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Biodiversity Indicators for European Farming Systems

A Guidebook

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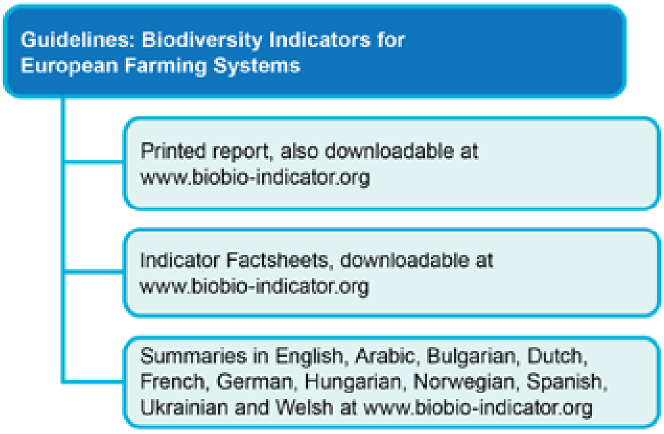
Preface

The report that lies before you summarises the lessons learnt from the EU FP7 Research Project BioBio (Biodiversity indicators for organic and low-input farming systems, KBBE-227161) conducted between 2009 and 2012. The report is aimed at stakeholders and potential users of the indicator set resulting from this research, and is structured as follows:



In addition, supporting information and all other BioBio Project public reports are available at www.biobio-indicator.org.

Summary

The overall objective of the Research Project BioBio – Biodiversity indicators for organic and low-input farming systems (KBBE-227161) was to identify scientifically sound and practicable farmland biodiversity indicators. Based on an exhaustive literature review and in iterative interaction with a stakeholder advisory board, candidate indicators were identified and tested on 195 farms in 12 case-study regions across Europe. The findings permitted a further narrowing-down of the indicator list to a core set of eight indicators for habitat diversity, four indicators for species diversity, three indicators for genetic diversity and eight indicators for farm-management practices. The indicator set has been tested for redundancies, and correlating indicators have been removed. It is applicable across Europe and for major farm types (Table).

The BioBio indicator set complements other indicator systems (IRENA, SEBI):

- State indicators are emphasised (the actual status of agricultural biodiversity);
- Indicators operate at farm scale (rather than at plot, landscape or national scale). Farms are the operational units for decision-making by farmers, administrators and policy-makers.

Guidelines for applying the BioBio indicator set can be summarised as follows:

- Random selection of farms from the "farm population" to be evaluated / monitored;
- Obtain agreement and farm boundaries from farmer;
- Farm-habitat mapping and random selection of plots from among habitat types for species recording;
- Recording of vascular plants, bees, spiders and earthworms via standard methods;
- Farm interview vis-à-vis genetic diversity of crops and livestock, and for management practices.

Table: BioBio indicator set and applicability to major farm types.

	Indicator	Field crops & horticulture	Specialist grazing livestock	Mixed crops - livestock	Permanent crops
Genetic diversity of livestock	Number and amount of different breeds		✓	✓	
	Number and amount of different varieties	✓	✓	✓	✓
	Origin of crops	✓		✓	
Species diversity indicators	Vascular plants	✓	✓	✓	✓
	Wild bees and bumblebees	✓	✓	✓	✓
	Spiders	✓	✓	✓	✓
	Earthworms	✓	✓	✓	✓
Habitat diversity indicators	Habitat richness	✓	✓	✓	✓
	Habitat diversity	✓	✓	✓	✓
	Average size of habitat patches	✓	✓	✓	✓
	Length of linear elements	✓	✓	✓	✓
	Crop richness	✓		✓	
	Percentage of farmland with shrubs	✓	✓	✓	✓
	Tree habitats	✓	✓	✓	
	Percentage of semi-natural habitats	✓	✓	✓	✓
Farm management indicators	Total direct and indirect energy input	✓	✓	✓	✓
	Intensification/Extensification	✓	✓	✓	✓
	Area with use of mineral N-fertiliser	✓	✓	✓	✓
	Total nitrogen input	✓	✓	✓	✓
	Field operations	✓	✓	✓	✓
	Pesticide use	✓		✓	✓
	Average stocking rate		✓	✓	✓
	Grazing intensity		✓	✓	

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 €1'000, mainly for the identification of the species. 0.25 % of European Union expenditure on the Common Agricultural Policy would suffice to implement a biodiversity monitoring on 50,000 farms across Europe. The information thereby obtained would allow for better targeting of agricultural policies towards the Aichi 2020 biodiversity goals.

Applications were tested beyond Europe in Tunisia, Ukraine and Uganda. The BioBio approach proved feasible, but would require adaptations to the countries in question.

1 Introduction

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The diversity of habitats, species, crop varieties and livestock breeds is a cornerstone of farming, with many wild species being reliant upon European farmland. Indicators are needed that will enable us to evaluate the impact of different farming systems and agri-environmental policies on the state of European farmland biodiversity. The European BioBio research project has developed an indicator set for the three major levels of biodiversity: genetic, species and habitat diversity. In addition, farm-management practices have been assessed and linked to biodiversity indicators.

1.1 What is farmland biodiversity?

Arable and pastoral farmland constitutes a dominant land use in Europe, accounting for over 47 % (210 million hectares) of the EU-27 (EC 2007). An estimated 50 % of all European species are reliant on agricultural habitats (Kristensen 2003). Consequently, some of the most critical conservation issues today relate to changes in farming practices which directly affect the wildlife on farms and adjacent habitats.

Farmland biodiversity is determined by the three components of habitat, species and genetic diversity (Figure 1.1):

(i) The diversity of habitats in agricultural landscapes, consisting of intensively used production fields (arable, grassland, orchards) and extensively managed habitats (e.g. semi-natural grasslands, structuring elements such as hedgerows, grassy strips, etc.);

(ii) The species diversity of wildlife which depends on the farmland habitats, including annual flowering plants (some familiar as weeds) in crop fields; grasses and herbs of semi-natural grasslands; small vertebrates such as birds and rodents; numerous arthropods, countless microorganisms, etc.;

(iii) The genetic diversity of crop and fruit-tree varieties, grassland species, and breeds of farm animals. In addition to this, genetic diversity is essential for the population viability of wild plant and animal species.

Farmland biodiversity is the basis for agricultural activities: artificial habitats with favourable conditions for selected varieties of crops and breeds of animals are created by farmers working with the natural conditions of climate, soil and topography for agricultural production, and with benefits from the wild species occurring on the farm (ecosystem services). The latter can either function to support production with services such as pollination, nutrient cycling or predation, or hamper them, as is the case with pests, diseases and problematic weeds.

Figure 1.1: The three components of farmland biodiversity: (a) Habitats in a gently rolling landscape of central Europe; (b) Plant species of a mountain meadow in the Alps; (c) Traditional pig breeds of the Hungarian Puszta. Photos: (a) G. Brändle; (b) G. Lüscher; (c) F. Herzog.

1.2 The status of farmland biodiversity in Europe

Historically, farming activities have substantially increased the diversity of natural European landscapes and habitats by introducing arable fields, grasslands, orchards, etc., primarily at the expense of the forest which previously dominated the European continent (Ellenberg 1988). More recently, the intensification and specialisation of farming practices has led to a simplification of agricultural landscapes and a loss of (semi-natural) habitats. At the same time, the tendency is for marginal farmland to be abandoned and to undergo natural succession, which also leads to the replacement of farmland habitats and the associated species by scrub and secondary forest (Brown 1991).

In 2010 the European Environmental Agency assessed the status of biodiversity (EEA 2010a). Based primarily on the member states' reporting obligations deriving from the Habitats Directive (EC 1992), the report concludes that 76 % of farmland habitats and 70 % of European farmland species have an unfavourable conservation status. These figures relate to European habitats and species of conservation interest – i.e. those that are rare or under threat – as listed in the Habitats Directive. The only information on species which are more common stems from the monitoring of the populations of 38 common farmland birds and of grassland butterflies (Figure 1.2). Both groups have substantially declined – the birds since 1990 and the butterflies since 1980 (EEA 2010b). Apart from this, there is no consistent information on the status of more-common species, despite the fact that these are to a great extent

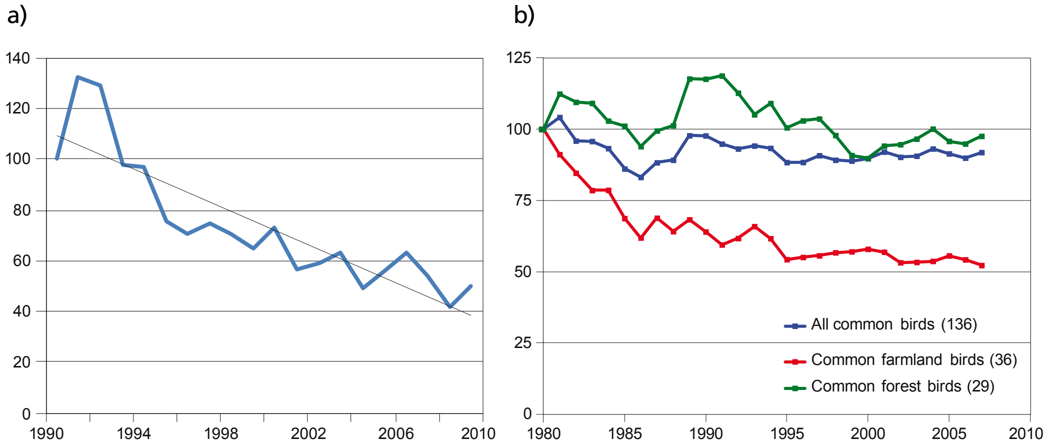

Figure 1.2: Trends of the grassland butterfly index (a) and of the common bird index (b).
Source: EEA (2010).

the ones that interact with farming practices, provide services or cause damage, since they make the greatest contribution to important ecosystem functions (Gaston 2010).
In terms of genetic diversity, the report (EEA 2010) relies on the Food and Agriculture breeds database for animal genetic resources, which lists 2500 European breeds, many of which are endangered. No information is available on the status of crop genetic resources.

