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Reconciling agricultural production with biodiversity conservation

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Introduction

More intensive, monocultural agriculture has been associated with a decline in diversity of habitat and plant species which leads to corresponding declines in diversity of insect, bird and mammal species. There is mounting evidence that a more biodiverse landscape improves ecosystem services which benefits farmers. This collection summarises the wealth of research on ways of improving biodiversity in agricultural landscapes, with a focus on temperate agriculture.

The first part of this volume reviews landscape approaches to biodiversity conservation, mapping and modelling biodiversity as well as assessing the economic value of biodiversity conservation practices. Part 2 reviews management practices promoting biodiversity such as field margins and hedgerows, ways of reconciling agricultural production and biodiversity in grassland management as well as the role of agroforestry in promoting biodiversity.

Part 1 Methods to study biodiversity in agroecosystems

The book begins with a focus on the challenge of mapping biodiversity in agricultural landscapes at the EU level. Chapter 1 reviews the current surveys of biodiversity in agricultural areas in the EU. It begins by examining established surveys, ongoing pilots and plans for new surveys at the EU level, focusing specifically on the monitoring of farmland birds and butterflies, grasslands, pollinators and soil biodiversity. The chapter also assesses where we stand in the short–medium term in terms of our knowledge of agrobiodiversity in the EU and which gaps still need to be filled to sufficiently describe biodiversity dynamics.

The next chapter looks at modelling biodiversity in agriculture. Models have been widely used in agricultural science to understand complexity, predict the consequence of change and extend knowledge to new scales. ‘Crop modelling’ began in the 1960s and is now well advanced and applied globally but is restricted to a few economic species. More recently, modelling has been expanded to cover biota as mediators of ecological process or as endpoints for assessment of environmental status. Chapter 2 examines the range of modelling approaches in biodiversity studies, including individual-based approaches that combine within- and between-species diversity, process-based models operating at plot, field and increasingly at landscape scales, integrated system models that seek optimal trade-offs between biodiversity and economic outputs, and global frameworks that combine the biophysical, economic, social and political forces acting on biodiversity. The chapter concludes with a more practical approach known as multi-attribute decision modelling that can be developed and applied by biodiversity managers and planners.

The subject of Chapter 3 is assessing the economic value of agricultural biodiversity. The chapter reviews developments in methods to assess the economic value of agricultural biodiversity, outlines their limitations and proposes a possible, novel way forward. It discusses the different definitions of agrobiodiversity. It then highlights ways of evaluating agrobiodiversity. This is followed by two sections, the first introducing and discussing the ecosystem services framework (ESF) and its limitations, the second outlining the integration of ecosystem interactions in the ESF. The chapter then explores two fundamental problems affecting the evaluation of agricultural biodiversity: the ecosystem services whose value cannot be derived from the market and uncertainty. On the basis of these considerations, the authors propose a novel way forward, the investor perspective, where by giving the natural environment the rights of a legal persona enshrined in a Bill of Rights, the authors address many of the drawbacks of current evaluation methods. The chapter concludes with recommendations for evaluators and decision and policy makers, and with an extended bibliography.

The final chapter of Part 1 examines functional biodiversity for the provision of agroecosystem services. In the context of sustainable agricultural development, the provision of other services beyond production is becoming a priority. Chapter 4 highlights that a functional approach to agrobiodiversity is the best approach to meeting this goal in both research and agricultural practice. The chapter includes an analysis of the development of studies on agriculture-biodiversity relationships and refers to two milestones that had a tremendous impact on research: the United Nation's Convention on Biological Diversity (1992) and the Millennium Ecosystem Assessment (2005). Interest in the functional aspects of agrobiodiversity, i.e. the potential or actual provision of ecosystem services, has boomed in the latest 15 years, yet use of the term 'functional biodiversity' is still scarce. The chapter also provides a trait-based definition of functional biodiversity and a four-step methodology that should shed light on the potential of elements at each agrobiodiversity level – from gene to species and habitat – to provide single or multiple agroecosystem services in any context.

