propose the following functional agrobiodiversity list:

- Belowground
  - *Ecosystem functions*: Decomposition of organic matter, maintenance of soil structure and regulation of soil hydrological processes, nutrient cycling and plant growth control;
  - *Keystone species*: Earthworms.
- Aboveground:
  - *Ecosystem functions*: Seed dispersion, pollination, predation, pest and disease control.
  - *Keystone species*: Vascular plants, bees, spiders, butterflies, birds and bats.

3.5 The need of a guidance note on monitoring land health

Based on all the information previously described, there is a need of a guidance note to provide a step-by step process for monitoring land health in geographical areas where agriculture is the dominant land use. Therefore, to test the feasibility of the implementation of the framework, the author suggest the following steps:

1. Define clearly the objective for monitoring
Assess the baseline of the state of the ecosystem/landscape of interest and the impact on services delivered to farm production and society, identifying the threats and the drivers and the ecosystem dependencies.

This step would need to clearly define:

- The area concerned (and specific levels for monitoring).
- The production/value chains and other land uses if landscape level is included.
- The needs for the monitoring and the ecosystem functions that need to be preserved (this would be the priority issues that are faced in the landscape e.g. soil fertility, water quality, etc.) to guide the selection of indicators.

2. Document existing information
After defining the area and the objectives for monitoring, the next step would be to document the information and data that is already available at different levels. This will help to better define the indicators that will be needed through a gap analysis (indicators/monitoring tools proposed, existing and gaps found at field, farm, landscape and national level)

3. Select the ecosystems typology
Step three will define the targeted agroecosystem. This step is needed to identify links between ecosystem types and natural resources or biodiversity that may facilitate the choice of indicators in the future steps.

3.1. Define the ecosystem that aligns the most to the selected area.

3.2. Define the main characteristics of the area linked to the ecosystem typology to which it belongs (type of habitats, possible threats, main practices, biodiversity, etc.)

3.3. Define how the selected area is in terms of conservation status, the desired level to reach and the changes that need to be made.

4. Select the priority ecosystem functions, services and key species of the targeted area

This step is divided in two parts. The first one aims to explain how to find the main functions, services and species at each of the 4 levels of the land health framework. Afterwards a series of meetings with experts and relevant stakeholders will be performed to obtain the final list of functions, services and species that should be monitored.

4.1 Review the functions and species at each scale:

Under step 4, the four levels (national, landscape, farm and soil) will be targeted.

4.2 Agree on functions, services and key species to be monitored. Selection of indicators

Based on results of step 3, and the step 4.1, a list of the main functions and services that need to be targeted will be obtained.

In 4.2, that list of preselected functions and services should be presented to a group of experts including the review of the available information collected in steps 1, 2 and 3.

5. Develop a monitoring protocol with indicators at different levels
This protocol will be based on the results of all the previous steps and will measure the biotic structure within 3 (landscape, farm and field) of the 4 scales of the framework.

6. Monitor selected species, natural resources and functions
After developing the monitoring framework, the step number 6 would be to proceed with the monitoring.

7. Incorporate the information in a common table
The aim of this final step is to share the results of all the sites in a similar way to scale up results.

3.6 Conclusion

This approach, that builds on existing tools, can support the development of locally relevant monitoring systems to measure functional and landscape diversity and estimate land health.

A next step would be developing sampling techniques for collecting data on the keystone species by AFG, for comparison purposes and to be able to consolidate a list of relevant functional and landscape diversity indicators specific to each ecosystem.

4. Conclusion and next steps

A biodiversity assessment tool is needed to encourage policymakers and stakeholders to assess the agrobiodiversity impact of public policy and private initiatives, especially in prioritized areas. However, there is no existing tool that measures the entire framework of agrobiodiversity, nor its three-dimensional biotic structure. While available tools exist to assess the individual components of the agriculture for biodiversity framework, there are gaps when it comes to defining the biotic structure by type, level and scale.

The author proposed three groups of indicators: belowground, aboveground and habitat diversity, which, taken together, are representative of the field (soil), farm and landscape levels, as well as the three levels of agrobiodiversity: genetic, species and ecosystem.

This report provides a general overview of the available tools and indicators to measure all the components of the agriculture for biodiversity model, highlighting the gaps that must be filled to achieve a comprehensive tool. This report also proposes a first draft approach to identify relevant land health indicators and a monitoring protocol. This approach remains to be developed into a detailed guidance that should be tested on the ground.

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Annexes

Annex I. Agrobiodiversity tools

The following are the 14 agrobiodiversity tools that were analysed in this research.

- Agrobiodiversity Index
- Holistic Agricultural Diversity Index
- Multidimensional Biodiversity Index (MBI)
- SIREN-Project
- Cool Farm Tool
- Agroecosystemic Resilience Index
- Farm Sustainability Tool (FaST Platform)
- geoFootprint
- Sustainable Rural Development Index
- BIOBIO (Indicators for biodiversity in organic and low-input farming systems)
- Healthy Farm Index
- Indice de Agrobiodiversidad
- Swiss Agricultural Life Cycle Assessment (SALCA) - subcategory Biodiversity
- Indicator Reporting on the Integration of Environmental concerns in Agricultural (IRENA)

Annex II. Agrobiodiversity indicators

The 'snowball technique' used to find indicators allowed the identification of 36 sources of 48 agrobiodiversity tools. These collections (each with its hyperlink) are arranged by a rough classification of institutional origin.

- **International organizations**
  - IUCN tools: Species threat abatement and restoration (STAR) metric; Global Standard for Nature-based-Solutions; Red List of Ecosystems; Global Ecosystem Typology; Guidelines for planning and monitoring corporate biodiversity performance
  - UNCCD: Good Practice Guidance for SDG Indicator 15.3.1 "Proportion of land that is degraded over total land area"
  - FAO: Global Soil Organic Carbon Map; Visual soil assessment (VSA)
  - UNEP: Multidimensional Biodiversity Index; The Aligning Biodiversity Measures for Business
  - OECD: Agri-environmental indicators

- **Public institutes**
  - Joint Research Centre of the European Commission: Global Soil Biodiversity Maps
  - Directorate-General for Agriculture and Rural Development (European Commission): Common Agricultural Policy Indicators – Biodiversity; FaST
  - European Environment Agency (European Commission): Pan-European High-Resolution Layers, the Copernicus Land Monitoring Service.
  - Norwegian Institute of Bioeconomy Research: Norway The Norwegian Agricultural Environmental Monitoring Programme (JOVA)
  - Agrobioscope (Switzerland): ALL-EMA Agricultural Species and Habitats
  - L'Agence de la transition écologique (France): Les bio-indicateurs de l'état des sols
  - CEEweb (NGOs network in Central and Eastern Europe): Sustainable Rural Development Index (EU funded project)

- **Research platforms**
  - EBONE project (18 research institutions in 16 mainly European countries): Selection of biodiversity indicators
  - Biobio project (15 research institutions in 14 mainly European countries): Biobio indicators for Biodiversity (EU-funded project).
  - Life Biorgest (six research institutions from Spain and France): Indice de biodiversidad potencial (EU-funded project).
  - Hercules project (13 research institutions from 11 European countries): Indicator database (EU-funded project).
  - Food & biodiversity (seven research institutions from four European countries): Biodiversity Performance Tool (EU-funded project).

- **Research institutions**
  - Cornell University: Comprehensive Assessment of Soil Health
  - World Resources Institute: Aqueduct; NDC Partnership
  - University of Colorado Boulder: LandPKS
  - Universidad Nacional de Colombia: Agroecosystemic Resilience Index (AgRI)

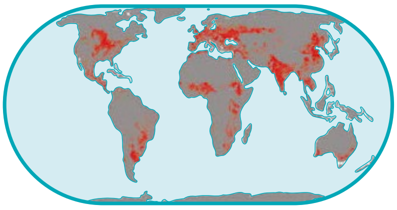
- **Multi-stakeholder initiatives**
  - Bioversity International and CIAT: The Agrobiodiversity Index.
  - CGIAR, WAC: Farmland Biodiversity Score
  - A global coalition led by Rainforest alliance, Verra and Conservation International: Landscale
  - A global alliance of 100+ actors: Cool Farm Alliance
  - A partnership of 25 actors led by Quantis: GeoFootprint
  - The Climate, Community & Biodiversity Alliance (a five NGOs partnership): Sustainable Landscapes Rating Tool

- **Participative-science platforms**
  - Vigie-Nature : Observatoire Agricole de la biodiversité
  - Ecobiosoil : L'Observatoire Participatif des Vers de Terre

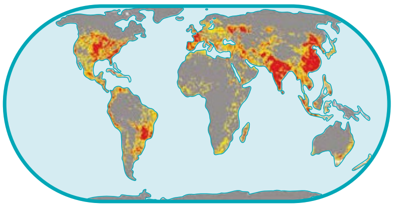
- **Academic collaboration**
  - 56 affiliated institutions: Soil nematode abundance at a global scale
  - 134 affiliated institutions: Global distribution of earthworm diversity
  - Nine affiliated institutions: A global atlas of the dominant bacteria found in soil
  - Ten affiliated institutions: Global fungal distribution.
  - Three affiliated institutions: The healthy farm index
  - Two affiliated institutions: Indice de Agrobiodiversidad
  - Three affiliated institutions: Holistic Agricultural Diversity Index