Within the framework of the Common Agricultural Policy (CAP), the European Union invests in agri-environmental schemes as a key component of the second pillar (€ 22.2*109 for the period 2007–13, ECA 2011). Many of these schemes aim to promote farmland biodiversity. Since there is very little information available on common farmland biodiversity, it is also difficult to evaluate the respective effects of agri-environment policy and corresponding changes in management practices. The European Court of Auditors found very few "pockets of good monitoring practices" when it assessed the design and management of agri-environmental support measures (ECA 2011).

1.3 What is a farm?

European farms are highly diverse. In the EU27 there are more than $13*10^6$ farms. The average farm size is 12.6 ha, with 70 % of farms being smaller than 5 ha, 24.5 % ranging between 5 and 50 ha in size, and 5 % being larger than 50 ha (EU 2011). Farms can be categorised into different types according to their economic activities, e.g. crop-producing farms, livestock production farms or mixed farms. In the EC (1985), 17 main types of farming are defined, each with specific sub-categories. In addition, there are various farming systems such as organic (EC 2007), non-organic and integrated farming.

In BioBio we defined a farm as the area of land managed by a farmer (owner, tenant), i.e. an economic management unit. The farm consists of both artificial habitats (crop fields, orchards, sown grasslands, etc.) and semi-natural habitats (e.g. hedgerows and extensively managed native grasslands and heaths). Rather than lying adjacent to one another, in many instances the fields of an individual farm may be separated by other farmers' fields, or by land put to non-agricultural use (Figure 1.3). In most situations, therefore, a farm does not constitute a cohesive ecological unit. It is, however, a unit for decision-making (by the farmer). Moreover, agricultural and agri-environmental policies primarily address the farm scale. This is the justification for developing farm-scale biodiversity indicators.

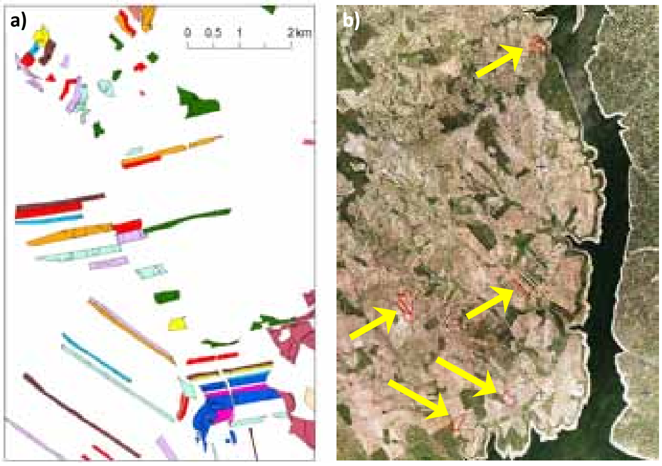

Figure 1.3: (a) Unconsolidated smallholdings in Norway. Fields belonging to a specific farm are the same colour. (b) Scattered plots of an olive farm in Extremadura, Spain. Although they are not cohesive ecological units (in terms of biodiversity), farms represent decision-making units for farmers, administrative bodies and policy-makers. Source: (a) W. Fiellstad, (b) G. Moreno

1.4 What is an indicator?

Which type of indicator is needed depends on the context and the intended application. According to Alexandra *et al.* (1996), "[An] indicator is a measurement that reflects the status of a system, for example an oil pressure gauge on an engine or the number of owls in a forest". This is a simple and straightforward definition of an indicator as a measured value. "Indicators help you understand where you are, which way you are going, and how far you are from where you want to be" (Hart 1995) is a more ambitious (normative) definition of an indicator and implies knowledge of the favourable direction of trend for the in-

dicator values and the threshold values that should be reached. For biodiversity, this knowledge is only partial, i.e. it is available only for the minimum size of viable populations of certain species. There is, however, no threshold value for the number of species or habitats in a region or on a farm. Such values can be defined e.g. in the context of output-oriented agri-environmental schemes, which link the success of a scheme to the occurrence of target species.

Due to the complexity of all its aspects, biodiversity in the broadest sense of the Rio Convention cannot be measured as such, and it is assumed that no single all-inclusive index for biodiversity can be devised (e.g. Büchs 2003). Ideally, indicators that express or represent biodiversity as a whole AND which are sensitive to environmental conditions resulting from e.g. land use and agricultural management practices should be selected.

Indicators for assessing the effects of particular farming systems or agri-environmental schemes on biodiversity have been proposed e.g. by Wascher (2000) and De Roeck (2005), who for the most part rely on standard agricultural statistics as indirect measures of biodiversity. Indirect indicators for biodiversity have been implemented both in life-cycle assessments (e.g. SALCA, Jeanneret *et al.* 2008), and in agro-environmental diagnosis of farms (INDIGO and SOLAGRO in France, KUL/USL and REPRO in Germany). Nevertheless, indirect indicators must be discussed and chosen with caution. As argued by Wascher (2000), because of the huge number of species and the complexity of ecological processes within agricultural habitats, many potential influencial factors may not yet be recognised or monitored. The intensity of agricultural management varies considerably across Europe (Herzog *et al.* 2006), whilst the environmental heterogeneity of the European continent reduces the certainty with which predictions can be made about the link between agricultural management and biodiversity (Dormann *et al.* 2008). Moreover, the impacts of agricultural practices are often poorly understood, so that the most relevant parameters that can be monitored practically are unclear. Indicators of the actual state of biodiversity are therefore essential.

1.5 Identifying farmland biodiversity indicators for Europe

This report summarises the lessons learnt from the EU FP7 BioBio research project (Biodiversity indicators for organic and low-input farming systems, KBBE-227161), conducted between 2009 and 2012. The report addresses stakeholders and potential users of the set of indicators arising from the research.

The objectives of the study were as follows:

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.

A broad range of indicators have been tested against scientific, geographic and practical selection criteria (Figure 1.4). The indicators were required to withstand thorough scientific testing based on a literature review, expert and stakeholder evaluations, and a field test. The resulting indicator core set is applicable across Europe, and was considered practical and desirable following a two-stage stakeholder audit.

Indicators relate to habitat, species and genetic diversity, as well as to farm-management operations which act on farmland biodiversity. Whilst most indicators are applicable to all farm types, some are restricted to e.g. field crops and horticultural systems, specialist grazing livestock systems, mixed crops and livestock systems, or permanent crops.

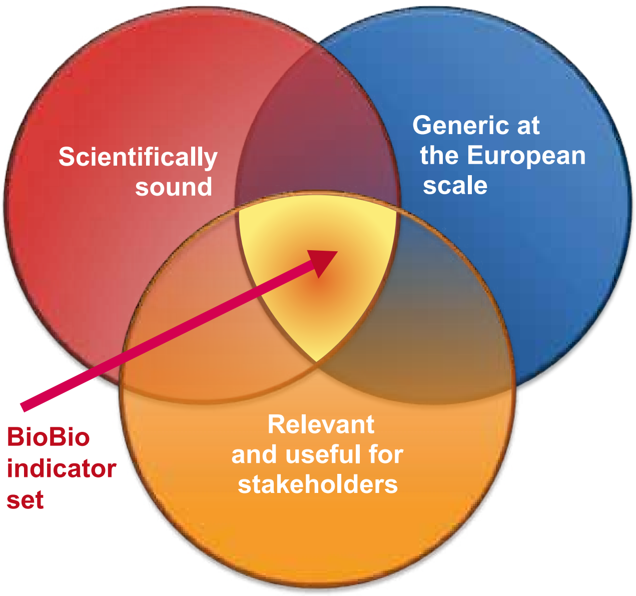

Figure 1.4: Criteria applied for indicator selection.