Part 2 Management practices to support agroecosystem services

Part 2 begins by discussing the role of field margins in biodiversity conservation in agroecosystems. Chapter 5 reviews research on ways of modifying the agricultural landscape to reverse the decline in a range of fauna and flora. The chapter starts by looking at the range of options for promoting biodiversity in agricultural landscapes. It then focuses on field margins, their characteristics and types as well as the role of field margins in agroecosystems. The chapter then reviews research on managing field margins to promote insect biodiversity. It also looks at managing field margins to promote rare arable plants (RAP), reptiles, amphibians, birds and mammals.

Chapter 6 considers the role of hedgerows in supporting biodiversity and other ecosystem services in intensively-managed agricultural landscapes. Over the past half century, agricultural intensification has substantially changed agricultural landscapes and farming systems. These changes have been beneficial to provisioning services, i.e. agricultural yields, but detrimental for biodiversity and associated ecosystem services. As a contribution to halting and reversing the decline, it has been suggested that conserving and/or restoring hedgerows would be beneficial. Hedgerows are key features of agricultural landscapes. The chapter begins by highlighting what hedgerows are and their role as a habitat in promoting biodiversity. It then looks at hedgerows and hedgerow networks and goes on to examine how hedgerows contribute to the provision of ecosystem services. The chapter also provides a case study on hedgerow plantation and bocage restoration and how it enhances biodiversity and other ecosystem services. It concludes by providing potential areas for future research as well as resources for further information.

The subject of Chapter 7 is reconciling production and biodiversity in management of pastures and grasslands. Grasslands are crucial for the conservation of biodiversity across the world. Current agricultural practices have increasingly replaced grasslands by crops or managed them more intensively, resulting in a dramatic reduction of biodiversity. Is it possible to reconcile profitable grassland production with conservation of biodiversity? The chapter reviews research on the relationship between biodiversity and the quantity and quality of biomass produced by grasslands. It also shows it is possible to manage grasslands to reconcile production and biodiversity of grasslands. A case study on flowering meadows is also provided, followed by an analysis of potential future trends in research.

The final chapter of the book focuses on the importance of agroforestry systems in supporting biodiversity conservation and agricultural production from a European perspective. Chapter 8 begins by reviewing the contribution of agroforestry to global biodiversity goals. It then discusses agroforestry and the protection of species and habitats, followed by a discussion of agroforestry and the maintenance and restoration of ecosystems. The chapter also analyses the importance of achieving sustainable agriculture and forestry practices as well as preserving global biodiversity.

Part 1

Methods to study biodiversity in agroecosystems

Chapter 1

The challenge of monitoring biodiversity in agricultural landscapes at the EU level

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1 Introduction

Following the acknowledgement that biodiversity in agricultural lands globally and in the European Union (EU) has been strongly impacted by the intensification of agricultural practices (Dudley and Alexander, 2017; IPBES, 2019), many efforts have been carried out to revert the trend, starting with

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agri-environmental schemes becoming compulsory for EU Member States in 1992 (EU Regulation 2078/92) (Batary et al., 2015) aimed at reducing pressures from agriculture in order to meet environmental objectives such as the protection or enhancement of biodiversity, the improvement of soil, water, landscape and air quality, climate change mitigation and adaptation.

Through the Common Agricultural Policy (CAP) cycles that followed, the concern for biodiversity has been embedded into the legislation as a target in general (e.g. protection and enhancement of biodiversity in axis 2 of rural development policy) and in specific terms (e.g. high nature value farming and forestry) (2006/144/EC). Persisting concerns about the fate of biodiversity, which emerged most evidently in the public consultation on modernizing and simplifying the common agricultural policy launched by the European Commission (EC) in 2017[1], have been embedded in the legislative proposal for the CAP post-2020 (COM (2018) 392 final), which identifies as one of its nine priorities to 'contribute to the protection of biodiversity, enhance ecosystem services and preserve habitats and landscapes'.