Annex III. Agroecosystem functional groups

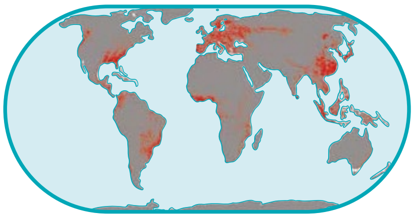
Worldwide



T7.1 Annual croplands

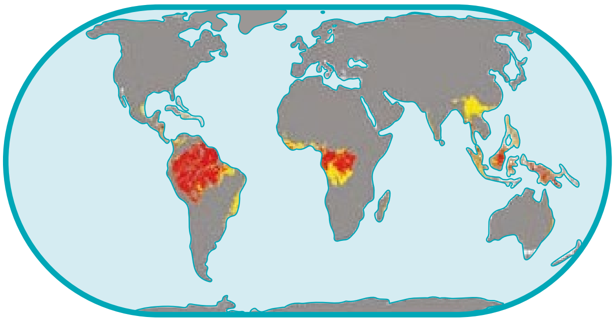


T7.2 Sown pastures and fields

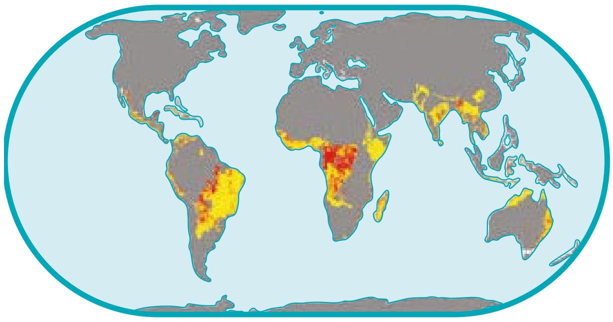


T7.3 Plantations

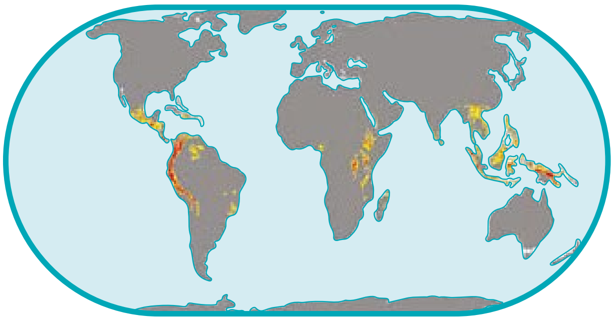
Tropics



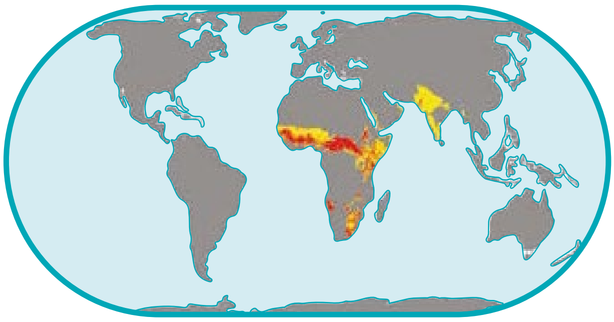
T1.1 Tropical subtropical lowland



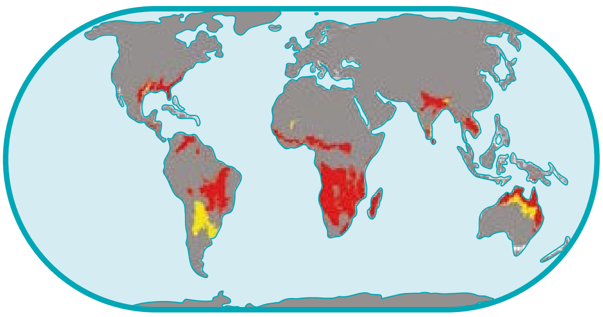
T1.2 Tropical subtropical dry forests



T1.3 Tropical-subtropical montane

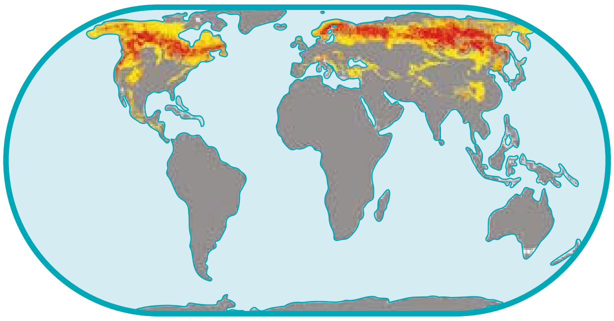


T4.1 Tropical Savannah

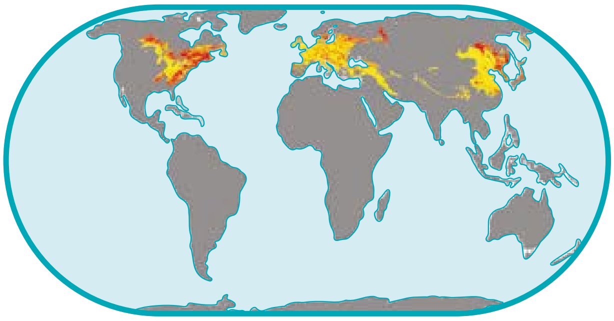


T4.2 Pyric tussock savannas

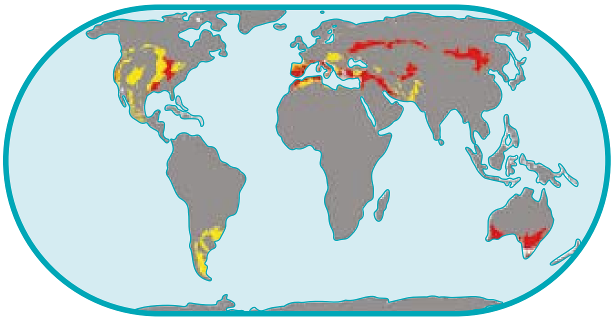
Temperate



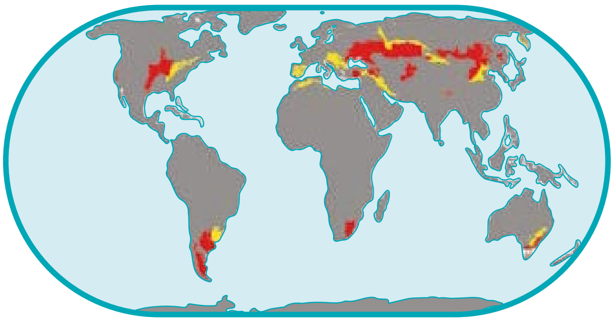
T2.1 Boreal and temperate montane



T2.2 Deciduous temperate forests



T4.4 Temperate woodlands



T4.5 Temperate subhumid grasslands

Figure 8. The 12 main Ecosystem Functional Groups that support, in various degrees, agricultural activities.
Source of all maps: Keith et al., 2020,

Annexes

Annex IV. List and description of the agrobiodiversity tools

Year	Name	Who developed it?	Entity category	Objective	Scale (field/ soil, farm, landscape, national)	Scope of biodiversity levels (genetic, species, ecosystem)		Directness of indicators (direct, indirect, both)	Regional applicability	Methodology	Data requirement and source	Implementation	External link
2021	Agrobiodiversity Index	Bioversity International	NGO	to help policymakers, non-governmental organizations, civil society leaders and businesses to understand relationships between dimensions of agrobiodiversity across the food system, compare agrobiodiversity use and conservation across countries, and identify priority interventions to enhance agrobiodiversity for more sustainable food systems"	food systems approach, can be applied on country, company or project level				Worldwide - comparison of 80 countries	a food systems approach to collating agrobiodiversity data. 22 indicators (+ associated sub-indicators to assess the status of, and actions or commitments to enhance, agrobiodiversity's contribution to sustainability outcomes across 3 pillars of the food system: consumption and markets, contributing to healthy diets (pillar 1); production systems, contributing to agricultural sustainability (pillar 2); and genetic resource conservation, contributing to safeguarding future use options (pillar 3)	Source: "globally available public data sets"	Not yet	https://www.nature.com/articles/s43016-021-00344-3.pdf
2021	Holistic Agricultural Diversity Index	Fatch et al.	Researchers - Scholars	The objective of this study was to measure the extent to which farmers in Lilongwe district in Malawi practiced agricultural diversifi-cation in their farming system. The research question was: how is the smallholder farmers' farming system integrating crop, fruit tree, live-stock and poultry production, in Lilongwe district of Malawi?	Farm level				landscape,	This approach helps to deal with the limitation of the conventional diversity indices. The choice of components of the index was informed by the general definition of agricultural diversity which entails diversity of different types (species) of crops and cate-gories of livestock. Crop rotation and intercropping were included because they promote crop diversification existing diversity ndices which fail to combine data on species which fall under different kingdoms of organisms such as plants and animals. A holistic index was used as it combines information on crops, trees, livestock, poultry and diversification related cropping patterns unlike		Only implemented in a specific district as part of a research program	https://reader.elsevier.com/reader/sd/pii/S0308521X20308520?token=F3A6C0844BC388404DC6DC1544519985D2002872A72190BA8B174F078DB6373F4CA2BD8A2C2B97614F7F1D0DC7193273&originRegion=eu-west-1&originCreation=20211012155551
2021	Mulitdimensional Biodiversity Index (MBI)	UNEP (World Conservation Monitoring Centre) x Luc Hoffmann Institute (part of WWF	Public Sector / NGO	"develop a policy-focused index for biodiversity health as a tool for decision makers to monitor if we are living within the regenerative capacity of nature, or whether we are piling up ecological debt for future generations"		Agrobiodiversity = part of 6 public health objectives (1 of these objectives is food provision, agrobiodiversity is a subobjective of food provision) However, MBI report very silent on biodiversity in agriculture - whereas places itself as index at interface of 'nature' and 'society'			Global (3 pilot countries: Mexico, Switzerland, Vietnam)	The framework we outline here considers multiple indicators structured in four analytical and aggregation levels: 1) two sub-indices (Biodiversity State sub-index (BI), and Biodiversity Contributions to People sub-index (BCPI)) representing the two perspectives described above on biodiversity health [ecological + social]; 2) a set of relevant dimensions under each of these two components representing fundamental facets of biodiversity and categories of contributions to people, 3) a set of public biodiversity health objectives, and sub objectives where relevant, under each dimension, and 4) policy-relevant metrics, indicators or proxies under each objective measuring performance as distance to a desired state or reference point.		not yet (unless in pilot countries)	https://www.unep-wcmc.org/system/comfy/cms/files/files/000/001/808/original/MBI_REPORT_Soto-Navarro_et_al_2020_Building_a_Multidimensional_Biodiversity_Index.pdf
2021	SIREN-Project	European Joint Programme on Soil	Public sector/ partnership between European public research organisations	To make an inventory of indicator systems for assessing soil quality and ecosystem services, as currently used by Member States associated in the EJP SOIL and beyond	soil	genetic			EU	- make an inventory of indicator systems for assessing soil quality and ecosystem services, as currently used by Member States associated in the EJP SOIL and beyond. - identify and review the national frameworks and chains from soil properties via soil functions to soil ecosystem services and the indicators of soil quality state and functions plus their reference values across pedo-climatic conditions for the main agricultural production systems in the EU. - identify if these have been translated into policy options and implementation, and into directions and guidance on land management. - stocktake the array of reference values for SOC, soil quality, soil biodiversity and degradation risk, the associated target values of indicators, and identify knowledge gaps and development needs.	not fully developed yet - end of the project Feb 2022	no	https://ejpsoil.eu/research-projects/siren/

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Year	Name	Who developed it?	Entity category	Objective	Scale (field/ soil, farm, landscape, national)	Scope of biodiversity levels (genetic, species, ecosystem)		Directness of indicators (direct, indirect, both)	Regional applicability	Methodology	Data requirement and source	Implementation	External link
2020	Cool Farm Tool	Cool Farm Alliance	NGO	to quantify how well farm management supports biodiversity. (Benefits: Communicate the positive impacts of supporting biodiversity, seeing which species groups are benefiting, credit where credit is due, employing a wide range of management practices, quantifying baseline impacts, expanding to other agricultural biomes)	farm	species, ecosystem		indirect	Temperate Forest biome (e.g. northern Europe, eastern North America) and the Mediterranean and Semi-Arid biomes (e.g. the Mediterranean basin, California, central Chile, western South Africa and similar regions). The CFA is busy expanding the metric to include Tropical Forest biomes.	assessment based on farm practices (eg. lower biodiversity score when using conventional crop protection products, or higher score when habitats such as hedgerows are maintained)	Farmers put in the data necessary to make the assessment through the website	Yes	https://coolfarmtool.org/coolfarmtool/biodiversity/
2020	Agroecosystemic Resilience Index	Cleves Leguizamo, Youkhana and Calderon	Researchers - Scholars	there is a need to propose a generic method to analyze and evaluate agroecosystemic resilience, through a complex and comprehensive approach that takes into consideration the interaction of physical, biotic, socioeconomic or symbolic components of the system. These interactions are differential (weighted), to facilitate decision-making by the community, farmers, or administrators, regarding adaptations, adjustments or modifications that allow the agroecosystem to maintain its productivity and permanence.	Landscape	Ecosystem		Indirect (farmers surveyed)	Tested in the Department of Meta (Colombia)	Methodology up of the following phases: i) selection of categories, components and parameters (Ecophysiological, Biotic --> mainly connectivity [extension/diversity of connectors], Sociocultural, Economic and Technological); ii) weighting of the categories, components and parameters; iii) assignment of the interpretation scales of the parameters; iv) equation for the calculation of the Agroecosystemic Resilience Index; and finally, v) interpretation of the Agroecosystemic Resilience Index.	"With the collaboration of technicians, farmers, and public and private institutions of a national and regional order, a format (survey) was designed for the compilation of the information to be presented, validated and adjusted in 10 community workshops."	No	https://www.biorxiv.org/content/10.1101/2020.12.03.409656v1.full
2020	Farm Sustainability Tool (FaST Platform)	European Commission	Public sector	It will support farmers in their administrative decision-making processes, for farm profitability and environmental sustainability. At the same time, it will provide a reliable on-farm landing spot for digital solution developers (including satellite-based solutions) and service providers. It will reduce administrative burdens for farmers and Paying Agencies, and streamline communication between the farmers and public authorities.	farm level				EU countries	The modular platform will support EU agriculture and the Common Agricultural policy by also enabling the use of solutions based on machine learning applied to image recognition, as well as the use and reuse of IoT data, various public sector data, and user generated data. + Maps overlaying farm data on GIS layers Copernicus/Sentinel imagery: RGB+NDVI Campaign management with import of IACS/GSAA farmer data Fertilization recommendation Geo-tagged photos Two-way communications Basic weather/climate			https://fastplatform.eu/
2018	geoFootprint	partnership with more than 25 public, private and academic stakeholders, including Quantis, arx iT, Cool Farm Alliance and leading agrifood companies)	Private Sector, Public Sector, NGO	to measure and manage the footprint of your supply chains	landscape, national	species		indirect	worldwide	Ecosystems quality metric: Impact category that measures the potential effect (i.e., damage) of air, soil and water pollution on the quality of ecosystems in the form of potentially disappeared fraction of species per m2 and year.	Combining data from satellite imagery with environmental metrics	Yes. Less than 10 companies using the advanced paid version. More companies using the free version.	https://quantis-intl.com/strategy/collaborative-initiatives/geofootprint/
2014	Sustainable Rural Development Index	CEE Web for Biodiversity	NGO	to provide an accurate indication of the social, economic and biodiversity state of the rural communities at various scales (from farm level to EU level)	farm, national	species		both	European Union	combining social index + economic index + biodiversity index (emissions, Farmland Bird Index, HNV farming, water quality, soil organic matter, soil erosion by water)	Mainly based on already existing indicators/ indexes and available data (Eurostat)	Apparently not	https://www.ceeweb.org/wp-content/uploads/2011/12/SRDI-Biodiversity-CAP-final-draft.pdf