1.6 Limits of the analysis

The process of testing and filtering indicators involved criteria relating to organic and low-input farming systems, as well as to conventional (non-organic) farming systems which were also tested in the case-study regions. These indicators are therefore also appropriate for non-organic systems of farming. In the majority of the case-study regions, however, farming practices were extensive (low-input) to medium-intensive. Very intensive (at the European scale) farming such as cereal production in the Paris Basin, vegetable production in the south of Spain, or large-scale

animal husbandry in central and eastern Europe are under-represented among the case studies, so the applicability of the indicators would have to be tested in these regions.

Although the analysis also covered the vast majority of European farm types (sensu EC 1985), some farm types, such as specialist citrus fruit, intensive livestock farming (cattle dairying, rearing and fattening combined; specialist granivores) were absent from the case-study regions. Mixed farming types were represented with only one case-study region. The indicators would therefore need to be tested in regions where these farm types are represented prior to application.

Exploratory investigations of the practical application of these indicators were conducted in Tunisia, Ukraine and Uganda. Applicability varied among the three regions and application of the indicator set could not be recommended without additional adaptations.

The BioBio approach

BioBio applied a two-step indicator-filtering approach (figure 1.5). The first step consisted in an exhaustive literature review on potential farmland biodiversity indicators, in which indicators were evaluated in terms of their scientific validity (Dennis *et al.* 2009). The remaining indicators were submitted to the Stakeholder Advisory Board and a set of candidate indicators was selected (Pointereau and Langevin 2012).

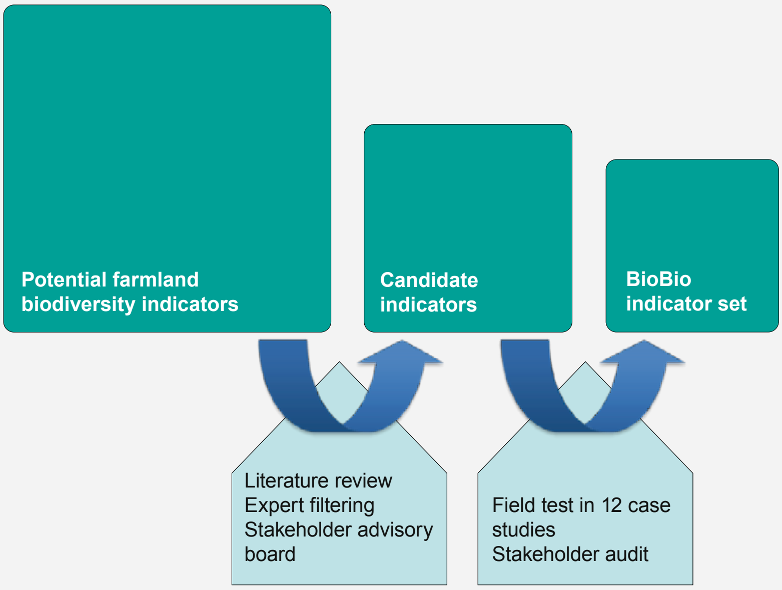

Figure 1.5: Process of indicator filtering in iterative interaction between researchers and stakeholders.

In the second step, the candidate indicators were taken forward for testing in 12 European case studies (Figure 1.6). Case-study regions were homogeneous in terms of biogeographical conditions and farming types. In each region, 8 –20 farms were selected. In regions containing both organic and non-organic farms, farms of both systems were randomly sampled. In 'high nature-value farming' regions (mostly specialist grazing livestock farms), a larger number of farms were screened, and farms were selected along a gradient of livestock density.

Indicators were then measured according to a standard protocol (Dennis *et al.* 2012). The costs of indicator measurement were also recorded. Indicator values were evaluated with respect to redundancies, coherence, applicability across Europe, and unsuitable indicators were discarded (Jeanneret *et al.* 2012). The remaining indicators were audited by the Stakeholder Advisory Board (Pointereau and Langevin 2012). The resulting indicator core set is presented in this report. The broader applicability of the core indicators was then tested in three case studies in Tunisia, Ukraine and Uganda.

ARA-A	Austria	Field crops & horticulture
ARA-F	France	Field crops & horticulture
ARA-Ukr	Ukraine	Field crops & horticulture
HOR-L	The Netherlands	Field crops & horticulture
GRA-B	Bulgaria	Specialist grazing livestock
GRA-C	Switzerland	Specialist grazing livestock
GRA-H	Hungary	Specialist grazing livestock
GRA-N	Norway	Specialist grazing livestock
GRA-W	Wales	Specialist grazing livestock
DEH-E	Spain	Specialist grazing livestock
MIX-D	Germany	Mixed crops & livestock
VIN-I	Italy	Permanent crops
OLI-E	Spain	Permanent crops
OLI-Tun	Tunisia	Permanent crops
INT-Uga	Uganda	Permanent crops

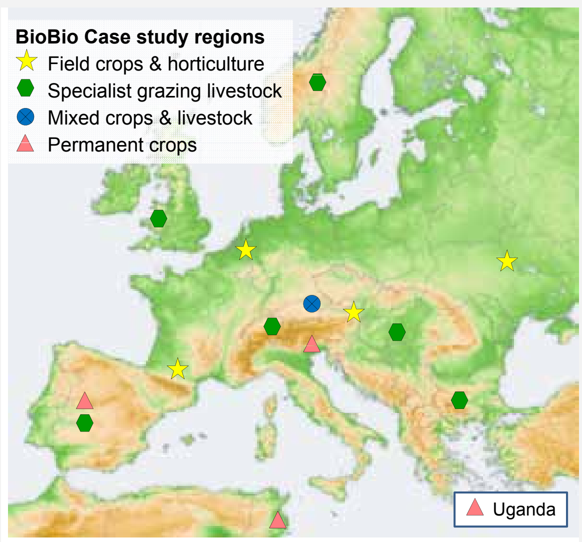

Figure 1.6: BioBio case study regions and farm types (EC 1985).

References

Alexandra J., Haffenden S., White T. 1996. Listening to the land. Australian Conservation Foundation, Fitzroy, Australia.

Brown, V.K. 1991. The effects of changes in habitat structure during succession in terrestrial communities. Habitat Structure In: S. S. Bell, E. D. McCoy and H. R. Mushinsky (Eds) The physical arrangement of objects in space. London, Chapman and Hall, pp. 141–168.

Büchs W. (Ed.) 2003. Biotic Indicators for Biodiversity and Sustainable Agriculture. Agriculture, Ecosystems and Environment 98 - Special Issue.

De Roeck E. (Ed.) 2005. Trends of some agri-environmental indicators in the European Union. Report EUR 21 669 EN, European Commission Directorate General Joint Research Centre, Ispra, Italy, 220 pages.

Dennis P., Arndorfer M., Balázs *et al.* 2009. Conceptual foundations for biodiversity indicator selection for organic and low-input farming systems. Aberystwyth, Deliverable 2.1 of the EU FP7 Project BioBio. ISBN 978-3-905733-16-7. http://www.biobio-indicator.org/deliverables.php

Dennis P., Bogers M.M.B., Bunce R.G.H., Herzog F. & Jeanneret P. 2012. Biodiversity in organic and low-input farming systems. Wageningen, Deliverable 2.2 of the EU FP7 Project BioBio. ISBN 1566-7197. ALTERRA Report 2308. http://www.biobio-indicator.org/deliverables.php

Dormann C.F., Schweiger O., Arens P. *et al.* 2008. Prediction uncertainty of environmental change effects on temperate European biodiversity. Ecology Letters 11, 235–244.

EC, 1985. Commission Decision of 7 June 1985 establishing a Community typology for agricultural holdings (85/377/EEC). http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:1985D0377:20030523:EN:PDF [Accessed 23/ 2/2012]

EC, 1992. Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31992L0043:EN:html [accessed 24/4/2012]

EC, 2007a. Note for the file. Subject: Situation and prospects for EU agriculture and rural areas. Brussels, AGRI G.2/BT/FB/LB/PB/TV/WM/ D(2007). http://ec.europa.eu/agriculture/analysis/markets/prospects12_2007_en.pdf [accessed 23/ 2/2012]

EC, 2007b. Council Regulation (EC) No. 834/2007 of 28 June 2007 on organic production and labelling of organic products and repealing Regulation (EEC) No. 2092/91. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:189:0001:0023:EN:PDF [accessed 3/4/2012]

ECA, 2011. Is agri-environmental support well designed and managed? European Court of Auditors, Special Report 7. Available at: http://eca.europa.eu/portal/pls/portal/docs/1/8760788.PDF [accessed 12/ 3/2012]

EEA, 2010a. Assessing biodiversity in Europe — the 2010 report. EEA Report 5/2010. Available at: http://www.eea.europa.eu/publications/assessing-biodiversity-in-europe-84 [accessed 23/2/2012]

EEA, 2010b. Abundance and distribution of selected species (SEBI 001). http://www.eea.europa.eu/data-and-maps/indicators/abundance-and-distribution-of-selected-species/abundance-and-distribution-of-selected-1#toc-0 [accessed 23/2/2012]

Ellenberg H., 1988. Vegetation ecology of Central Europe. Cambridge University Press, 705 pages.