In parallel, environmental legislation through the decades has targeted rare and threatened species, and rare natural habitats (EEC, 1979; EEC, 1992; European Parliament and the Council of the European Union, 2009): as a result, the European Union currently hosts the largest coordinated network of protected areas in the world, the Natura 2000 Network[2]. By adding the concept of restoration to the protection concept, the legislation of the past two decades has widened the scope, addressing all habitats and not only those more endangered and ecologically valuable. This started with the Commission's proposal to the Gothenburg European Council (EC, 2001), which calls for protecting and restoring habitats and natural systems and halting the loss of biodiversity by 2010, a concept which was reinforced in the EU Biodiversity Strategy to 2020 (EC, 2011). The latter, introducing the concept of ecosystem services, makes all habitats possible targets for restoration. In particular, target 3, which relates to agriculture specifically, defines the goal of maximizing '*areas under agriculture across grasslands, arable land and permanent crops that are covered by biodiversity-related measures under the CAP so as to ensure the conservation of biodiversity and to bring about a measurable improvement in the conservation status of species and habitats that depend on or are affected by agriculture and in the provision of ecosystem services as compared to the EU2010 Baseline, thus contributing to enhance sustainable management*'. The EU Biodiversity Strategy to 2030 reinforces this line of action by dedicating a whole section to bringing nature back to agricultural land (EC, 2020 – Section 2.2.2)[3].

[1] https://ec.europa.eu/agriculture/sites/agriculture/files/consultations/cap-modernising/highlights-public-consul_en.pdf
[2] (https://ec.europa.eu/environment/nature/natura2000/index_en.htm)
[3] https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1590574123338&uri=CELEX:52020DC0380

Lastly, legislative requirements that contribute to biodiversity preservation also include the so-called 'environmental safeguards' directives, requiring formal environmental assessments to be carried out for projects (under Directive 85/337/EEC[4] and following amendments), and plans/programs (under Directive 2001/42/EC[5]) with potential detrimental effects, including on biodiversity and habitats.

To assess the effectiveness of such efforts different techniques are applied, spanning from the analysis of case study areas (Kettunen and Ten Brink, 2006; Kleijn et al., 2006) to the use of proxies (Alliance Environnement, 2017) or models (Kok et al., 2018). In this frame, there is, overall, a lack of data recorded through monitoring efforts, EU wide assessments are in fact presently relying on a limited set of surveyed data: farmland birds (Gregory et al., 2005)[6], grassland butterflies (EEA, 2013a) and the reporting under the Birds and Habitats Directive (EC, 2015).

Biodiversity decline, and in particular the loss of genetic diversity, is within the nine global-scale processes that are essential to maintain the earth system in a resilient and accommodating state defined by Steffen et al. (2015), one of the two processes laying outside the safe operating space. Despite the urgency to revert the trend and the efforts from the policy side to incorporate the concern, signals are not encouraging (EC, 2020). Better targeting and improved assessments need filling knowledge gaps and using updated and detailed data, covering different taxa. Moreover, in the frame of planning, implementing, monitoring and assessing EU policy, sources of information should cover the entire European Union, and should be based on a harmonized approach for data collection. Establishing surveys is an important way to guarantee that such information becomes available.

The EU Biodiversity Strategy to 2020 defines biodiversity as 'the unique variety of life on our planet', the UN Convention on Biological Diversity as '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, 1993). Such definitions suggest a complexity that is probably the reason why it has been so difficult to put in place a large-scale monitoring system that includes surveys of the main components of biodiversity. Surveys can be burdensome and therefore the costs can exceed current financial and administrative capacity, especially when an entire continent should be covered. Nevertheless, initiatives and pilots are ongoing, to enlarge the available data pool.

This chapter reviews where we stand in surveying biodiversity in agricultural areas at the EU level as well as plans to increase monitoring efforts.