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Year	Name	Who developed it?	Entity category	Objective	Scale (field/ soil, farm, landscape, national)	Scope of biodiversity levels (genetic, species, ecosystem)		Directness of indicators (direct, indirect, both)	Regional applicability	Methodology	Data requirement and source	Implementation	External link
2012	BioBio	Agroscope/EU Commission	Public research	to identify scientifically sound and practicable farmland biodiversity indicators. (1. Conceptualisation of criteria for a scientifically based selection of biodiversity indicators for organic/low-input farming systems; 2. Assessment and validation of a set of candidate biodiversity indicators in representative case studies across Europe and beyond; 3. Preparation of guidelines for the implementation of biodiversity indicators for organic/low-input farming systems in Europe.	Farm level	Genetic, species, ecosystem		Both	Europe, major farm types, particularly organic, low-input farms. Feasible for other regions with adaptations.	eight indicators for habitat diverstiy, four indicators for species diversity, three indicators for genetic diverstiy and eight indicatores for farm-management practices	The cost of implementing the indicator set on a farm depends on its size and complexity. For a farm of 85 hectares and eight different habitat types, the effort amounts to 15 working days and EUR 1000	Tested in 12 countries in European Union, and Tunisia, Uganda and Ukraine. For the latter, adaptions would be needed for applicability	
2012	Healthy Farm Index	Quinn et al.	Researchers - Scholars	Tool for the farmer to monitor biodiversity and ecosystem services to track ecological change as a function of farming practices in an individual's farmland	Farm level				Indicators on farm-level biodiversity, climate, water	They selected indicators from multiple categories of ecosystem services to and from agroecosystems. These indicators fall under four categories of ecosystem services—food and fiber production, biodiversity enhancement, quality of life enhancement, and environmental quality enhancement. To demonstrate the preliminary framework, they created four farm scenarios, emphasizing a specific ecosystem service or management goal.	and eight different habitat types, the effort amounts to 15		https://johnquinniv.wixsite.com/agroecology/healthy-farm-index
2012	Indice de Agrobiodiversidad	Ángel Leyva Galán, Abady Lores Pérez	Academic Research	measure sustainability based on an agroecosystem's functional diversity, or the degree to which it meets man's nutritional, material and spiritual needs.	Farm scale but no soil biology	Species			Latin America	The research presented here is based on a 3 year participatory evaluation of agrobiodiversity in 15 agroecosystems located within the municipal-ity of San José de Las Lajas, Mayabeque Province, Cuba. Four groups of species were considered: human food species(FER); animal food species (FE); soil microorganisms (AVA), and non-nutrition related complementary species (COM). These groups were further subdivided into fourteen more specific categories, based on the roles played within an agroecoystem. A participatory process was then undertaken to develop a scale of values to be applied to each of the fourteen species categories.		One locality (the entire municipality of Jaruco) and 48 agro-ecosystems in four provinces of the country were studied and several reports and proposals were elaborated.	https://revistas.um.es/agroecologia/article/view/171061/146261
2009	Swiss Agricultural Life Cycle Assessment (SALCA) - subcategory Biodiversity	Agroscope	Public research institute	to be able to assess the environmental effects of production systems or the effectiveness of agro-environmental measures (by the government)	field, farm	species		indirect	valid for grasslands, arable crops and semi-natural habitats (SNHs) of farmland. Mostly Switzerland and neighbouring regions	11 species indicators: flora of crops and grasslands, birds, mammals, amphibians, snails, spiders, carabids, butterflies, wild bees, and grasshoppers. The biodiversity potential is composed of species abundance and species composition of each indicator and is assessed in two steps: First, the agricultural activities on the basis of their effect on the organisms is graded. In a second step the defined habitat types are weighed according to their importance for the indicators. The final grade is composed of a multiplication of both grades from the substeps	farming practices and information on habitat	yes. Applied by Agroscope (creator) in over 12 projects within Switzerland.	https://www.agroscope.admin.ch/agroscope/de/home/themen/umwelt-ressourcen/oekobilanzen/oekobilanz-methoden/oekobilanzmethode-salca.html#-2114605154 https://www.sciencedirect.com/science/article/pii/S1470160X14002830
2006	Indicator Reporting on the Integration of Environmental concerns in Agricultural (IRENA)	European Commission	Public Sector	Monitor the effectiveness of the strategy to integrate environmental concerns into agricultural and rural policies within the EU. Help monitor and assess agri-environmental policies and programmes, and to provide contextual information for rural development in general; Identify environmental issues related to European agriculture; to help target programmes that address agri-environmental issues; to understand the linkages between agricultural practices and the environment.	Field, farm, landscape	Genetic, species, ecosystem		Both	European Union	28 indicators grouped in 4 domains: responses (public policy, tech and skills, market signals), driving forces (input use, land use, farm management, trends), pressures and benefits (pollution, resource depletion, benefits), state/impact (biodiversity and habitats --> indicator = population trends of farmland birds, natural resources, landscape).		Very hard to find information on this online	https://www.eea.europa.eu/archived/projects/irena

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Annex V. List and description of the agrobiodiversity indicators

Indicator	Description		Input data	Link to document
A global atlas of the dominant bacteria found in soil (Academic collaboration)	Using 237 samples worldwide, the authors clustered the dominant taxa into ecological groups to build the first global atlas of soil bacterial taxa.		Soils from 237 locations across six continents	https://science.sciencemag.org/content/359/6373/320
Abiotic (pressures) indicator (EBONE)	The development of EBONE and the choice of these test indicators are set in the context of the emerging goal to develop a GEO (global) Biodiversity Observation Network (GEO BON) and its implementation within an institutional framework operating at the European level. Two groups of indicators were selected. The first related to abiotic, is composed of four indicators: 1- Land cover and land use intensity 2- Physical data (meteorological and water observations) 3- Atmospheric deposition, water chemistry and eutrophication 4- Soil chemistry and classification		In-situ biodiversity data from Long-term Ecosystem Research Sites (LTER) in Europe	https://www.wur.nl/en/Research-Results/Research-Institutes/Environmental-Research/Projects/EBONE/Products/Selection-of-biodiversity-indicators.htm
Active Carbon (SHAP - Cornell)	It is a measure of the small portion of the organic matter that can serve as an easily available food source for soil microbes, thus helping fuel and maintain a healthy soil food web. It is measured by quantifying potassium permanganate oxidation with a spectrophotometer.		Case specific field work in which farmers ship soil samples to cornell soil health laboratory.	https://soilhealth.cals.cornell.edu/training-manual/
Adoption of sustainable land management practices (Landscale)	A qualitative indicator in which the assessment team decides the field metrics. 1-Land area (ha) under major crop, livestock, and/or plantation forestry production that utilize Integrated Pest Management (IPM) and percentage of total production area that this represents 2- Land area (ha) under other specific sustainable land management (SLM) practices appropriate to the crop, livestock, and / or plantation forestry systems in the landscape, disaggregated by practice and production system and percentage (%) of total production area that this represents. 3- Extent and percentage of fire in natural ecosystems resulting from agricultural land management (ha and % burned area/year)		Case specific field work conducted by an interdsciplinary team during various weeks on a lanscape which boundaries were previously defined.	https://www.landscale.org/wp-content/uploads/2020/10/Assessment-Guidelines_V0.2_Oct2020-1.pdf
Adoption of sustainable waste management practices (Landscale)	A quantitative indicator which the field metrics are decided by the assessment team (Metrics depending on the crops)		Case specific field work conducted by an interdsciplinary team during various weeks on a lanscape which boundaries were previously defined.	https://www.landscale.org/wp-content/uploads/2020/10/Assessment-Guidelines_V0.2_Oct2020-1.pdf
Aggregate Stability (SHAP - Cornell)	It is a measure of how well soil aggregates resist disintegration when hit by raindrops. It is measured using a standardized simulated rainfall event on a sieve containing soil aggregates between 0.25 and 2.0 mm. The fraction of soil that remains on the sieve determines the percent aggregate stability.		Case specific field work in which farmers ship soil samples to cornell soil health laboratory.	https://soilhealth.cals.cornell.edu/training-manual/
Agricultural habitats (grassland) by conservation status (CAP - EU)	One of the 6 Indicators contributing to the assessment of the performance of the Common Agricultural Policy. The indicator shows the conservation status of agricultural habitats (grassland) and it measures the percentage of assessments of agricultural habitats (grassland) that have a favourable, unfavourable-inadequate and unfavourable-bad conservation status.		The indicator is based on data collected according to monitoring obligations under Article 11 of the Habitats Directive (92/43/EEC) and is therefore part of the indicator "Habitat types of European interest" (SEBI indicator 05). * Member State level: https://www.eea.europa.eu/data-and-maps/data/article-17-database-habitatsdirective-92-43-eec-1 * Conservation Status by Member State and biogeographical region for each species: https://natureart17.eionet.europa.eu/article17/habitat/report/?period=5&group=Grasslands&cou ntry=	https://ec.europa.eu/info/sites/default/files/food-farming-fisheries/key_policies/documents/context-indicator-fiches_en.pdf
Agricultural, agroforestry and tree plantation productivity (Landscale)	A set of quantitative indicators to measure agricultural, agroforestry, and tree plantation productivity: 1- Average crop productivity (yield/ha) disaggregated by crop; 2- Average productivity pasture-raised animals (livestock units/ha) disaggregated by animal type; 3- Average forest plantation productivity (timber volume/ha) disaggregated by plantation type.		Case specific field work conducted by an interdsciplinary team during various weeks on a lanscape which boundaries were previously defined.	https://www.landscale.org/wp-content/uploads/2020/10/Assessment-Guidelines_V0.2_Oct2020-1.pdf
Available Water Capacity (SHAP - Cornell)	Reflects the quantity of water that a disturbed sample of soil can store for plant use. The difference between water held at field capacity and the wilting point is measured using pressure chambers.		Case specific field work in which farmers ship soil samples to cornell soil health laboratory.	https://soilhealth.cals.cornell.edu/training-manual/
Bats protocol (Vigie Nature)	The Observatoire Agricole de la Biodiversité include five protocols for observing ordinary biodiversity in agricultural settings. Farmers upload their observations for receiving recommendations, while Vigie-Nature, a participative-science platform, collects data for monitoring biodiversity at the national level. - Bats: An ultrasonic recorder is placed in the middle of the field, and using a software, bat recordings are uploaded.		Case specific field work conducted by farmers using a web-based platform to help decision-making.	https://www.vigienature.fr/fr/agriculteurs
Bees protocol (Vigie Nature)	The Observatoire Agricole de la Biodiversité include five protocols for observing ordinary biodiversity in agricultural settings. Farmers upload their observations for receiving recommendations, while Vigie-Nature, a participative-science platform, collects data for monitoring biodiversity at the national level. - Bees: two 32-tube-nesting boxes are placed, with a five-meters distance, and monthly observations are uploaded.		Case specific field work conducted by farmers using a web-based platform to help decision-making.	https://www.vigienature.fr/fr/agriculteurs
Biotic (states) indicator (EBONE)	The development of EBONE and the choice of these test indicators are set in the context of the emerging goal to develop a GEO (global) Biodiversity Observation Network (GEO BON) and its implementation within an institutional framework operating at the European level. Two groups of indicators were selected. The second related to biotic, is composed of four indicators: 1- Primary producers (vascular plants, phytoplankton, bacteria, biomass, NPP) 2- Invertebrate taxa (selected on the basis of ecosystem type) 3- Invasive alien species in Europe since 1900 (EU check list)		In-situ biodiversity data from Long-term Ecosystem Research Sites (LTER) in Europe	https://www.wur.nl/en/Research-Results/Research-Institutes/Environmental-Research/Projects/EBONE/Products/Selection-of-biodiversity-indicators.htm
Breeds (BioBio)	A continuous indicator of the number and abundance of different breeds per farm animal species (average of breeds per farm), collected through a questionary survey.		Case specific field work	https://cordis.europa.eu/project/id/227161/reporting
Butterflies protocol (Vigie Nature)	The Observatoire Agricole de la Biodiversité include five protocols for observing ordinary biodiversity in agricultural settings. Farmers upload their observations for receiving recommendations, while Vigie-Nature, a participative-science platform, collects data for monitoring biodiversity at the national level. - Butterflies: five times a year, all butterflies observed on a ten-minute walk along a 100 to 300 mts transect, are identified and registered.		Case specific field work conducted by farmers using a web-based platform to help decision-making.	https://www.vigienature.fr/fr/agriculteurs