Leuschner C., 2010. Vegetation Mitteleuropas mit den Alpen. UTB Ulmer.

EU, 2011. Rural Development in the European Union. Statistical and economic information. European Union, Directorate-General for Agriculture and Rural Development. http://ec.europa.eu/agriculture/agrista/rurdev2011/ruraldev.htm [accessed 3/4/2012]

Gaston K. J., 2010. Valuing Common Species. Science 327, 154–155.

Hart M., 1995. Guide to sustainable community indicators. West Hartford, Sustainable Measures, 202 pages.

Herzog F., Steiner B., Bailey D. *et al.* 2006. Assessing the intensity of temperate European agriculture at the landscape scale. European Journal of Agronomy 24(2), 165 – 181.

Jeanneret Ph., Baumgartner D.U., Freiermuth Knuchel R. & Gaillard G., 2008. A new LCA method for assessing impacts of agricultural activities on biodiversity (SALCA-Biodiversity. Proceedings of the 6th International Conference on Life Cycle Assessment in the Agri-Food Sector 2008, Zurich, 34–39.

Jeanneret P., Lüscher G., Schneider M. *et al.* 2012. Report on scientific analysis containing an assessment of performance of candidate farming and biodiversity indicators and an indication about the cost of indicator measurements. Deliverable 4.1 of the EU FP7 Project BioBio. http://www.biobio-indicator.org/deliverables.php

Kristensen P., 2003. EEA core set of indicators: revised version April 2003. Technical report. EEA, Copenhagen.

Pointereau P. & Langevin B.. 2012. Report on the contribution of the stakeholders to the selection of the biodiversity indicators for organic and low input farming systems. Toulouse, Deliverable 7.1 of the EU FP7 Project BioBio. http://www.biobio-indicator.org/deliverables.php

Wascher D.W. (Ed.) 2000. Agri-Environmental Indicators for Sustainable Agriculture in Europe. Tilburg: European Centre for Nature Conservation (ECNC Technical Report Series).

2 Farmland biodiversity indicators in Europe

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BioBio indicators were selected by iterative interaction between researchers and stakeholders. Whilst researchers ensured the scientific credibility of the indicators, stakeholders screened them for usefulness, attractiveness and practicability. Focus group discussions with farmers revealed a generally positive attitude towards biodiversity. Apart from monetary incentives, soft factors such as consciousness-raising and knowledge about biodiversity may be just as important for protecting farmland biodiversity.

2.1 The need for biodiversity indicators for farms

2.1.1 Stakeholders involved in biodiversity issues

Stakeholders interested in biodiversity are immensely diverse, consisting of public bodies (national and regional administrative bodies), research and education organisations, farmers' organisations, consumers' associations, and numerous NGOs dedicated to the conservation of nature and the environment. Their interest in biodiversity may be connected with the sustainability of agricultural production and/or the conservation of rare/emblematic breeds and species as well as landscapes. Because stakeholders often collaborate, e.g. to implement agro-environmental measures, it is important for them to have a set of indicators meeting their common and individual needs. Hence, the involvement of stakeholders in the BioBio project, and the active interaction between the Stakeholder Advisory Board (SAB) and scientists for the selection of the most appropriate indicators.

2.1.2 Specific interests of stakeholders

Depending on the interests of the social groups they represent, stakeholders decide on different issues regarding the relationship between agriculture and the natural environment.

Objectives of the BioBio Stakeholder Advisory Board (SAB)

Playing an active role throughout three workshops (Zurich, 25–27 March 2009; Brussels, 21–22 October 2009; Brussels 25–26 January 2012), the SAB has supported the BioBio project since its inception by formulating the main expectations and criteria for relevant and useful biodiversity indicators. Stakeholders were heavily involved in the selection of candidate biodiversity indicators to ensure that their needs were duly taken into account.

The SAB conducted a critical review and made recommendations vis-à-vis the first list of indicators selected based on their scientific performance. Indicators were tested in the field, with stakeholders assessing their practicability and relevance. In addition to the SAB, local stakeholders were also consulted in each case study at two local workshops at the start of the investigation, and then later on for their feedback on BioBio findings – see Pointereau & Langevin (2012).

Farmers decide how to manage their farms. In order to implement productive and sustainable practices, farmers must assess the correlations between farming practices and biodiversity. Farmers engaged in organic, low-input or integrated farming as well as those farming in protected areas need advice. They are generally proud of having a wide variety of species on their farmland, and of managing agricultural resources sustainably whilst conserving heritage landscapes. One main concern of theirs is being able to assess the positive and negative impacts of their practices on biodiversity, as well as the feedback on agricultural productivity.

Regional governments decide on agro-environmental policies. Biodiversity indicators are needed to design agro-environmental policies and subsequently to assess the effectiveness of the measures implemented. These indicators can be used e.g. to determine whether a given agricultural system should be maintained, modified, promoted or eliminated within the framework of management plans for protected areas where agriculture plays an important role. They can also be used to set up contracts to obtain specific subsidies based on environmental criteria, e.g. in defining the management of land stewardship contracts signed between farmers and NGOs (Spain). Indicators are crucial for monitoring biodiversity over time, and hence for assessing and adapting policies.

Farm advisers decide how to assess biodiversity on farms. Assessing biodiversity as a whole is impossible. Suitable indicators provide a manageable tool for reflecting main patterns of biodiversity. Farm advisers require meaningful biodiversity indicators to allow them to suggest a set of actions for preserving and/or enhancing farm biodiversity.

Professional organisations decide on the labelling and certification of products. Biodiversity indicators are needed to help define relevant specifications for the labelling/certification of agricultural products or practices. Examples are Organic Farming, Protection of Geographical Indications and Designations of Origin, Integrated Production, or private certification related to nature conservation, such as 'apple juice from traditional orchards' in Germany, the French 'High Environmental Value' certification, or the European label of 'High Nature Value' farmland.

The demand for quality and sustainability in the agricultural sector is expected to increase. Despite this, more proof is needed

to ascertain that these labels/certifications actually benefit biodiversity. The monitoring of biodiversity with a set of standardised indicators would help in assessing the relevance of these labels/certifications.

Consumers decide which products to buy. Biodiversity awareness is growing, but knowledge on biodiversity remains low. Indicators would help publicise the importance of biodiversity and support sustainable practices through the promotion of environmentally friendly products.

NGOs for nature conservation work towards improved protection of biodiversity. NGOs generally deal with specific habitats and/or species such as wetlands and corncrakes. Some NGOs or local authorities buy farmland in order to preserve heritage habitats and species. They then decide how this land is to be managed.

Examples

Thierry Fabian wants to evaluate the environmental benefit of producing French cheeses and cider with a geographical indication as opposed to producing conventional products. Biodiversity indicators could also be used to characterise the area of a PDO (Protected Designation of Origin) product. Since 1991, Peter Mayrhofer has been developing the Ecopoint system in Lower Austria in the frame of the agro-environmental schemes. This system subsidises farmers in the maintenance of cultivated landscapes and promotes environmentally friendly farming methods and low-intensity farming, including biodiversity in the countryside and quality of landscape elements. Mr Mayrhofer is interested in measuring the direct impact on biodiversity of this Austrian environmental scheme. In order to assess the benefit of a number of agri-environmental measures on biodiversity in Wallonia, Thierry Walot needs direct indicators that require a moderate expenditure of effort to apply. Claudio De Paola requires biodiversity indicators in order to compare his experience in the Ticino Italian Regional Park with others. Patrick Ruppol wishes to provide organic farmers in Belgium with a tool for measuring their sustainability. Eva Corral is focused on measuring European farmers' efforts to support greater biodiversity at farm level. In Spain, Eduardo de Miguel wants biodiversity indicators that reflect the real impacts of farming practices after accounting for changes in climate, or specific landscape elements such as wetlands. Jörg Schuboth needs genetic biodiversity indicators to measure the decrease in fruit varieties in Germany and to promote their preservation. Simeon Marin wants to evaluate the impact of farmland abandonment in the Bulgarian mountains.

2.1.3 Information required for taking action, and desirable quality of indicators

Some stakeholders may be interested in just one particular aspect of biodiversity, such as the abundance of rare species or the heritage landscape area. Even so, a set of several indicators is needed both to record the various elements of biodiversity (conservation and functional biodiversity) and to meet the common and specific needs of all stakeholders. Farm management indicators are necessary for creating a plan of action and proposing adapted measures.

Farmers need biodiversity indicators that reflect the productive capacity of agrosystems: for example, they are very interested in indicators assessing the health of their soil, and/or the pollination of their orchards. Farmers also need to quantify their progress and the necessary efforts towards more sustainable agricultural production. Indicators must therefore be sensitive to the implemented farming practices, especially so as to be able to serve as an early warning of adverse farming practices. One major issue concerns the efforts devoted either to increasing the share of semi-natural habitats (SNHs) on farm, or to implementing more adapted farming practices (tillage, inputs, crop protection etc.).