[4] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:01985L0337-20090625
[5] https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32001L0042
[6] https://pecbms.info/trends-and-indicators/indicators)

The sections that follow describe established surveys, ongoing pilots and plans for new surveys at the EU scale. A multiplicity of information is available at local/regional/national scale, but this chapter focusses on the long and winding road to wall-to-wall coverage of the European Union. At the end, the point can be made on where we will stand in the short-medium term with our knowledge of agro-biodiversity in the European Union, and which gaps still need to be filled to appropriately and sufficiently describe biodiversity dynamics.

2 Farmland birds and butterflies

2.1 The Pan-European common bird monitoring scheme

Many countries of the European Union are characterized by a long-lasting tradition of bird-watching, on which scientifically grounded countrywide surveys were nested. Countries such as Finland, Sweden and Denmark organized a countrywide monitoring scheme in 1975, the United Kingdom in the 1960s. Others started later on, but nowadays all EU countries except Malta have a monitoring scheme in place.

In 2002, the Pan-European Common Bird Monitoring Scheme (PECBMS) was started as a joint initiative of the European Bird Census Council (EBCC) and BirdLife International, with the aims of: collecting data on European common bird species from national monitoring schemes and calculate European common bird indices and indicators, to raise awareness and to feed the policy process; support the national coordinators in setting up the schemes, and guarantee a harmonized approach in the calculation of the indices; explore the relation between population trends and main driving forces (EBCC, 2019).

Most surveys are carried out through point or line transect counts, where the selection of the plots to be surveyed (each plot containing one or more point or transect) is made either following rigorous statistical procedures (e.g. systematic selection, stratified random selection) or a free choice approach (Table 1). The surveyor visits the assigned location one or more times during the year, in predetermined time windows (e.g. 10 May–20 June as in the Italian survey), and records the individuals seen or heard. A thorough statistical analysis is followed to identify errors and outliers.

The extraordinary component of PECBMS are the thousands volunteers who count the birds in the field, each year, according to a methodology standardized at national level. The data are sent to the national offices, where, using TRIM software made available by PECBMS (van Strien et al., 2001; Statistics Netherlands, 2017), calculate the national species indices and trends. PECBMS combines national species indices with supra-national indices for individual species for the European Union and its main regions (new and old European Union, and West, South, North, Central and East Europe), plus Europe

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Table 1 Principal characteristics of national breeding birds monitoring schemes

Country	Generic breeding bird monitoring scheme	Contributes to PECBMS	Start year	Field survey methods	Selection of plots	Number of species
Austria	Yes	Yes	1998	Point counts	Free choice	85
Belgium	Yes	Yes	1990	Point counts	Stratified random, other	134
Bulgaria	Yes	Yes	2004	Line transects	Stratified random	63
Croatia	Yes	Not yet	2015	Point counts	Stratified semi-random	30
Cyprus	Yes	Yes	2006	Line transects	Other	45
Czech Republic	Yes	Yes	1982	Point counts, line transects	Free choice, stratified random	218
Denmark	Yes	Yes	1975	Point counts	Free choice	143
Estonia	Yes	Yes	1983	Point counts	Free choice	90
Finland	Yes	Yes	1975	Point counts, line transects, other	Systematic, other	140
France	Yes	Yes	1989	Point counts	Other	150
Germany	Yes	Yes	1989	Line transects, point counts, territory mapping	Free choice, stratified random	100
Greece	Yes	Yes	2007	Point counts	Stratified random	233
Hungary	Yes	Yes	1999	Point counts	Stratified random	420
Ireland	Yes	Yes	1998	Line transects	Stratified random	55
Italy	Yes	Yes	2000	Point counts	Random	103
Latvia	Yes	Yes	1995	Point counts, territory mapping	Random, systematic, other	90
Lithuania	Yes	Yes	1994	Point counts	Stratified semi-random	70

(Continued)

Table 1 (Continued)