Indicator	Description		Input data	Link to document
Carbon Stock (UNCCD)	It is part of SDG15.3.1 meta indicator "proportion of land that is degraded over total land area." It is a binary indicator composed of three indicators assessed by national authorities following their methodologies. It follows a one-out-all-out logic: A negative change in one indicator implies an overall negative change. 3- Carbon stock: Changes in soil organic carbon. SOC stocks reflect the balance between organic matter gains, dependent on plant productivity and management practices, and losses due to decomposition through the action of soil organisms and physical export through leaching and erosion.		Comparable and standardized national official data sources.	https://prais.unccd.int/sites/default/files/helper_documents/4-GPG_15.3.1_EN.pdf
Coastal eutrophication potential (WRI Aqueduct)	Coastal eutrophication potential (WRI Aqueduct) measures the potential for riverine loadings of nitrogen (N), phosphorus (P), and silica (Si) to stimulate harmful algal blooms in coastal waters.		Data from selected river basins	https://www.wri.org/applications/aqueduct/water-risk-atlas/#/?advanced=false&basemap=hydro&indicator=cep_cat&lat=29.99300228455108&lng=-80.06835937500001&mapMode=view&month=1&opacity=0.5&ponderation=DEF&predefined=false&projection=absolute&scenario=optimistic&scope=baseline&timeScale=annual&year=baseline&zoom=3
Crop rotation (Biodiversity Performance Tool)	One indicator of the BPT index "Characterization of farming practices". It is divided into several easy-to-answer questions based on farm observations. The farmer responds directly on the free-access platform and the software analyses the data to provide a report on the state of potential for biodiversity on a farm and recomend improvement actions. - A categorical measure to evaluate the length of the main annual crop rotation at plot level.		Case specific field work conducted by farmers using a software of multi-criteria assessment to help decision-making	https://www.biodiversity-performance.eu/
Cultivar density (BioBio)	A continuous indicator of the number and amount of different varieties per species per farm, collected through a questionary survey.		Case specific field work	https://cordis.europa.eu/project/id/227161/reporting
Dispersal and pollination processes (U.Javeriana).	It analyses the changes (loss/increase) of the geographic coincidence between the pairs of interacting species that inform dispersal and pollination processes.		Data from selected ecosystems	https://sandbox.makinaeditorial.com/ecosistemas-colombianos/build/#/procesos-ecologicos
Diversity and Quality of Species and Habitats in BPAs (ALL-EMA Switzerland)	The ALL-EMA ('Agricultural Species and Habitats') monitoring programme was developed in order to evaluate the extent to which the agriculture-related Environmental Objectives for biodiversity in species and habitats have been achieved. This is one of five target values, in order to provide answers to the following questions: What is the state of the quality of BPAs with reference to species and habitats, and how is this changing? * Number of plant species per sampling area * Number of AEO plant species per sampling area * Percentage of observations with AEO butterfly species * Percentage of nesting grounds with AEO nesting-bird species * Percentage of sampling areas with floristic quality		1- Data for ALL-EMA are collected from 170 survey squares. Only the agricultural landscape is sampled within the 1km2 survey squares, e.g. forests and settlements are ignored. The balanced selection of survey squares allows us to derive representative results for the individual agricultural zones and the main regions of the agriculture-related environmental objectives. Data on butterfly occurrences on transects are recorded by Biodiversity Monitoring Switzerland BDM, whilst data on breeding territories of the breeding birds are collected by the Common Breeding Bird Survey MHB. 2- Using aerial images, ALL-EMA stereoscopically records woody structural elements within the survey squares in collaboration with the Swiss Federal Institute for Forest, Snow and Landscape Research WSL. This produces a detailed map illustrating hedgerows and shrubs, individual trees and groups of trees as well as individual bushes and groups of bushes. 3- Within the agricultural landscape of each survey square, a regular 50-metre grid defines the sampling points for data collection in the field, the so-called habitat survey. 4- For each grid point, habitat type and diversity of characteristic habitat-type species are determined on a circular area of 10m2. More on the habitat survey. On an extended circular area of 200m2, neophytes on the Black List and structures of the agricultural landscape such as piles of branches, clearance cairns and small water bodies are recorded. A GPS device is used to navigate to the grid points, and data is entered directly into a smartphone. 5- Detailed vegetation surveys (circular areas of 10m2) are conducted in each survey square on around 10% of the habitat surveys.	https://www.agroscope.admin.ch/agroscope/en/home/topics/environment-resources/monitoring-analytics/monitoring-programm-all-ema/programme/Methodology/_jcr_content/par/columncontrols/items/1/column/externalcontent_1559084617.bitexternalcontent.exturl.pdf/aHR0cHM6Ly9pcmEuYWdyb3Njb3BlLmNoLzAvQWpheC9FaW56ZW/xwdWJsaWthdGlvbi9Eb3dubG9hZD9laW56ZWxwdWJsaWthdGlv/bklkPTQxMDA0.pdf
Diversity of aquatic macroinvertebrates (Wold Health Organization)	Using the Biological Monitoring Working Party score, invertebrates are collected from different habitats at representative sites on river stretches using a pond net and identified at the family level. According to their sensitivity to environmental disturbance, each family is allocated a score between 1 and 10, according to their sensitivity to environmental disturbance (table 11.2 on the link). Scores are summed up and divided by the number of families. A BMWP score greater than 100 implies a healthy environment.		Case specific field work	https://www.who.int/water_sanitation_health/resourcesquality/wqmchap11.pdf
Dominant Leaf Type and Dominant Leaf Type Change (Copernicus)	1- A categorical indicator provides a primary land cover classification with three thematic classes (all non-tree covered areas / broadleaved/coniferous) at 10m spatial resolution. 2- A categorical indicator that maps the changes in Dominant Leaf Type. It provides information on the change between the reference years 2015 and 2018 and consists of 7 thematic classes (unchanged areas with no tree cover / new broadleaved cover / recent coniferous cover/loss of broadleaved cover/loss of coniferous cover / unchanged areas with tree cover / potential change among dominant leaf types) at 20m spatial resolution		The HRLs are produced from satellite imagery through a combination of automatic processing and interactive rule based classification. Since 2018, the products have increased in resolution to 10 meters.	https://land.copernicus.eu/pan-european/high-resolution-layers/forests/dominant-leaf-type
Earthworms protocol (Vigie Nature)	The Observatoire Agricole de la Biodiversité include five protocols for observing ordinary biodiversity in agricultural settings. Farmers upload their observations for receiving recommendations, while Vigie-Nature, a participative-science platform, collects data for monitoring biodiversity at the national level. - Earthworms: Once each three years, using mustard to bring worms to the surface in three sampling zones of one m2 , worms are identified and registered.		Case specific field work conducted by farmers using a web-based platform to help decision-making.	https://www.vigienature.fr/fr/agriculteurs

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Indicator	Description		Input data	Link to document
Ecological Focus Area (CAP - EU)	One of the 6 Indicators contributing to the assessment of the performance of the Common Agricultural Policy. Ecological focus area corresponds to arable land in hectares dedicated to 'ecologically beneficial elements'. It is calculated as the number of hectares declared by farmers as EFA.		Data notified by Member State (number of hectares declared by farmers as EFA under direct payments).	https://ec.europa.eu/info/sites/default/files/food-farming-fisheries/key_policies/documents/result-indicator-fiches-pillar-i_en.pdf
Economic Farm Size (Hercules)	Part of the Landscape management index. It is a continuous indicator of the number of ESU (European Size Units) using the Farm Accounting Data Network. Data for individual farms was aggregated to the administrative level unit.		FADN data	http://www.hercules-landscapes.eu/tartalom/HERCULES_WP4_D4_2_UBER.pdf
Ecosystem Restoration (Landscale)	A qualitative indicator in which the assessment team decides the field metrics. Total area under restoration and rate of increase in total area under restoration.		Case specific field work conducted by an interdsciplinary team during various weeks on a lanscape which boundaries were previously defined.	https://www.landscale.org/wp-content/uploads/2020/10/Assessment-Guidelines_V0.2_Oct2020-1.pdf
Farm management indicators - Cultivation (BioBio)	A set of indicators collected through a questionary survey. 1-Total direct and indirect energy input GJ per ha farm 2- Intensification/Extensification: Expenditures (in monetary value) on fuel, pesticides, fertilizer, and animal fodder. 3- Number of livestock units per ha farm 4- Number of grazing livestock units per ha grazing area		Case specific field work	https://cordis.europa.eu/project/id/227161/reporting
Farm management indicators - Nutrition (BioBio)	A set of indicators collected through a questionary survey. 1- Area percentage with use of mineral nitrogen fertilizer 2- Total nitrogen input in kilograms per hectare.		Case specific field work	https://cordis.europa.eu/project/id/227161/reporting
Farm management indicators - Pest (BioBio)	A set of indicators collected through a questionary survey. 1- Number of applications of pesticides (herbicide, insecticide, fungicide).		Case specific field work	https://cordis.europa.eu/project/id/227161/reporting
Farm management indicators - Soil (BioBio)	A set of indicators collected through a questionary survey. 1- Number of field operations (mowing and plowing) 2- Mowing time: Date of the first cut		Case specific field work	https://cordis.europa.eu/project/id/227161/reporting
Farmland birds index (CAP - EU)	One of the 6 Indicators contributing to the assessment of the performance of the Common Agricultural Policy. The indicator is a composite index that measures the rate of change in the relative abundance of common bird species at selected sites. These species, chosen from a list of selected common species at EU level (the so-called "EU list of species" currently cover 39 species7), are dependent on farmland for feeding and nesting and are not able to thrive in other habitats. Unit: 2000 = 100		EBCC/RSPB/BirdLife/Statistics Netherlands: the European Bird Census Council (EBCC) and its Pan-European Common Bird Monitoring Scheme (PECBMS), http://www.ebcc.info/pecbm.html .	https://ec.europa.eu/info/sites/default/files/food-farming-fisheries/key_policies/documents/context-indicator-fiches_en.pdf
Fertilization management (Biodiversity Performance Tool)	One indicator of the BPT index "Characterization of farming practices". It is divided into several easy-to-answer questions based on farm observations. The farmer responds directly on the free-access platform and the software analyses the data to provide a report on the state of potential for biodiversity on a farm and recomend improvement actions. - A categorical measure to evaluate: Mineral nitrogen fertilization for dominant crop system kg N per ha; Organic fertilization and awareness of N content richness; Good practices for N management.		Case specific field work conducted by farmers using a software of multi-criteria assessment to help decision-making	https://www.biodiversity-performance.eu/
Fertilizer application (Hercules)	Part of the Landscape management index, it is a categorical indicator (three groups of low, medium, and high rates of nitrogen input) was modeled, adding to the LUCAS points data from the Farm Structure Surveys.		Farm Structure Survey (FSS) Land Use/Cover area Frame Statistical Survey (LUCAS)	http://www.hercules-landscapes.eu/tartalom/HERCULES_WP4_D4_2_UBER.pdf
Field size (Hercules)	Part of the Landscape structure index. It is a categorical indicator (four groups from less than 0.5ha to more than 10ha) modeled using LUCAS ground survey data as raw data.		Land Use/Cover area Frame Statistical Survey (LUCAS) database	http://www.hercules-landscapes.eu/tartalom/HERCULES_WP4_D4_2_UBER.pdf
Global distribution of earthworm diversity (Academic collaboration)	A global map composed of three continuous indicators. 1- Abundance: individuals per m2. 2- Biomass: grams per m2 3- Species richness: Number of species. It was calculated through a model that used 7.000 data sets, each one with the following metrics: total (adults and juveniles) abundance of earthworms at the site, total (adults and juveniles) fresh biomass of earthworms at the site, and the number of species at the site. Using the area sampled at the site, both abundance and biomass were transformed to individuals per m2 and grams per m2, respectively. Species richness of each site was calculated from available species lists.		Data from more than 7.000 sites around the world.	https://science.sciencemag.org/content/366/6464/480
Global fungal distribution (Academic collaboration)	Using a metadata set, the authors described the distribution of fungal taxa. They looked for correlations with different environmental factors such as climate, soil, and vegetation variables to map the global distribution of common fungi and the composition and diversity of fungal communities.		Metadataset consisting of previously generated mycobiome data linked to specific geographical locations across the world.	https://www.nature.com/articles/s41467-019-13164-8
Global Soil Organic Carbon Map (SOC-FAO)	A continuous indicator that informs the number of Soil Organic Carbon Tonnes per hectare. It consists of national SOC maps, developed as 1 km soil grids (with any scaling method, preferably the digital soil mapping), covering a depth of 0-30 cm. It assesses tons of soil carbon per hectare using any of the three standard methods: 1- Total soil carbon from dry combustion with higher temperatures (600-800 C) 2-Total soil organic matter by loss on ignition: a dry combustion method using a furnace followed by calculating the difference in weight of the sample before and after the heating. 3- Organic carbon is obtained after oxidation with a dichromate-sulfuric acid mixture.		Partners of the Global Soil Partnership collect and upload local SOC assessments.	http://54.229.242.119/GSOCmap/
Governance assesment (Landscale)	A quantitative indicator in which the assessment team decides the field metrics. 1- Land tenure: Percentage of the landscape with formalized land tenure rights. 2- Land conflict: Number of unresolved land and resource conflicts or grievances, and the area of land (ha) subject to such conflicts 3- Land use plan adoption and enforcement: Percentage of the landscape covered by land-use or zoning plans that are formally adopted and enforceable; percentage of the landscape that is subject to overlapping and competing land-use plans; percentage of the landscape with recent land-use change that is inconsistent with the land-use plan(s) 4- Coordination of government agencies in land-use policy: Quality and status of government coordination on land-use policy, planning, and management across sectors based on the Sustainable Landscapes Rating Tool (SLRT) 5- Stakeholder participation and inclusion in land-use policy: Quality and status of stakeholder participation and inclusion in land-use policy, planning, and management based on SLRT indicators.		Case specific field work conducted by an interdsciplinary team during various weeks on a lanscape which boundaries were previously defined.	https://www.landscale.org/wp-content/uploads/2020/10/Assessment-Guidelines_V0.2_Oct2020-1.pdf