Indicators should also provide information on other environmental issues such as carbon storage and water quality, as well as on the overall sustainability of the farm. Biodiversity indicators need to be put in context, particularly in order to distinguish between the status of species: a Welsh stakeholder, for example, remarked that "agri-environmental schemes should really be benefiting species that have declined from agricultural land through changing practices and that are being replaced by species which are already ubiquitous in the managed countryside".

It is important to improve the indirect indicators currently implemented and used in the different EU countries, such as the "surface area of landscape elements" or "extensive grassland management" (mowing period, number of cuts, stocking density, quantity of nitrogen used). Indirect indicators are essential because they are used frequently by stakeholders. Although these indicators are easy to measure and to record, regardless of the season, more knowledge about the relationship between direct and indirect indicators is needed. How important, for example, are ecological focus areas (EFAs) or semi-natural habitats (SNHs) for species? Are these indicators (EFAs or SNHs) relevant for all landscape types, such as open fields? Must they be adapted to the specific conditions of areas such as the lowlands or highlands?

Indicators should be easy for a range of people – from farmers to skilled advisers – to record. Ideally, the indicator should allow any user to understand how it is set up, as well as being quick and easy to record, particularly since farm advisers have little time to spend on the assessment of a single farm. Indicators should ideally be observable by the farmer, such as common species of plants, or the presence of earthworms. We must ensure that the indicator is linked to agricultural practices rather than to other features outside the farm (e.g. presence of lagunes, lakes or forest) or the management of the surrounding farms.

Austrian Case Study: Arable Farming System

The 'Marchfeld' case-study area is situated in the Pannonian lowlands of Austria. The landscape is characterised by intensively managed arable-farming systems. Irrigation is routinely used in vegetable production, as well as in certain arable crops such as sugar beet, potatoes and maize. Nearly 10 % of all cash-crop farms are certified organic.

Number of farms surveyed: 8 organic, 8 non-organic
Average farm size: 68 ha
Average N-Input: 97 kg/ha
Average energy input: 357 kg fuel equivalents
Total number of habitat types: 16
Total number of plant species: 244
Total number of bee species: 52
Total number of spider species: 133
Total number of earthworm species: 11
Total number of crop species: 31
Total number of crop varieties: 100

2.1.4 Biodiversity monitoring in Europe

The European Environmental Agency uses 28 agro-environmental indicators **(IRENA)** to monitor the impact of agriculture on biodiversity as well as to assess the impact of agricultural and environmental policies. Of these, two have a direct impact on biodiversity: High Nature Value farmland area, and Population trends of farmland birds. Different methodologies, generally based on land use, nature conservancy area and farming practices, have been used to define HNV farmland area. The farmland bird indicator, which has been progressively implemented throughout Europe since 1980, has shown a decline of around 50 %.

The Streamlining European Biodiversity Indicators 2010 initiative **(SEBI 2010)** has been implemented by the European Environmental Agency to reveal complex biodiversity phenomena and trends. This pan-European process ensures that Europe's governments, businesses and citizens know the status of our biodiversity, and thus have a baseline for making sound decisions. In addition to the farmland bird indicator, several other biodiversity indicators are provided, such as the Red List Index for European Birds (based on pan-European extinction risk), the Grassland Butterfly Population Index (showing a 60 % decrease in numbers since 1990), the Evolution of Native Population Sizes and Endangered Breeds (revealing, for example, that 70 % of native sheep breeds in Greece are endangered), the Conservation Status of Natura 2000 Habitats (with only 7 % of the habitats in agro-ecosystems having a favourable conservation status).

Various biodiversity surveys with different objectives have been implemented on the national scale. Carried out intermittently since 1978 and most recently in 2007, **the UK Countryside Survey** provides scientifically reliable evidence on many aspects of the state of the UK countryside. The results of the different surveys can be compared in order to measure and assess change, and can be used to review and develop policies that influence the management of the countryside. The field surveys conducted involve a sample of 600 1km*1km squares across Great Britain. Botanical diversity has changed, with the species richness of plants growing in fields, woods, heaths and moors decreasing by 8 % between 1978 and 2007.

The Swiss **Biodiversity Monitoring** scheme was set up in 2001. Species lists of plants, butterflies and birds are compiled every five years on 519 square kilometres randomly distributed across Switzerland. In addition, plants, mosses and land snails are sampled at the same intervals on another 1650 10 m^2 sampling points. This monitoring scheme enables a general assessment of the evolution of species numbers of the observed groups.

In France, the **National Monitoring of Hay Meadows** scheme has been implemented since 2001 to monitor populations of breeding grassland birds and plant-species diversity, and to assess and explain the impact of the management of hay meadows on biodiversity. This survey was initiated by the Ministry of Ecology within the context of the decline of wet meadows and of the populations of several associated species such as the Corn Crake (*Crex crex*) linked with an intensification of farming practices (maize cultivation, early hay harvest, increased fertiliser use). The main finding concerns the negative correlation between an early hay harvest and the meadow passerines index. About 1000 stations are surveyed every year. Indicators are related to both farming practices (time of hay harvest, size of field, cropping plan, amount and frequency of

fertiliser application, type of fertiliser) and biodiversity (meadow passerines index of abundance, floristic species richness).
These surveys and monitoring programmes operate at the landscape scale (e.g. square kilometre), whilst the BioBio indicators operate at the farm scale, the scale at which farmers make their management decisions.

2.1.5 Aichi Targets require biodiversity monitoring

The most recent Convention on Biological Diversity (CBD Nagoya 2010) set out international goals – the Aichi Targets for 2020 – to address such concerns. BioBio has particular relevance to the following targets:

- Target 5: The rate of loss of all natural habitats, including forests, is at least halved, and where feasible brought close to zero, whilst degradation and fragmentation are significantly reduced.
- Target 7: Areas under agriculture, aquaculture and forestry are managed sustainably, ensuring conservation of biodiversity.
- Target 19: Knowledge, the science base and technologies relating to biodiversity and its values, functioning, status and trends, and the consequences of its loss, are improved, widely shared and transferred, and applied.

A comprehensive consultation on pressing concerns in science and policy that would best be served by monitoring, yielded a series of key questions (Sier *et al.* 2010; Table 2.1). This calls for indicators which both develop scientific understanding of ecosystems and produce clear and timely information to aid in policy development and decision-making.

Table 2.1: Pressing questions arising from scientific and policy circles concerned with biodiversity and environmental monitoring (Sier *et al.* 2010).

Sector	Questions
Fundamental science-based questions that the monitoring community must consider	• How is biodiversity changing? • What are the main factors causing this change, and what is driving them? • Can we predict the likely effect on biodiversity with the aid of projections and policy options? • How do ecosystem functions work, and how does biodiversity change affect them?
Pressing questions from the policy arena that must be addressed	• Are biodiversity strategies achieving the desired outcomes? • How successful have interventions such as the Rural Development Programme been? • Can we deliver biodiversity information satisfactorily to our European and international commitments?

2.2 Selecting good indicators – a participatory approach

2.2.1 Scientific screening

The first research step in BioBio focused on a review of established 'direct' indicator groups at the three levels of biological organisation:

- Genetic
- Species
- Ecosystem (commonly equated with habitat)

Indirect indicators represented by information on farm management were taken into account:

- Farm management system (e.g., organic or non-organic)
- Farm type (e.g., arable, livestock production or mixed farming)
- Agricultural management practices

The review of potential indicators was not initially restricted to those designed exclusively for use in agricultural ecosystems, but instead included possibilities represented in the scientific literature and developed in various analogous ecosystems (habitats) across Europe (Figure 2.1).

The key selection criterion was the general agreement of the BioBio scientists that the indicator group showed potential for use in the biodiversity monitoring of marginal agricultural regions of Europe. This yielded a sizeable list of potential indicators that were screened and reduced in the following steps:

- Potential indicators considered by scientific experts to possess scientific credibility were identified in a project workshop at Aberystwyth University in September 2009 (Figure 2.2).
- Each potential indicator was identified as reasonably cost-effective based on best available estimates.
- Indicators were identified as complying with the list of criteria for 'usefulness' generated by the first Stakeholder Advisory Board meeting in April 2009.

This selection system was compatible with the ten United Nations Environment Programme criteria for the selection of effective and useful indicators (UNEP 2003; Table 2.2). Following the scoring and ranking of indicators based on these criteria, the four groups of indicators were further reduced. This exercise resulted in a comprehensive report on biodiversity indicators for the above-mentioned four categories (Dennis *et al.* 2009).