Country	Generic breeding bird monitoring scheme	Contributes to PECBMS	Start year	Field survey methods	Selection of plots	Number of species
Luxembourg	Yes	Yes	2002	Point counts, territory mapping, line transect	Random, stratified random	120
Malta	No					
Netherlands	Yes	Yes	1984	Territory mapping, point counts, line transects	Free choice, random, stratified random	100
Poland	Yes	Yes	2000	Line transects	Stratified random	110
Portugal	Yes	Yes	2004	Point counts	Stratified random	64
Romania	Yes	Yes	2006	Point counts	Stratified semi-random	70
Slovak Republic	Yes	Yes	1994	Point counts	Free choice	100
Slovenia	Yes	Yes	2007	Line transects	Stratified non-random	29
Spain	Yes	Yes	1996	Point counts, line transects	Stratified random, other	200
Sweden	Yes	Yes	1975	Point counts, line transects	Free choice, systematic	180
United Kingdom	Yes	Yes	1966	Territory mapping, line transects	Free choice, stratified random	111

Table 2 Species composing the EU farmland bird index

Alauda arvensis	*Emberiza melanocephala*	*Passer montanus*
Alectoris rufa	*Falco tinnunculus*	*Perdix perdix*
Anthus campestris	*Galerida cristata*	*Petronia petronia*
Anthus pratensis	*Galerida theklae*	*Saxicola rubetra*
Bubulcus ibis	*Hirundo rustica*	*Saxicola torquatus*
Burhinus oedicnemus	*Lanius collurio*	*Serinus serinus*
Calandrella brachydactyla	*Lanius minor*	*Streptopelia turtur*
Carduelis cannabina	*Lanius senator*	*Sturnus unicolor*
Ciconia ciconia	*Limosa limosa*	*Sturnus vulgaris*
Corvus frugilegus	*Melanocorypha calandra*	*Sylvia communis*
Emberiza cirlus	*Miliaria calandra*	*Tetrax tetrax*
Emberiza citrinella	*Motacilla flava*	*Upupa epops*
Emberiza hortulana	*Oenanthe hispanica*	*Vanellus vanellus*

as a whole. All indices are annually updated, and EU indices are regularly sent to and published by EUROSTAT[7]. Thirty-nine species compose the Farmland Bird Index (FBI, Table 2). These are common species, which are dependent from agroecosystems for feeding and nesting, and as such are considered to be a descriptor of the state of agroecosystems. The index is a composite, multispecies index calculated using Monte Carlo simulations as described in Soldaat et al. (2017).

Of the monitoring initiatives presented in this paper, this is the only one that has a wall-to-wall coverage of the European Union, with a sampling density sufficient to derive statistically meaningful information at different scales (EU, national, regional), on different ecosystem types (farmland, forest; montane birds and mire birds for North Europe indicators are under development) or climate change (Gregory et al., 2009).

The information is valuable and widely used, since it is considered that, being at the top of the food chain, birds are indicators of the environment's health. The farmland bird indicator is to date the most widespread biodiversity indicator used in EU policies (impact indicator of the CAP[8]; condition indicator of the Monitoring and Assessment of Ecosystems and their Services – MAES[9]), indicator frameworks (Streamlining European Biodiversity Indicators – SEBI[10]; agri-environmental indicators – AEIs[11]; OECD agri-environmental indicators[12]) and global assessments (e.g. FAO, 2019).

[7] https://ec.europa.eu/eurostat/web/products-datasets/-/t2020_rn130
[8] https://ec.europa.eu/info/sites/info/files/food-farming-fisheries/key_policies/documents/impact-indicator-fiches_en.pdf
[9] https://ec.europa.eu/environment/nature/knowledge/ecosystem_assessment/pdf/5th%20MAES%20re port.pdf
[10] https://www.eea.europa.eu/data-and-maps/indicators/abundance-and-distribution-of-selected-species-8/assessment-1
[11] https://ec.europa.eu/eurostat/web/agriculture/agri-environmental-indicators
[12] https://stats.oecd.org/Index.aspx?QueryId=77269&lang=en

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