Annexes

Indicator	Description		Input data	Link to document
Grassland and Grassland Change (Copernicus)	1- A binary indicator that provides a primary land cover classification with two thematic classes (grassland / non-grassland) at 10m spatial resolution 2- A categorical indicator that maps the changes in grassland. It provides information on changes in grassland vegetation cover between the reference years 2015 and 2018. The thematic classes indicate all non-grassland areas, grassland gain and grassland loss, unchanged grassland in both years, and unverified grassland gain and loss areas at 20m resolution.		The HRLs are produced from satellite imagery through a combination of automatic processing and interactive rule based classification. Since 2018, the products have increased in resolution to 10 meters.	https://land.copernicus.eu/pan-european/high-resolution-layers/grassland
Green elements (Hercules)	Part of the Landscape structure index is a categorical indicator to assess landscape elements like ditches, tree rows, etc. Using LUCAS ground survey data (235 thousand records of land-cover types along 250m transects (minimum 1m width and minimum 20m length)).		Land Use/Cover area Frame Statistical Survey (LUCAS) database	http://www.hercules-landscapes.eu/tartalom/HERCULES_WP4_D4_2_UBER.pdf
Habitat Diversity (ALL-EMA Switzerland)	The ALL-EMA ('Agricultural Species and Habitats') monitoring programme was developed in order to evaluate the extent to which the agriculture-related Environmental Objectives for biodiversity in species and habitats have been achieved. This is one of five target values, in order to provide answers to the following questions: What is the state of habitat diversity in the agricultural landscape, and how is this changing? * Number of habitat types * Diversity of habitat types * Spatial heterogeneity of habitat types * Number of biodiversity- romoting structural types * Diversity of biodiversity-promoting structural types * Spatial heterogeneity of biodiversity-promoting structural types * Length of wood boundaries adjacent to the agricultural landscape * Percentage of sampling areas with woods * Length of waterbody boundaries contiguous with the agricultural landscape * Standard deviation of average moisture indicator values (Landolt, 2010) of the vegetation surveys in the agricultural landscape per survey square		1- Data for ALL-EMA are collected from 170 survey squares. Only the agricultural landscape is sampled within the 1km2 survey squares, e.g. forests and settlements are ignored. The balanced selection of survey squares allows us to derive representative results for the individual agricultural zones and the main regions of the agriculture-related environmental objectives. Data on butterfly occurrences on transects are recorded by Biodiversity Monitoring Switzerland BDM, whilst data on breeding territories of the breeding birds are collected by the Common Breeding Bird Survey MHB. 2- Using aerial images, ALL-EMA stereoscopically records woody structural elements within the survey squares in collaboration with the Swiss Federal Institute for Forest, Snow and Landscape Research WSL. This produces a detailed map illustrating hedgerows and shrubs, individual trees and groups of trees as well as individual bushes and groups of bushes. 3- Within the agricultural landscape of each survey square, a regular 50-metre grid defines the sampling points for data collection in the field, the so-called habitat survey. 4- For each grid point, habitat type and diversity of characteristic habitat-type species are determined on a circular area of 10m2. More on the habitat survey. On an extended circular area of 200m2, neophytes on the Black List and structures of the agricultural landscape such as piles of branches, clearance cairns and small water bodies are recorded. A GPS device is used to navigate to the grid points, and data is entered directly into a smartphone. 5- Detailed vegetation surveys (circular areas of 10m2) are conducted in each survey square on around 10% of the habitat surveys.	https://www.agroscope.admin.ch/agroscope/en/home/topics/environment-resources/monitoring-analytics/monitoring-programm-all-ema/programme/Methodology/_jcr_content/par/columncontrols/items/1/column/externalcontent_1559084617.bitexternalcontent.exturl.pdf/aHR0cHM6Ly9pcmEuYWdyb3Njb3BlLmNoLzAvQWpheC9FaW56ZW/xwdWJsaWthdGlvbi9Eb3dubG9hZD9laW56ZWxwdWJsaWthdGlv/bklkPTQxMDA0.pdf
Habitat diversity indicators (BioBio)	Description Mapping habitat through the EBONE's General Habitat Categories (154 GHCs derived from easily identifiable (on the ground and from the air) 16 Life-Forms and 18 Non Life Forms), each aerial or linear habitat is delineated (on a map, aerial photo, or satellite picture). 1- habitat richness: Number of habitat types per hectare. 2- Habitat diversity: Shannon diversity to assess the relative abundances of different species 3-Average size of habitat patches 4- Length per hectare of linear elements 5- Crop richness: number of crops per hectare 6- Percentage of farmland with shrubs 7- Percentage of farmland with three cover 8-Percentage of farmland with semi-natural habitats		Case specific field work	https://cordis.europa.eu/project/id/227161/reporting
Habitat Quality (ALL-EMA Switzerland)	The ALL-EMA ('Agricultural Species and Habitats') monitoring programme was developed in order to evaluate the extent to which the agriculture-related Environmental Objectives for biodiversity in species and habitats have been achieved. This is one of five target values, in order to provide answers to the following questions: What is the state of the quality of habitats in the agricultural landscape, and how is this changing? * Percentage of sampling areas with quality according to ALL-EMA * Number of AEO habitat types * Average nutrient indicator values of the plant species in sampling areas * Average mowing compatibility of plant species in sampling areas * Average land-use intensity value * Percentage of woods sampling areas with ecologically valuable woodland (tiered, richly structured forest edge, old trees and briars).		1- Data for ALL-EMA are collected from 170 survey squares. Only the agricultural landscape is sampled within the 1km2 survey squares, e.g. forests and settlements are ignored. The balanced selection of survey squares allows us to derive representative results for the individual agricultural zones and the main regions of the agriculture-related environmental objectives. Data on butterfly occurrences on transects are recorded by Biodiversity Monitoring Switzerland BDM, whilst data on breeding territories of the breeding birds are collected by the Common Breeding Bird Survey MHB. 2- Using aerial images, ALL-EMA stereoscopically records woody structural elements within the survey squares in collaboration with the Swiss Federal Institute for Forest, Snow and Landscape Research WSL. This produces a detailed map illustrating hedgerows and shrubs, individual trees and groups of trees as well as individual bushes and groups of bushes. 3- Within the agricultural landscape of each survey square, a regular 50-metre grid defines the sampling points for data collection in the field, the so-called habitat survey. 4- For each grid point, habitat type and diversity of characteristic habitat-type species are determined on a circular area of 10m2. More on the habitat survey. On an extended circular area of 200m2, neophytes on the Black List and structures of the agricultural landscape such as piles of branches, clearance cairns and small water bodies are recorded. A GPS device is used to navigate to the grid points, and data is entered directly into a smartphone. 5- Detailed vegetation surveys (circular areas of 10m2) are conducted in each survey square on around 10% of the habitat surveys.	https://www.agroscope.admin.ch/agroscope/en/home/topics/environment-resources/monitoring-analytics/monitoring-programm-all-ema/programme/Methodology/_jcr_content/par/columncontrols/items/1/column/externalcontent_1559084617.bitexternalcontent.exturl.pdf/aHR0cHM6Ly9pcmEuYWdyb3Njb3BlLmNoLzAvQWpheC9FaW56ZW/xwdWJsaWthdGlvbi9Eb3dubG9hZD9laW56ZWxwdWJsaWthdGlv/bklkPTQxMDA0.pdf

Annexes

Indicator	Description		Input data	Link to document
Heavy Metals (SHAP - Cornell)	It is a measure of levels of metals of possible concern to human or plant health. They are measured by digesting the soil with concentrated acid at high temperature.		Case specific field work in which farmers ship soil samples to cornell soil health laboratory.	https://soilhealth.cals.cornell.edu/training-manual/
Human Well-Being assessment - health (Landscale)	A quantitative indicator in which the assessment team decides the field metrics. 1- Health and nutrition: Percentage of malnourished children; percentage of the population without access to health services; and mortality rate of children under 18 years.		Case specific field work conducted by an interdsciplinary team during various weeks on a lanscape which boundaries were previously defined.	https://www.landscale.org/wp-content/uploads/2020/10/Assessment-Guidelines_V0.2_Oct2020-1.pdf
Human Well-Being assessment - material (Landscale)	A quantitative indicator in which the assessment team decides the field metrics. 1- Household income and assets: Percentage of population living below the local poverty line and percentage of households owning or lacking specific context-appropriate assets. 2- Education: Percentage of school-aged children who are not attending school and the percentage of adults who have not completed primary education. 3- Water, sanitation, and hygiene: Percentage of households without access to safe drinking water and a sanitation facility. 4- Basic infrastructure. Percentage of households without access to electricity and long-term durability in construction materials."		Case specific field work conducted by an interdsciplinary team during various weeks on a lanscape which boundaries were previously defined.	https://www.landscale.org/wp-content/uploads/2020/10/Assessment-Guidelines_V0.2_Oct2020-1.pdf
Human Well-Being assessment -Vulnerability (Landscale)	A quantitative indicator in which the assessment team decides the field metrics. Percentage of households with severe shock in the past 12 months due to a natural disaster or human-caused events.		Case specific field work conducted by an interdsciplinary team during various weeks on a lanscape which boundaries were previously defined.	https://www.landscale.org/wp-content/uploads/2020/10/Assessment-Guidelines_V0.2_Oct2020-1.pdf
Indice CMT-Végétaux (L´ADEME)	A representative leaves sample is lab-analyzed to assess the accumulation of metallic trace elements in plants.		Case specific field work	https://www.ademe.fr/sites/default/files/assets/documents/bio-indicateurs_010216.pdf
Indice Nématodes (L´ADEME) .	A soil sample (300-500 grams) is lab-analyzed to assess the abundance of nematodes (more than 200 nematodes for 100 grams of the soil of chaque group (phytophages, microbivores, omnivores, and carnivores)		Case specific field work	https://www.ademe.fr/sites/default/files/assets/documents/bio-indicateurs_010216.pdf
Indice Oméga 3-Végétaux (L´ADEME)	A representative leaves sample is lab-analyzed to assess the fatty acid composition by gas chromatography. These lipids are essential for the proper functioning of photosynthesis.		Case specific field work	https://librairie.ademe.fr/sols-pollues/1971-bio-indicateurs-de-l-etat-des-sols-les.html
Indice SET-Escargots (L´ADEME)	Fifteen snails stay 28 days in a cage over the soil. Their viscera are lab-analyzed to assess the accumulation of metallic trace elements in comparison with control snails.		Case specific field work	https://www.ademe.fr/sites/default/files/assets/documents/bio-indicateurs_010216.pdf
Input, use efficiency (Landscale)	A quantitative indicator in which the assessment team decides the field metrics. Fertilizer use efficiency (quantity of product produced per unit of nitrogen, phosphorus, and/or potassium [NPK] use) disaggregated by-product; and water use efficiency (amount of product made per unit of water use) disaggregated by product.		Case specific field work conducted by an interdsciplinary team during various weeks on a lanscape which boundaries were previously defined.	https://www.landscale.org/wp-content/uploads/2020/10/Assessment-Guidelines_V0.2_Oct2020-1.pdf
Insertion of farm in the socio-economic system (Biodiversity Performance Tool)	One of the three indexes that composed the BPT index. It is made up of thee sub-indicators, each divided into several easy-to-answer questions based on farm observations. The farmer responds directly on the free-access platform and the software analyses the data to provide a report on the state of potential for biodiversity on a farm and recomend improvement actions. 1- Farm performance monitoring (a categorical measure to evaluate the existence of: a product certification process; Farm map; Traceability; Multi-criteria diagnostic) 2- Awareness of farmers and worker (a categorical measure to evaluate the temporary of: training sessions organized by standards or farmers association or cooperative etc.; Qualification on pesticide use positive and negative lists; Exchange with assessors and or experts from standards or farmers association or cooperative; Qualification of workers and update of knowledge; Exchange of experience with suppliers, millers, distributors on biodiversity aspects; Self-learning about agroecology and alternative methods). 3- Cooperation (a categorical measure to evaluate the cooperation with external experts and the involvement in a local network).		Case specific field work conducted by farmers using a software of multi-criteria assessment to help decision-making	https://www.biodiversity-performance.eu/
Invertebrates protocol (Vigie Nature)	The Observatoire Agricole de la Biodiversité include five protocols for observing ordinary biodiversity in agricultural settings. Farmers upload their observations for receiving recommendations, while Vigie-Nature, a participative-science platform, collects data for monitoring biodiversity at the national level. - Invertebrates: three poplar planks are placed in the flied (one inside, two on the edges). Once a month, each plank is returned and observations on carabes, mollusques and others invertebrates are registered.		Case specific field work conducted by farmers using a web-based platform to help decision-making.	https://www.vigienature.fr/fr/agriculteurs
Land cover (UNCCD)	It is part of the SDG15.3.1 meta indicator "proportion of land that is degraded over the total land area." It is a binary indicator composed of three indicators assessed by national authorities following their methodologies. It follows a one-out-all-out logic: A negative change in one indicator implies an overall negative change. 1- Land cover: changes on area. LC refers to the observed physical cover of the Earth's surface which describes the distribution of vegetation types, water bodies, and human-made infrastructure. Changes in land cover may point to land degradation when there is a loss in productivity in terms of ecosystem services considered desirable in a local or national context.		Comparable and standardized national official data sources.	https://prais.unccd.int/sites/default/files/helper_documents/4-GPG_15.3.1_EN.pdf
Land degradation Surveillance framework (ICRAFT)	This framework is composed of the following indicators: 1- Soil health (Soil organic carbon (SOC); Total nitrogen; Infiltration capacity; Soil pH/acidity; Texture (sand and clay); Cumulative soil mass; Earthworm presence). 2- Land Cover (Vegetation structure, vegetation types, woody vegetation, herbaceous vegetation, rangelands) 3- Land use (Current, historical Ownership). 4- Land degradation: (Soil erosion prevalence; Soil water conservation measures; Root-depth restrictions; Rock/stone cover). 5- Topography/Landform		Soil samples are collected in multiple localtions using a nested hierarchical sampling desing.	http://landscapeportal.org/blog/2015/03/25/the-land-degradation-surveillance-framework-ldsf/#:~:text=The%20Land%20Degradation%20Surveillance%20Framework%20(LDSF)%20was%20developed%20as%20a,of%20soil%20and%20ecosystem%20health.
Land Potential (LPKS - U. Colorado)	Individual assessment with an open access app to assess the long-term potential of the land to generate ecosystem services sustainably. It analyzes all users' information to provide in-situ reports. 1- Land info: GPS coordinates, record slope, texture, color for Soil ID. 2- Land cover: A 20-minute vegetation monitoring with a yard/meter stick. 3- Soil health: record field observation and available lab data.		Case specific field work	https://landpotential.org/mobile-app/