Table 2.2: Quality criteria of biodiversity indicators (UNEP 2003).	
Criterion	Description
For individual indicators:	
1. Policy relevant and meaningful	Indicators should send a clear message and provide information at an appropriate level for policy and management decision-making by assessing changes in the status of biodiversity (or of pressures, responses, use or capacity), if possible with reference to baselines and agreed policy targets.
2. Biodiversity relevant	Indicators should address key properties of biodiversity or related issues such as status, pressures, responses, use or capacity.
3. Scientifically sound	Indicators must be based on clearly defined, verifiable and scientifically acceptable data collected using standard methods of known accuracy and precision, or based on traditional knowledge that has been appropriately validated.
4. Broad acceptance	The strength of an indicator depends on its broad acceptance. Involvement of policy-makers, major stakeholders and experts in the development of an indicator is crucial.
5. Affordable monitoring	Accurate, affordable measurement of indicators as part of a sustainable monitoring system, using determinable baselines and targets for the assessment of improvements and regressions, is essential.
6. Affordable modelling	Information on cause-and-effect relationships should be available and quantifiable, in order to link pressures, status and response indicators. These relational models enable scenario analyses and form the basis of the ecosystem approach.
7. Sensitive	Indicators should be sensitive in order to show trends, and where possible permit the distinction between human-induced and naturally occurring changes. They should thus be able to detect changes in systems within the time frames and on the scales that are relevant to the decisions, but should also be robust so that measuring errors do not affect their interpretation. It is important to detect changes before it is too late to correct the problems detected.
For sets of indicators:	
8. Representative	The set of indicators provides a representative picture of the pressures, biodiversity status, responses, uses and capacity (coverage).
9. Low number	The lower the total number of indicators, the more communicable they are to policy-makers and the public, and the lower the cost of communicating them.
10. Aggregation and flexibility	Indicators should be designed so as to facilitate aggregation at a range of scales for different purposes. Aggregation of indicators at the level of ecosystem types (thematic areas) or at the national or international level requires the use of coherent indicator sets (see criterion 8) and consistent baselines. This also applies for pressure, response, use and capacity indicators.

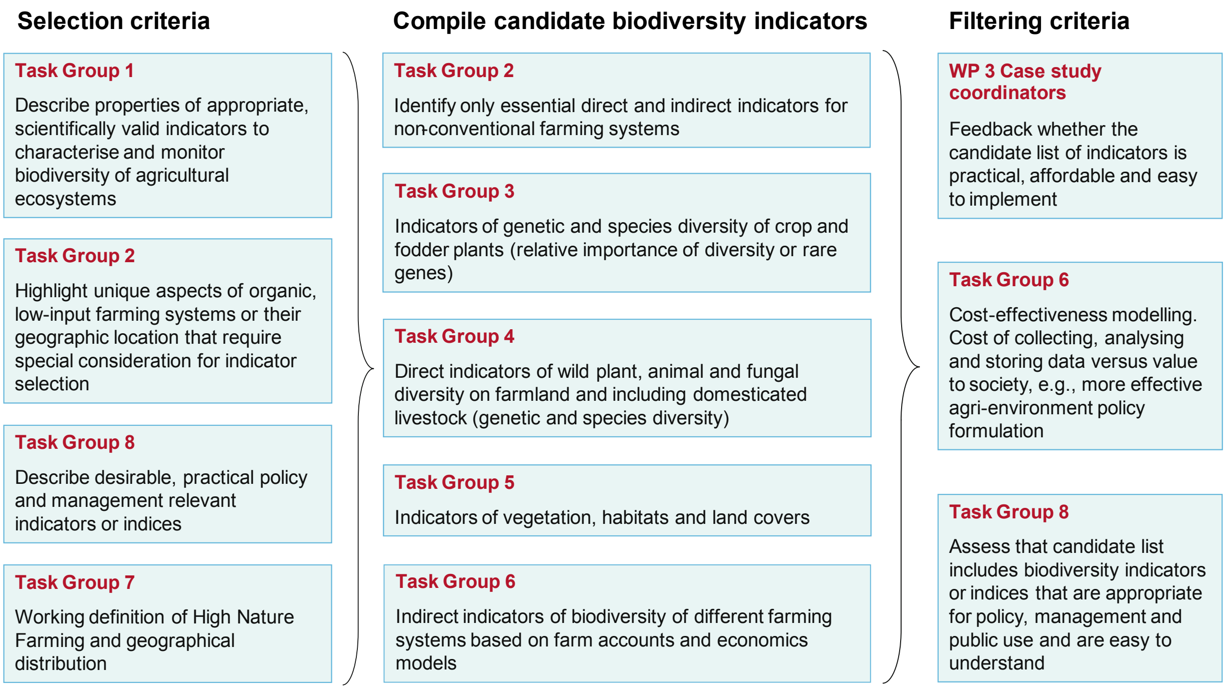

Figure 2.1. Task groups and activities organised to select scientifically sound biodiversity indicators.

Figure 2.2: Scientific review and selection of biodiversity indicators at the Aberystwyth Workshop, September 2009. Photo: J. Wilkes, Agroscope

2.2.2 Interaction of scientists and stakeholders

Indicator factsheets were compiled and presented for the consideration of European stakeholders in a further Stakeholder Advisory Board Workshop held in Brussels in December 2009. After taking on board feedback and requests for biodiversity indicators from various public-policy and third-sector environmental and commercial stakeholders, a further reduction in the list of potential indicators was agreed for evaluation in the WP 3 case studies (Figure 2.3).

Figure 2.4 shows the stakeholders' rating of the twelve species that were proposed by the scientific team, including plants present in crops and in grassland, earthworms, wild bees and wasps, birds, spiders, carabid beetles, and butterflies. from among the groups with the highest scores, flowering (vascular) plants, earthworms, spiders, and bees and wasps were selected for field testing. The inclusion or otherwise of farmland birds was heavily debated. Bird monitoring is already well established and implemented throughout several European countries, where the general population trends of 37 widespread farmland bird species are used to produce a European Farmland Bird Indicator (FBI; BirdLife International, no date; European Bird Census Council, no date) and national trends are also used as an OECD National Environmental Quality of Life indicator. The European FBI has demonstrated an alarming decline between 1980 and 2012 equivalent to 300 million birds (BirdLife International, no date). It was therefore concluded that there was no need for additional research on bird monitoring, and birds were not retained for field testing. What's more, owing to their size and mobility, birds are of limited use as an indicator for habitats below the individual-farm scale, and hence could only realistically be used as an indicator for farms as the smallest unit of comparison. They cannot be measured within the stratified sampling design created for other BioBio species indicators based on the mapping of general-habitat categories.

The assessment of the 47 indicators revealed that stakeholders focused mainly on the species diversity and farm management indicators. Not accustomed to being aware of genetic diversity indicators, stakeholders had difficulty assessing the latter at the start of the project. Over the course of the project this state of affairs changed, and indicators for genetic diversity were explicitly encouraged as part of the BioBio indicator set following the final stakeholder audit. As for the habitat diversity indicators, stakeholders agreed with the necessity of describing and accounting for the various habitats of a farm, but requested that they be presented in a simplified form. They also asked for the inclusion of more indicators describing farming practices such as the feeding system, manure management and tillage practices, energetic balance, GHG emissions, and improved consideration of the indirect indicators commonly used by many stakeholders, e.g. the ecological compensation area (landscape elements).

On the whole, stakeholders preferred generic to specific indicators. A set of indicators was also more highly rated than one or two aggregated indicators. Habitat and farm management indicators were given high ratings by the stakeholders, as they are easier to record and more often used in their work.

Fig. 2.5 shows the subsequent reduction of the number of indicators during the course of the BioBio project.

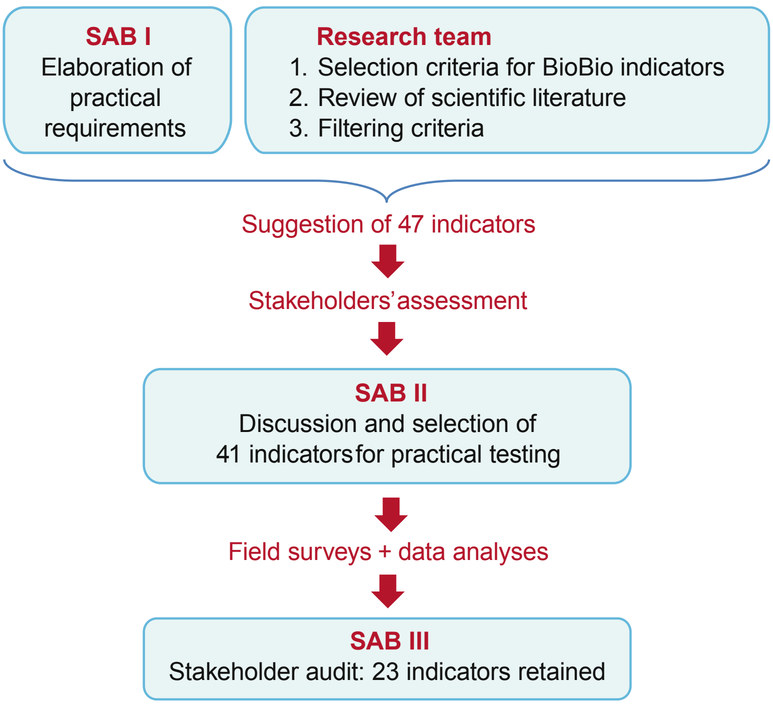

Figure 2.3: Indicator-filtering process involving repeated interactions between researchers and stakeholders (Stakeholder Advisory Board SAB).