Indicator	Description		Input data	Link to document
Land productivity (UNCCD)	It is part of SDG15.3.1 meta indicator "proportion of land that is degraded over total land area." It is a binary indicator composed of three indicators assessed by national authorities following their methodologies. It follows a one-out-all-out logic: A negative change in one indicator implies an overall negative change. 2- Land productivity: changes on net primary productivity (defined as the energy fixed by plants minus their respiration, translating into the rate of biomass accumulation that delivers a suite of ecosystem services). It points to changes in the health and productive capacity of the land. It reflects the net effects of changes in ecosystem functioning on plant and biomass growth, where declining trends are often a defining characteristic of land degradation.		Comparable and standardized national official data sources.	https://prais.unccd.int/sites/default/files/helper_documents/4-GPG_15.3.1_EN.pdf
Land use history (Hercules)	A categorical indicator of land-use change antiquity (three groups depending on when the change occurred) using a combination of land cover data since 1900.		Forest resource assessment FRA (FAO) from 1948 to 2010 National land-cover statistics (1900 – 2010) EUROSTAT land-cover statistics (1974 – 2010)	http://www.hercules-landscapes.eu/tartalom/HERCULES_WP4_D4_2_UBER.pdf
Landcover and use extent (Hercules).	An index calculated from four indicators: 1- Land Cover. A categorical indicator using CORINE Land cover/use satellite data (resolution 100 m). 2- Land conversion. A continuous indicator assesses high/low changes in land cover using a combination of datasets (CORINE, Wilderness Quality Index, CAPRI biomass, Pan-European forest cover map). 3- Farmland abandonment: a binary indicator using MODIS (moderated resolution image spectroradiometer) satellite image time series (from 2000 to 2012). 4- Protected areas: a binary indicator using nationally designated areas from the European Environmental Agency.		CORINE, Wilderness Quality Index, CAPRI biomass, Pan-European forest cover map). MODIS satellite image time series and protected areas designated by the European Environmental Agency.	http://www.hercules-landscapes.eu/tartalom/HERCULES_WP4_D4_2_UBER.pdf
Landscape diversity (Biodiversity Performance Tool)	One indicator of the BPT index "Characterization of the environment of the farm". It is made up of five sub-indicators, each divided into several easy-to-answer questions based on farm observations. The farmer responds directly on the free-access platform and the software analyses the data to provide a report on the state of potential for biodiversity on a farm and recomend improvement actions. 1- Landscape diversity: landscape diversity around farm. 2- Insertion of the farm into an area of ecological interest 3- Percentage of SNH destructed in the farm in previous years. 4- Percentage of grassland converted to arable land in the farm in previous years. 5- Types of SNH per plot on average at farm scale.		Case specific field work conducted by farmers using a software of multi-criteria assessment to help decision-making	https://www.biodiversity-performance.eu/
Landscape structure (Hercules).	An index calculated through two indicators: 1- Field size. A categorical indicator (four groups from less than 0.5ha to more than 10ha) modeled using LUCAS ground survey data as raw data. 2- Green elements: A categorical indicator using LUCAS ground survey data (235 thousand records of land-cover types along 250m transects (minimum 1m width and minimum 20m length)).		LUCAS Ground Survey	http://www.hercules-landscapes.eu/tartalom/HERCULES_WP4_D4_2_UBER.pdf
Landscape value (Hercules)	Landscape value (Hercules). An index calculated through two indicators: 1- Traditional foodstuffs: A continuous indicator of the number of protected designations of origin food products per region using the Legal PDO documents from the DOOR database. 2- Panoramio: A continuous indicator of the number of unique users' uploaded geotagged photos per square kilometer (in non-urban areas) in Google service Panoramio.		Legal PDO documents from DOOR database REST API from Panoramio Photos geotagged in built-up area (see CORINE data layer).	http://www.hercules-landscapes.eu/tartalom/HERCULES_WP4_D4_2_UBER.pdf
Les Indices Vers de Terre (L´ADEME and EcoBioSoil).	Six soil samples (a 20cm*20*25 cm block) or chemical extraction (one square meter of soil is watered three times at 15 minutes) to assess total abundancy (number and weight) of compost worms, earth-worker worms, and root dwelling worms.		Case specific field work	https://www.ademe.fr/sites/default/files/assets/documents/bio-indicateurs_010216.pdf
Les Indices Vers de Terre anéciques - the earthworker worm (L´ADEME and EcoBioSoil).	Six soil samples (a 20cm*20*25 cm block) or chemical extraction (one square meter of soil is watered three times at 15 minutes) to assess earth-worker worms' total abundancy (number and weight).		Case specific field work	https://www.ademe.fr/sites/default/files/assets/documents/bio-indicateurs_010216.pdf
Les Indices Vers de Terre endogés - the root dwelling worm (L´ADEME and EcoBioSoil).	Six soil samples (a 20cm*20*25 cm block) or chemical extraction (one square meter of soil is watered three times at 15 minutes) to assess root dwelling worms' total abundancy (number and weight).		Case specific field work	https://www.ademe.fr/sites/default/files/assets/documents/bio-indicateurs_010216.pdf
Les Indices Vers de Terre épigés - the compost worms (L´ADEME and EcoBioSoil).	Six soil samples (a 20cm*20*25 cm block) or chemical extraction (one square meter of soil is watered three times at 15 minutes) to assess compost worms' total abundancy (number and weight).		Case specific field work	https://www.ademe.fr/sites/default/files/assets/documents/bio-indicateurs_010216.pdf
Level of water stress by crop (WRI Aqueduct)	A categorical indicator of the percentage of irrigated crop area by the level of water stress and volume of demand (six groups which vary from low to extremely high). WRI employs a weighted aggregation methodology that brings Aqueduct's granular subbasin level information up to the country and river basin scale, generating global rankings of water-quantity-related risks.		Data from selected river basins	https://www.wri.org/applications/aqueduct/food/#/?basemap=hydro&crop=all&food=none&indicator=1a1d4f61-f1b3-4c1a-bfb5-9d0444ecdd56&irrigation=all&lat=24.93&lng=-68.73&opacity=1&period=year&period_value=baseline&scope=global&type=absolute&year=baseline&zoom=3
Livestock management (Biodiversity Performance Tool)	One indicator of the BPT index "Characterization of farming practices". It is divided into several easy-to-answer questions based on farm observations. The farmer responds directly on the free-access platform and the software analyses the data to provide a report on the state of potential for biodiversity on a farm and recomend improvement actions. - A categorical measure to evaluate:: Maximal average livestock density LU per ha of main fodder area; Type of concentrates; Quantity of concentrates t per LU; Type of forage; Forage autonomy; Grazing use; Management of permanent grasslands; Use of alternative methods for combating diseases and parasitisms; Implementation of grazing areas including trees for livestock such as poultry.		Case specific field work conducted by farmers using a software of multi-criteria assessment to help decision-making	https://www.biodiversity-performance.eu/
Microbial carbon per gram of soil	Individual assessment with the microbiometer (a commercial kit) to evaluate microbial carbon per gram of soil. A small soil sample is mixed with a chemical compound to, after 20 minutes of exposure, assess the biomass using a color-sensitive app.		Case specific field work	https://microbiometer.com/our-test/
Natural ecosystem connectivity (Landscale)	A qualitative indicator in which the assessment team decides the field metrics. Spatial analysis of the fragmentation of natural ecosystem patterns.		Case specific field work conducted by an interdsciplinary team during various weeks on a lanscape which boundaries were previously defined.	https://www.landscale.org/wp-content/uploads/2020/10/Assessment-Guidelines_V0.2_Oct2020-1.pdf

Indicator	Description		Input data	Link to document
Natural Ecosystem Conversion (Landscale):	A qualitative indicator in which the assessment team decides the field metrics. 1- Percentage of area of natural ecosystems in the landscape that has been recently converted (baseline between 5 and 30 years old) and percentage of conversion per year. 2- Percentage of natural ecosystems in the landscape that are currently degraded and percentage of degradation per year.		Case specific field work conducted by an interdisciplinary team during various weeks on a lanscape which boundaries were previously defined.	https://www.landscale.org/wp-content/uploads/2020/10/Assessment-Guidelines_V0.2_Oct2020-1.pdf
Natural Ecosystem Degradation (Landscale)	A qualitative indicator in which the assessment team decides the field metrics. Percentage of natural ecosystems in the landscape that are currently degraded and rate of degradation per year.		Case specific field work conducted by an interdisciplinary team during various weeks on a lanscape which boundaries were previously defined.	https://www.landscale.org/wp-content/uploads/2020/10/Assessment-Guidelines_V0.2_Oct2020-1.pdf
Natural Ecosystem Protection (Landscale)	A qualitative indicator in which the assessment team decides the field metrics. Percentage of natural ecosystems in the landscape that are currently degraded and rate of degradation per year.		Case specific field work conducted by an interdisciplinary team during various weeks on a lanscape which boundaries were previously defined.	https://www.landscale.org/wp-content/uploads/2020/10/Assessment-Guidelines_V0.2_Oct2020-1.pdf
Nitrogen balance (OECD)	Nitrogen balance (Kg/ha): Balance (surplus or deficit) expressed as kg nitrogen per hectare of total agricultural land calculated at the national level. OECD aggregate for nitrogen balance is calculated as the ratio between the total surplus and the total agricultural land area in the OECD area. European Union as a single area is calculated as the Gross Nitrogen Balance in the EU area over the utilised agricultural area of the EU.		Eurostat is in charge of the data collection statistics for EU countries plus Norway and Switzerland. The OECD Secretariat collects data for non-EU OECD countries on the basis of the OECD Agri-environmental Indicators questionnaire.	http://www.oecd.org/tad/sustainable-agriculture/agri-environmentalindicators.htm
Number of species of birds per farm (BioBio)	A continuous indicator on the number of species per farm (subdivision in gamma and alpha diversity, area-weighted diversity; rarefied richness; chao estimated richness).		Case specific field work (1490 plots were surveyed on 195 farms)	https://cordis.europa.eu/project/id/227161/reporting
Number of species of earthworms per farm (BioBio)	A continuous indicator on the number of species per farm (subdivision in gamma and alpha diversity, area-weighted diversity; rarefied richness; chao estimated richness). Extraction by applying an expellant solution causing the earthworms to come to the soil surface was first performed in three 30 x 30 cm samples. After this, three soil cores (each 30 x 30 x 20 cm deep) were taken with a spade. Cool and wet seasons were the preferred time for sampling.		Case specific field work (1490 plots were surveyed on 195 farms)	https://cordis.europa.eu/project/id/227161/reporting
Number of species of spiders per farm (BioBio)	A continuous indicator on the number of species per farm (subdivision in gamma and alpha diversity, area-weighted diversity; rarefied richness; chao estimated richness). Five subsamples were taken within a sample ring (0.357 m internal diameter and 40 cm height) placed beforehand at random on the target vegetation within the habitat. Sampling was repeated three times throughout the season.		Case specific field work (1490 plots were surveyed on 195 farms)	https://cordis.europa.eu/project/id/227161/reporting
Number of species of vascular plants per farm (BioBio)	A continuous indicator on the number of species per farm (subdivision in gamma and alpha diversity, area-weighted diversity; rarefied richness; chao estimated richness). It used two types of plots, square (Vegetation was recorded in nested plots of 4 m2, 25 m2, 50 m2, and 100 m2 in areal habitats) and linear (10m x 1m in linear habitats). All vascular plants were recorded. Once the whole plot was recorded, the estimated cover percentage for the entire plot was listed against each species, using 5 %-cover categories.		Case specific field work (1490 plots were surveyed on 195 farms)	https://cordis.europa.eu/project/id/227161/reporting
Number of species of wild bees and bumblebees per farm (BioBio)	A continuous indicator on the number of species per farm (subdivision in gamma and alpha diversity, area-weighted diversity; rarefied richness; chao estimated richness). Bees were captured with an aerial net. Each habitat was surveyed by a slow walk (15 minutes) along a 100-meter-long, 2-meter-wide transect crossing the center of the vegetation plot, and the collector caught all individual bees seen within the 2m-wide' belt'. The transect walk was repeated three times throughout the season.		Case specific field work (1490 plots were surveyed on 195 farms)	https://cordis.europa.eu/project/id/227161/reporting
Organic Matter (SHAP - Cornell)	It is a measure of all carbonaceous material that is derived from living organisms. The percent OM is determined by the mass of oven-dried soil lost on combustion in a 500 C furnace.		Case specific field work in which farmers ship soil samples to cornell soil health laboratory.	https://soilhealth.cals.cornell.edu/training-manual/
Participatory Earthworm Observatory (ARB idF)	L´observatoire participative de vers de Terre épigés, anéciques et endogés / the compost worms, the earthworker worm and the root dwelling worm (ARB idF). Thorugh simplified methods to observe and account for earthworms. It aggregates observation at the national level using volunteers for site comparisons of abundance (number of individuals) and diversity (number of species).		Volunteers at the national level	https://ecobiosoil.univ-rennes1.fr/OPVT_accueil.php
Percentage of landraces per farm (BioBio)	A continuous indicator of the origin of crops continuous indicator (percentage of landraces per farm), collected through a questionary survey.		Case specific field work	https://cordis.europa.eu/project/id/227161/reporting
Pesticide management (Biodiversity Performance Tool)	One indicator of the BPT index "Characterization of farming practices". It is divided into several easy-to-answer questions based on farm observations. The farmer responds directly on the free-access platform and the software analyses the data to provide a report on the state of potential for biodiversity on a farm and recomend improvement actions. - A categorical measure to evaluate: Preventive measures and monitoring; Surface area non-treated with synthetic pesticides; Alternative methods against weeds; Alternative methods against other pests; Handling of harmful substances.		Case specific field work conducted by farmers using a software of multi-criteria assessment to help decision-making	https://www.biodiversity-performance.eu/
Phosphorus balance (OECD)	Phosphorus balance (Kg/ha): Balance (surplus or deficit) expressed as kg phosphorus per hectare of total agricultural land calculated at the national level. OECD aggregate for phosphorus balance is calculated as the ratio between the total surplus and the total agricultural land area in the OECD area. European Union as a single area is calculated as the Gross Phosphorous Balance in the EU area over the utilised agricultural area of the EU.		Eurostat is in charge of the data collection statistics for EU countries plus Norway and Switzerland. The OECD Secretariat collects data for non-EU OECD countries on the basis of the OECD Agri-environmental Indicators questionnaire.	http://www.oecd.org/tad/sustainable-agriculture/agri-environmentalindicators.htm
Potential Biodiversity Index (Biorgest)	It evaluates habitat capacity to host biodiversity based on its composition, structure, and context through a linear walk with side observations on: 1- Number of native tree species (more than 50 cm in height) dead or alive. 2- Vertical structure: Vegetation occupation in each of the 5 vertical nest layers (herbaceous; <1.5m; 1.5-5m; 5-15m;> 15m). 3- Number of large deadwood standing and on the ground (> 1 m in length or height; Ø> 17.5 cm). 4- Number of large trees (Ø> 37.5cm). 5- Number of trees with some type of dendromicrohabitats according to the European catalog. 6- Percentage of the surface with clearings or low-density vegetation. 7- Temporal continuity of the forest: triangulation of information to assess the forest history. 8- Number of aquatic and rocky environments according to PBI classification.		Case specific field work	http://cpf.gencat.cat/es/cpf_03_linies_actuacio/cpf_transferencia_coneixement/Index-Biodiversitat-Potencial/documents-i-publicacions-relacionades-amb-libp/

Indicator	Description		Input data	Link to document
Potentially Mineralizable Nitrogen (SHAP - Cornell)	It is a combined measure of soil biological activity and substrate available to mineralize nitrogen to make it available to the plant. It is measured as the change in mineralized plant-available nitrogen present after a seven-day anaerobic incubation.		Case specific field work in which farmers ship soil samples to cornell soil health laboratory.	https://soilhealth.cals.cornell.edu/training-manual/
Prevention measures (Biodiversity Performance Tool)	One indicator of the BPT index "Characterization of farming practices". It is divided into several easy-to-answer questions based on farm observations. The farmer responds directly on the free-access platform and the software analyses the data to provide a report on the state of potential for biodiversity on a farm and recomend improvement actions. - A categorical measure to evaluate: average plot size, average plot width, number of breeded species or races, number of rare or endangered species, number of crop plant species, number of crop plant varieties for dominant crop, number of rare or endangered crop species or varieties, use of GMO and percentage of cropper area/livestock; types and percentage of mass-flowering crops, special measures for the protection of species.		Case specific field work conducted by farmers using a software of multi-criteria assessment to help decision-making	https://www.biodiversity-performance.eu/
productive and sustainable agriculture (UNCCD)	Indicator SDG2.4.1 meta indicator "Proportion of agricultural area under productive and sustainable agriculture". It is a proportion whose numerator includes 11 subindicators negotiated during a two-year consultation process. 1 Land productivity: Farm output value per hectare 2 Profitability: Net farm income 3 Resilience: Risk mitigation mechanisms 4 Soil health: Prevalence of soil degradation 5 Water use: Variation in water availability 6 Fertilizer pollution risk: Management of fertilizers 7 Pesticide risk: Management of pesticides 8 Biodiversity: Use of agro-biodiversity-supportive practices 9 Decent employment: Wage rate in agriculture 10 Food security: Food Insecurity Experience Scale (FIES) 11 Land tenure: Secure tenure rights to land		Comparable and standardized national official data sources.	https://unstats.un.org/sdgs/metadata/files/Metadata-02-04-01.pdf
Quality of Semi-Natural Habitat - Composition (Biodiversity Performance Tool)	One indicator of the BPT index "Characterization of the environment of the farm". It is made up of three sub-indicators, each divided into several easy-to-answer questions based on farm observations. The farmer responds directly on the free-access platform and the software analyses the data to provide a report on the state of potential for biodiversity on a farm and recomend improvement actions. 1- Precision on composition of hedges, forest edges, woodlots and agroforestry (a categorical measure to evaluate the presence of: indigenous species, hardwoods species, early/late flowering species, autum-winter fruit species, defensive plants, dead trees and stumps, local plants, SNH continuity, grass strips on both sides of the hedges and at the adjacent side of the cultivated plot, alien invasive species). 2- Precision on composition of floral strips and areas / fallow lands / field margins / grass strips / grasslands (a categorical measure to evaluate the presence of early/late flowering species, local seeds, natural vegetation for fallow land, Spontaneous vegetation for field margins or grass strip; number of different colours of flowering species; monocotyledons/dicotyledons composition of grass strip; alien invasive species; annual/perennial composition of floral strips; exotic/horticultural/none composition of flora strips; multiespecies grasslands composition). 3- Precision on composition of water elements (a categorical measure to evaluate the presence of: permanent water, grassland, odonates, amphibians, palustrine plants, alien invasive species, origin of the ater for the pond; connected biological corridors, depth of the pond, wetland-dependant avifauna, grassy or woody buffer zones)		Case specific field work conducted by farmers using a software of multi-criteria assessment to help decision-making	https://www.biodiversity-performance.eu/
Quality of Semi-Natural Habitat - Management (Biodiversity Performance Tool)	One indicator of the BPT index "Characterization of the environment of the farm". It is made up of one sub-indicators divided into several easy-to-answer questions based on farm observations. The farmer responds directly on the free-access platform and the software analyses the data to provide a report on the state of potential for biodiversity on a farm and recomend improvement actions. - A categorical measure to evaluate: use of fertilizer, perticides, export of mowing products; SNH management book, rotational grazing, management of grass strips (early/late ploughin/grinding/mowing); management of hedgerow (any/late/multiyear bailer/cutter bar); Management of ditch/ripisylves; existence of biologica corridors, burning, percentage of farm where specific managment of SNH are implemented.		Case specific field work conducted by farmers using a software of multi-criteria assessment to help decision-making	https://www.biodiversity-performance.eu/
Quantity and diversity of the Semi-Natural Habitats (SNH) (Biodiversity Performance Tool)	One indicator of the BPT index "Characterization of the environment of the farm". It is made up of five sub-indicators, each divided into several easy-to-answer questions based on farm observations. The farmer responds directly on the free-access platform and the software analyses the data to provide a report on the state of potential for biodiversity on a farm and recomend improvement actions. 1- Woody, bushy elements: number of solitary trees (min 1m-diameter of crown); the linear length in meters of: low hedges (< 1 m of height and minimum 2m-width), bushy hedges (1 to 7 m of height), monospecific tree hedges(> 7 m of height), forest edges (in all cases minimum 4m-width); surface area in ha of shrub and woodlots patches. 2- Grass-herb elements: surface area in ha of: fallow lying land, permanent grasslands, meadows, mountain pastures, flowering grasslands. Linear length in meters of flower strips, buffer strips, grass strips and field margins. 3- Water elements: number of ponds; average surface area in ha of ponds; surface area in ha of wetlands; linear length in meters of ditches. 4- Stone/rock elements: Linear length in meters of dry stone walling or terrace. 5- Complex structures: Linear length in meters of multi-strata hedges including riparian galleries (min. 4-m width); surface area in ha of agroforestry; trees (forest+crops) per ha.		Case specific field work conducted by farmers using a software of multi-criteria assessment to help decision-making	https://www.biodiversity-performance.eu/
Root Pathogen Pressure Rating (SHAP - Cornell)	It is a measure of how sensitive test-plant roots show disease symptoms when grown in standardized conditions in assayed soil. Assessed by rating washed roots through visual inspection for disease symptoms.		Case specific field work in which farmers ship soil samples to cornell soil health laboratory.	https://soilhealth.cals.cornell.edu/training-manual/
Seal soil change (Copernicus)	A categorical indicator that maps the changes in Imperviousness (new cover, loss of cover, increased and decreased densities) or soil sealing and is based primarily on the analysis of NDVI (Normalized Difference Vegetation Index). Changes are available between 2012 - 2015 and 2015 - 2018.		The HRLs are produced from satellite imagery through a combination of automatic processing and interactive rule based classification. Since 2018, the products have increased in resolution to 10 meters.	https://land.copernicus.eu/pan-european/high-resolution-layers/forests/tree-cover-density/change-maps
Share of Ecological Focus Area in total arable land (CAP - EU)	One of the 6 Indicators contributing to the assessment of the performance of the Common Agricultural Policy. Ecological focus area corresponds to arable land in hectares dedicated to 'ecologically beneficial elements'. It is calculated as follows: The number of hectares declared by farmers as EFA, total and by EFA type, out of the total arable land. EFA types are: (a) land lying fallow; (b) terraces; (c) landscape features; (d) buffer strips; (e) agro-forestry; (f) strips along forest edges; (g) short rotation coppice; (h) afforested areas; (i) catch crops, or green cover; (j) nitrogen-fixing crops.		Data notified by Member State (number of hectares declared by farmers as EFA under direct payments).	https://ec.europa.eu/info/sites/default/files/food-farming-fisheries/key_policies/documents/result-indicator-fiches-pillar-i_en.pdf