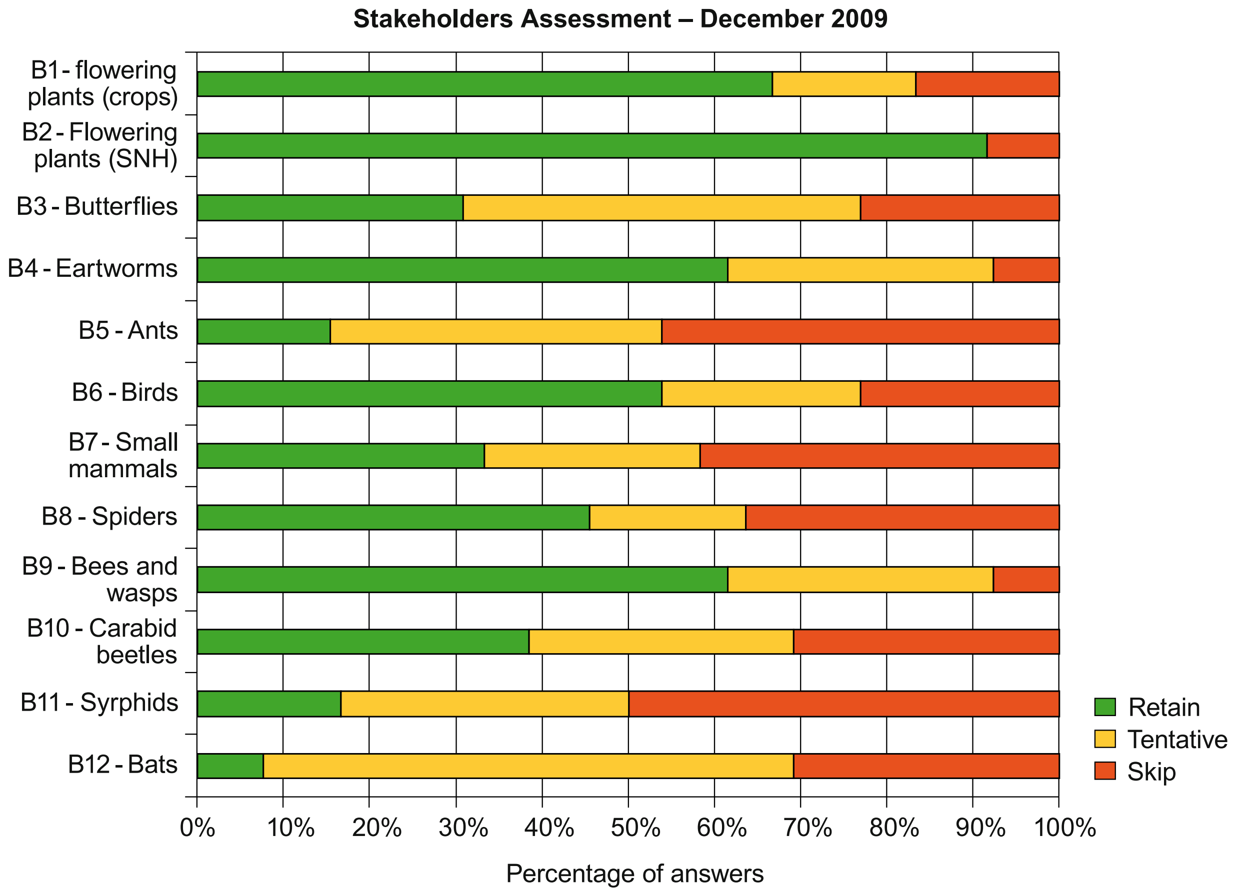

Figure 2.4: Overall assessment by the Stakeholder Advisory Board of species diversity indicators.

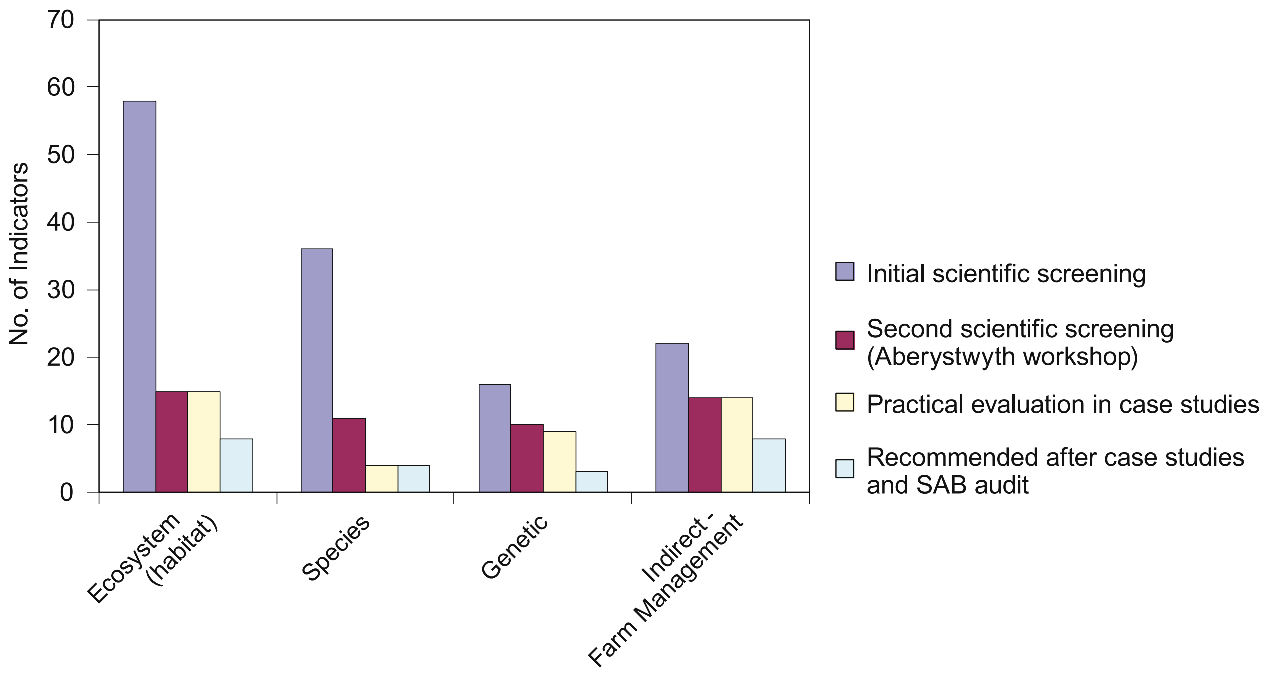

Figure 2.5. Refinement of indicator sets divided into four categories during each phase of the BioBio project.

2.3 Farmers' perception of biodiversity and of biodiversity indicators

2.3.1 How do farmers value biodiversity?

It is important to explore and understand the attitudes and values attached to biodiversity by local residents, villagers and farmers because these actors perceive the non-importable, non-marketable functions resulting from biodiversity-enhancing agricultural activities in a highly direct manner and to include their approaches in scientific and policy discussions.

The ecological values of biodiversity can be comprehensively recorded by means of biodiversity indicators, whilst market-based (monetary) valuation methods are useful for assessing the private monetary benefits provided by biodiversity (Nunes & van den Bergh 2001). Many public benefits, however, which are often expressed in social/psychological value categories, are difficult to monetise or describe with ecological indicators. Moreover, it is often difficult for people to conceptualise biodiversity (Soini & Aakkula 2007), both because it is an inherently scientific term, and because its benefits are better perceived at a general level (e.g. it is the basis of human life, it provides balance, it has aesthetic functions and creates a sense of place).

Non-monetary valuation, and more explicitly the focus group method, was tested in the BioBio project with French, Hungarian, Italian, Welsh and Ugandan organic and extensive non-organic farmers, in order to expand the valuation of biodiversity benefits to the most comprehensive level (Figure 2.6). The advantages of non-monetary valuation are that it uses a holistic approach, focusing on the values inherent in the integrity, stability and resilience of complex systems, and that it often focuses on public involvement, which could lead to social learning and conflict resolution (Buijs *et al.* 2008).

2.3.2 Farmers' interpretation of biodiversity

The focus group experiences revealed that biodiversity is very much connected to farmers' everyday lives and agricultural practices, with farmers often talking about the methods used on their farms and their approach to agriculture as regards biodiversity.

Biodiversity was sometimes transformed into a symbol of social life (it was seen as a human being, or used to conceptualise contradictory opinions, etc.). This shows once again that for farmers, biodiversity is not an independent, purely scientific concept. Both species and landscape diversity seem to be important manifestations of biodiversity to farmers because they found it easier to conceptualise biodiversity when it was linked to personal experiences and observations.

In spite of this, the essence of biodiversity – especially for organic farmers – is not the richness of species, but the interactions within nature that form the basis of life. Even though farmers do not fully understand these interactions, their complexity and universality provides a strong ethical and philosophical justification for preserving this biodiversity.