Indicator	Description		Input data	Link to document
Share of agricultural area in Natura 2000 (CAP - EU)	One of the 6 Indicators contributing to the assessment of the performance of the Common Agricultural Policy. Natura 2000 is the main European network of protected areas aiming to improve the conditions for habitats and birds. The indicator provides information on the area protected under Natura 2000 that is used for agriculture and/or forestry. It consists of 3 sub-indicators: 1. share of territory under Natura 2000 by categories (Special Protection Areas - SPAs, Sites of Community Importance - SCIs, Natura 2000's network) 2. share of UAA under Natura 2000 (agricultural area, agricultural area including natural grassland) 3. share of forest area under Natura 2000 (forest area, forest area including transitional woodland-shrub)		1: Natura 2000 Barometer Statistics Report (release version End2018 – 15/03/2019) 2-3: CORINE Land Cover (CLC) 2018	https://ec.europa.eu/info/sites/default/files/food-farming-fisheries/key_policies/documents/context-indicator-fiches_en.pdf
Share of land under contracts supporting biodiversity and/or landscapes and forest (CAP - EU)	One of the 6 Indicators contributing to the assessment of the performance of the Common Agricultural Policy. The hectares of agricultural land and forestry under management contracts supporting biodiversity and/or landscapes reported divided by the total Utilised agricultural area.		The hectares under management contracts are reported by Member States to the Commission in the Annual implementation reports (AIR) of Rural Development programmes. The denominator refers to 2013 data in the Farm Structure Survey (Eurostat).	https://ec.europa.eu/info/sites/default/files/food-farming-fisheries/key_policies/documents/target-and-result-indicator-fiches-pillar-ii_en.pdf
Small Woody Features (Copernicus)	A categorical indicator that provides harmonized information on both Small Woody Features (SWFs - woody linear and small patchy elements, but will not be differentiated into trees, hedges, bushes, and scrub. The spatial pattern shall be limited to linear structures and isolated patches (patchy structures) based on geometric characteristics) and Additional Woody Features (AWFs- woody structures that do not fulfill the SWF geometric specifications but which are connected to valid SWFs structures.).		The HRLs are produced from satellite imagery through a combination of automatic processing and interactive rule based classification. Since 2018, the products have increased in resolution to 10 meters.	https://land.copernicus.eu/pan-european/high-resolution-layers/small-woody-features
Soil fertility (Agrocares)	This measure is composed of three main indicators: 1- Ph scale (pH (KCl)) micro 2- Micronutrients: (Aluminium (exch.) (%); Boron (exch.) (mmol-/kg); Boron (Mehlich 3) (mg/kg); Lime (g/kg); Total Zinc (g/kg); Total Copper (mg/kg); Electrical conductivity (dS/m); Iron (Mehlich 3) (mg/kg); Potassium (Mehlich 3) (mg/kg); Magnesium (Mehlich 3) (g/kg); Manganese (M3) (mg/kg); Molybdenum (mg/kg); Sodium (exch.) mmol+/kg); Phosphorus (Mehlich 3) (mg/kg); CEC (mmol+/kg); Copper (Mehlich 3) (mg/kg); Organic matter (g/kg); Zinc (Mehlich 3) (mg/kg); Clay (%); Sand (%); Silt (%). 3- Macro nutrients (Total nitrogen (g/kg); Total phosphorus (g/kg); Potassium (exch.) (mmol+/kg); Total Sulfur (g/kg);Calcium (exch.) (mmol+/kg); Magnesium (exch.) (mmol+/kg))		Case specific field work conducted by farmers using the Lab-in-a box toolkite provided by Agrocare, and comparing with their Global Soil Database.	https://webshop.agrocares.com/
Soil fertility (Biodiversity Performance Tool)	One indicator of the BPT index "Characterization of farming practices". It is divided into several easy-to-answer questions based on farm observations. The farmer responds directly on the free-access platform and the software analyses the data to provide a report on the state of potential for biodiversity on a farm and recomend improvement actions. - A categorical measure to evaluate: Length of crop rotation; Mass-flowering crops such as legume oilseed rape sunflower orchards vegetable; Percentage of legumes including temporary grassland; Soil analysis with SOM; Soil analysis with soil microbiological activities; Presence of cover crops; Presence of intercropping; Typology of permanent crops such as orchards or vineyards; Soil management.		Case specific field work conducted by farmers using a software of multi-criteria assessment to help decision-making	https://www.biodiversity-performance.eu/
Soil nematode abundance at a global scale (Academic collaboration)	Using thousand of samples, the authors generated a mechanistic understanding of the patterns of the global abundance of nematodes in the soil and the composition of their functional groups.		6,759 georeferenced samples	https://www.researchgate.net/publication/334662921_Soil_nematode_abundance_and_functional_group_composition_at_a_global_scale
Soil Protein (SHAP - Cornell)	It is a measure of the fraction of the soil organic matter, which contains much of the organically bound N. Microbial activity can mineralize this N and make it available for plant uptake. This is measured by extraction with a citrate buffer under high temperature and pressure.		Case specific field work in which farmers ship soil samples to cornell soil health laboratory.	https://soilhealth.cals.cornell.edu/training-manual/
Soil Respiration (SHAP - Cornell)	It is a measure of the metabolic activity of the soil microbial community. It is measured by re-wetting air-dried soil and capturing and quantifying carbon dioxide (CO2) produced.		Case specific field work in which farmers ship soil samples to cornell soil health laboratory.	https://soilhealth.cals.cornell.edu/training-manual/
Soil-based Climate-Smartness Index (SCSI)	The SCSI is computed using normalized indicators of trend and variability of annual changes on yield and SOC data.			https://www.sciencedirect.com/science/article/pii/S0308521X21000391

Annexes

Indicator	Description		Input data	Link to document
Species Diversity (ALL-EMA Switzerland)	The ALL-EMA ('Agricultural Species and Habitats') monitoring programme was developed in order to evaluate the extent to which the agriculture-related Environmental Objectives for biodiversity in species and habitats have been achieved. This is one of five target values, in order to provide answers to the following questions: What is the state of species diversity in the agricultural landscape, and how is this changing? Species Diversity) * Number of plant species, butterfly species and nesting-bird species (gamma diversity) * Number of plant species per sampling area (alpha diversity) * Dissimilarity of plant communities between sampling areas		1- Data for ALL-EMA are collected from 170 survey squares. Only the agricultural landscape is sampled within the 1km2 survey squares, e.g. forests and settlements are ignored. The balanced selection of survey squares allows us to derive representative results for the individual agricultural zones and the main regions of the agriculture-related environmental objectives. Data on butterfly occurrences on transects are recorded by Biodiversity Monitoring Switzerland BDM, whilst data on breeding territories of the breeding birds are collected by the Common Breeding Bird Survey MHB. 2- Using aerial images, ALL-EMA stereoscopically records woody structural elements within the survey squares in collaboration with the Swiss Federal Institute for Forest, Snow and Landscape Research WSL. This produces a detailed map illustrating hedgerows and shrubs, individual trees and groups of trees as well as individual bushes and groups of bushes. 3- Within the agricultural landscape of each survey square, a regular 50-metre grid defines the sampling points for data collection in the field, the so-called habitat survey. 4- For each grid point, habitat type and diversity of characteristic habitat-type species are determined on a circular area of 10m2. More on the habitat survey. On an extended circular area of 200m2, neophytes on the Black List and structures of the agricultural landscape such as piles of branches, clearance cairns and small water bodies are recorded. A GPS device is used to navigate to the grid points, and data is entered directly into a smartphone. 5- Detailed vegetation surveys (circular areas of 10m2) are conducted in each survey square on around 10% of the habitat surveys.	https://www.agroscope.admin.ch/agroscope/en/home/topics/environment-resources/monitoring-analytics/monitoring-programm-all-ema/programme/Methodology/_jcr_content/par/columncontrols/items/1/column/externalcontent_1559084617.bitexternalcontent.exturl.pdf/aHR0cHM6Ly9pcmEuYWdyb3Njb3BlLmNoL2AvQWpheC9FaW56ZW/xwdWJsaWthdGlvbi9Eb3dubG9hZD9laW56ZWxwdWJsaWthdGlv/bklkPTQxMDA0.pdf
Species Quality (ALL-EMA Switzerland)	The ALL-EMA ('Agricultural Species and Habitats') monitoring programme was developed in order to evaluate the extent to which the agriculture-related Environmental Objectives for biodiversity in species and habitats have been achieved. This is one of five target values, in order to provide answers to the following questions: What is the state of species diversity in the agricultural landscape by quality-indicating species according to the according to the agriculture-related environmental objectives - AEOs, and how is this changing? * Number of AEO plant species, AEO butterfly species and AEO nesting-bird species (gamma diversity) * Number of AEO plant species per sampling area * Percentage of sampling areas with invasive neophytes		1- Data for ALL-EMA are collected from 170 survey squares. Only the agricultural landscape is sampled within the 1km2 survey squares, e.g. forests and settlements are ignored. The balanced selection of survey squares allows us to derive representative results for the individual agricultural zones and the main regions of the agriculture-related environmental objectives. Data on butterfly occurrences on transects are recorded by Biodiversity Monitoring Switzerland BDM, whilst data on breeding territories of the breeding birds are collected by the Common Breeding Bird Survey MHB. 2- Using aerial images, ALL-EMA stereoscopically records woody structural elements within the survey squares in collaboration with the Swiss Federal Institute for Forest, Snow and Landscape Research WSL. This produces a detailed map illustrating hedgerows and shrubs, individual trees and groups of trees as well as individual bushes and groups of bushes. 3- Within the agricultural landscape of each survey square, a regular 50-metre grid defines the sampling points for data collection in the field, the so-called habitat survey. 4- For each grid point, habitat type and diversity of characteristic habitat-type species are determined on a circular area of 10m2. More on the habitat survey. On an extended circular area of 200m2, neophytes on the Black List and structures of the agricultural landscape such as piles of branches, clearance cairns and small water bodies are recorded. A GPS device is used to navigate to the grid points, and data is entered directly into a smartphone. 5- Detailed vegetation surveys (circular areas of 10m2) are conducted in each survey square on around 10% of the habitat surveys.	https://www.agroscope.admin.ch/agroscope/en/home/topics/environment-resources/monitoring-analytics/monitoring-programm-all-ema/programme/Methodology/_jcr_content/par/columncontrols/items/1/column/externalcontent_1559084617.bitexternalcontent.exturl.pdf/aHR0cHM6Ly9pcmEuYWdyb3Njb3BlLmNoL2AvQWpheC9FaW56ZW/xwdWJsaWthdGlvbi9Eb3dubG9hZD9laW56ZWxwdWJsaWthdGlv/bklkPTQxMDA0.pdf
Surface and subsurface Hardness (SHAP - Cornell)	1- Surface Hardness: is a measure of the maximum soil surface (0 to 6-inch depth) penetration resistance (psi), or compaction, determined using a field penetrometer. 2- Subsurface Hardness: A measure of the maximum resistance (psi) encountered in the soil between 6 to 18-inch depths using a field penetrometer.		Case specific field work in which farmers ship soil samples to cornell soil health laboratory.	https://soilhealth.cals.cornell.edu/training-manual/
The Environmental Impact Quotient (U. Cornell)	The EIQ is used to determine the environmental impact in a particular landscape calculating the EIQ field use rating (FUR): EIQ x % active ingredient x dose (volume/mass per area). If multiple active ingredients are in use, you would add the EIQ-FUR scores across the landscape. A lower EIQ-FUR value indicates a lower environmental impact.		Case specific field work	https://nysipm.cornell.edu/eiq/
Threats to species (Landscale):	A qualitative indicator in which the assessment team decides the field metrics. 1- Changes in threats to threatened species using The IUCN's Species Threat Abatement and Recovery (STAR)		Case specific field work conducted by an interdsciplinary team during various weeks on a lanscape which boundaries were previously defined.	https://www.landscale.org/wp-content/uploads/2020/10/Assessment-Guidelines_V0.2_Oct2020-1.pdf

Annexes

Indicator	Description		Input data	Link to document
Tree Cover Density and Tree Cover Change Mask(Copernicus)	1- A continuous indicator that provides information on the proportional crown coverage per pixel at 10m spatial resolution and ranges from 0% (all non-tree covered areas) to 100%, whereby Tree Cover Density is defined as the "vertical projection of tree crowns to a horizontal earth's surface. " 2- A categorical indicator that maps the changes in Tree Cover Change Mask. It consists of 4 thematic classes (unchanged areas with no tree cover / new tree cover/loss of tree cover / unchanged areas with tree cover) at 20m spatial resolution. It provides information on the change between the reference years 2015 and 2018.		The HRLs are produced from satellite imagery through a combination of automatic processing and interactive rule based classification. Since 2018, the products have increased in resolution to 10 meters.	https://land.copernicus.eu/pan-european/high-resolution-layers/forests/tree-cover-density
Water and Wetness (Copernicus)	A categorical indicator that shows the occurrence of water and wet surfaces over the period from 2012 to 2018 with four defined classes of (1) permanent water, (2) temporary water, (3) permanent wetness, and (4) temporary wetness.		The HRLs are produced from satellite imagery through a combination of automatic processing and interactive rule based classification. Since 2018, the products have increased in resolution to 10 meters.	https://land.copernicus.eu/pan-european/high-resolution-layers/water-wetness
Water management (Biodiversity Performance Tool)	One indicator of the BPT index "Characterization of farming practices". It is divided into several easy-to-answer questions based on farm observations. The farmer responds directly on the free-access platform and the software analyses the data to provide a report on the state of potential for biodiversity on a farm and recomend improvement actions. - A categorical measure to evaluate: Type of water use, material for irrigation, water management.		Case specific field work conducted by farmers using a software of multi-criteria assessment to help decision-making	https://www.biodiversity-performance.eu/
Yield in agriculture, grazing intensity and wood extraction (Hercules)	Landscape management (Hercules). An index calculated through various indicator, depending on land use: 1- Yields in Agriculture: A categorical indicator of Total Energy Content Output per ha per year (five groups) derived from CORINE and CAPRI databases. 2- Grazing intensity: a categorical indicator of density (five groups of livestock unit per km2) using a probabilistic model informed by regional statistics on livestock, land cover data, and socioeconomic data. 3- Wood extraction: a continuous indicator of wood extraction in 1000m3/km2, modeled using European and national forest databases.		CORINE land-cover for the years 1990, 2000, and 2006 CAPRI-Dynaspat database CLC 2000 land cover data (EEA, 2005) EU-wide regional statistics on livestock types National Forest Services / Institutes	http://www.hercules-landscapes.eu/tartalom/HERCULES_WP4_D4_2_UBER.pdf

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