According to our findings, organic farmers were more familiar with the term biodiversity. Furthermore, they were more aware of the complex nature of biodiversity, and approached it from a philosophical and spiritual viewpoint. By contrast, non-organic farmers tended to identify biodiversity with species diversity and to relate it more directly to farming.

2.3.3 Farmers' attitudes towards biodiversity

In general, farmers had positive attitudes towards biodiversity. Biodiversity was often linked to personal feelings, emotions and memories, and talking about these personal impressions was usually a pleasure for them. Rational arguments emerged more frequently when farmers discussed the connections between farm management and biodiversity protection.

Within focus groups of organic farmers, debate about the positive role of biodiversity was rare, and a strong existence value was consistently attributed to biodiversity.

Figure 2.6. Focus group meetings: Hungary, Italy, France.
Photos: Á. Kalóczkai, SIU, T. Zanetti, UNIPD, J. P. Choisis, INRA.

Bulgarian Case study: Semi-Natural Low-Input Grassland

Cattle-rearing and sheep-breeding are the basis for the manufacture of a variety of dairy products in the Smolyan region of the Rhodopes Mountains of south-central Bulgaria. Around one-third of the area of the Smolyan region is included in NATURA 2000 Special Protection Areas for birds. As the use of fertilisers and pesticides on grassland is limited, the farms are classified as low-input systems.

Number of farms surveyed: 16 low-input
Average farm size: 25 ha + 88 ha summer pasture
Average N-Input: 84 kg/ha
Average energy input: 126 kg fuel equivalents
Total number of habitat types: 31
Total number of plant species: 387 (of which 9 Red-list species and 8 Balkan endemics)
Total number of bee species: 105
Total number of spider species: 172
Total number of earthworm species: 8
Total number of livestock species: 2
Total number of breeds: 5

Non-organic farmers, on the other hand, also addressed the negative effects of biodiversity – e.g. weeds, pests, increasing costs – in addition to its importance, and differentiated between useful, neutral and harmful species. Hence, non-organic farmers tended to have a more instrumental (rational) view of biodiversity, whilst the majority of organic farmers referred to feelings and emotions, personal values and identity, which shows the importance of ethical considerations in farming and biodiversity management.

2.3.4 Farmers' perceptions of the benefits and values of biodiversity

Ethical and social values seem to be important aspects of biodiversity. Aesthetic value, value attached to lifestyle or life philosophy, bequest value and existence value were mentioned by farmers. Ethical values were attributed to species diversity and the heterogeneity of the landscape, as well as to the 'complex systems' view of biodiversity.

Ecological values were mentioned less frequently, and were mainly linked to the 'complex systems' approach of biodiversity. Economic values were more directly linked to biodiversity, in that economic benefits and costs are important factors in farm management decisions, and biodiversity has an impact on both benefits and costs. Farmers tend to rate biodiversity by comparing its contribution to the costs and benefits of farming because agriculture is their main livelihood.

The 'cost-benefit' approach to biodiversity is often in contradiction with the 'ethical and social values' approach. Farmers may respect biodiversity and attribute an existing value to it, while at the same time bearing in mind the economic viability of farming. This may cause cognitive dissonance, which is resolved either by blaming the contextual factors of farming, or by searching for further actions to protect biodiversity.

2.3.5 Farmers' perceived role in preserving biodiversity

Both organic and non-organic farmers see themselves as playing an important role in biodiversity protection because their farm management practices have a strong influence on nature. On the whole, farmers regarded their activities as tending to favour biodiversity, even if they admitted that some of their practices can harm nature.

Participating farmers primarily blamed the intensification of agriculture for the loss of biodiversity, while insisting that the use of practices with detrimental environmental impacts is usually due to external factors (e.g. market mechanisms).

Both individual and community responsibility were addressed in the discussions, and actions such as education, awareness raising, discussion with other farmers, and setting a good example were urged. Current policy was criticised in most of the focus groups for its failure to effectively protect biodiversity, however.

2.3.6 It's not all about money

Focus groups revealed the wealth of assessment approaches and wide range of benefits farmers attach to biodiversity: ethical, social, economic and environmental values were mentioned in almost all of the groups, and different beneficiaries were addressed by farmers. These results suggest that in addition to monetary incentives, the ethos and emotional response of farmers are important drivers to promote biodiversity in farming.

Providing clear information (i.e. which can be understood by less-well-educated people) and training – in particular collective training where experiences can be shared – is important for providing non-organic (i.e. more intensive) farmers with the minimum background necessary for understanding issues concerning biodiversity, which is a basis for preparing better cost-benefit analyses at the farm level. It may be possible to encourage non-organic (i.e. more intensive) farmers to protect biodiversity with soft policy tools. Consequently, policy-makers should pay more attention to raising awareness and to the greater involvement of farmers in designing policies sympathetic to biodiversity.

References

BirdLife International (no date) Available at: http://www.birdlife.org. [Accessed 18/07/12]

Buijs A., Fisher A., Rink D. & Young C.J., 2008. Looking beyond superficial knowledge gaps: Understanding public representations of biodiversity. International Journal of Biodiversity Science and Management, 4: 65–80.

Dennis P., Arndorfer M., Balázs K. *et al.*, 2009. Conceptual foundations for biodiversity indicator selection for organic and low-input farming systems. Aberystwyth, Deliverable 2.1 of the EU FP7 Project BioBio. ISBN 978-3-905733-16-7. http://www.biobio-indicator.org/deliverables.php

European Bird Census Council (no date) http://www.ebcc.info/index.php. [Accessed 14/02/12].

Nunes P.A.L.D. & van den Bergh J.C.J.M., 2001. Economic valuation of biodiversity: sense or nonsense? Ecological Economics 39, 203–222

Pointereau P. & Langevin B., 2012. Report on the contribution of the stakeholders to the selection of the biodiversity indicators for organic and low input farming systems. Toulouse, Deliverable 7.1 of the EU FP7 Project BioBio. http://www.biobio-indicator.org/deliverables.php

Sier A.R.J., Monteith D. & Brooks S., 2010. Beyond 2010: strategies for understanding and responding to long-term trends in UK biodiversity. Proceedings of the workshop held in the Natural History Museum London, 16–17 November 2010. NERC Centre for Ecology and Hydrology, Lancaster Environment Centre.

Soini K. & Aakkula J., 2007. Framing the biodiversity of agricultural landscape: The essence of local conceptions and constructions. Land Use Policy 24, 311–321.

UK NEA, 2011. The UK National Ecosystem Assessment: Synthesis of the Key Findings. UNEP-WCMC, Cambridge.

UNEP/CBD/SBSTTA/9/INF/26, 2003. Proposed biodiversity indicators relevant to the 2010 target. Report on the ninth meeting, Montreal, 10–14 November 2003.

3 Methods for assessing biodiversity indicators at farm scale

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In the BioBio case study regions, environmental and farming information and statistics were first used to define the investigation framework. Methods for collecting biodiversity and farm-management data were then applied in a standardised manner. Candidate indicators which distinguished between farms and case studies were retained. Case studies differed considerably from one another in terms of indicator values and correlations between indicators.

Activities for the farm scale monitoring of direct and indirect biodiversity indicators in BioBio were chronologically structured as follows:

Farm selection	Field training	First, farms were selected in regions (case study). In the meantime, field training was organised for the habitat mapping and the species sampling methods.
Habitat mapping		Second, habitats were mapped on farms.
Selection of habitats/fields for species sampling		Third, habitats/fields were selected from maps to be sampled for species indicators.
Species diversity sampling		Fourth, species indicators were sampled in the selected habitats/fields.
Interviews on farm management and genetic diversity		Fifth, farmers were interviewed to enable assessment of the management and genetic diversity of crops and livestock.

Detailed descriptions of methods used in BioBio are available from Dennis *et al.* (2012).

3.1 Approach to farm selection

BioBio case study regions representing major organic and low-input farming systems were selected on the basis of the HNV Farmland method (Andersen *et al.* 2003) and statistical sources (EUROSTAT, Organic Farming in Europe, no date) according to their relative importance and distribution across Europe.

Each of the 12 European case studies (as well as the additional case studies in Tunisia, Ukraine and Uganda) focused on a factor of interest, i.e. organic versus non-organic (baseline) systems or low-input systems along a gradient of farming intensity. To qualify as a BioBio case study farm, organic farms were required to have been certified since 2005, i.e. had to have been continuously managed according to organic farming standards (EC 2007) for a minimum of five years. In the case of low-input systems, one or two significant variables were chosen to define the largest possible intensity gradient for farm selection.

When selecting farms for biodiversity monitoring confounding factors must be accounted for, especially if different farming systems are to be sampled (organic and non-organic in BioBio). Two sets of potentially confounding factors were recognized in BioBio:

1) Environmental conditions: biogeographical region, geomorphological and soil features, landscape situation, altitude;

2) Farm characteristics: type of farm (crops, forage, mixed farming, animal species), size, management intensity, uncultivated habitat types.

Examples of possible confounding effects and problems of interpretation caused by poor farm selection include the following:

a) All (or most) of the organic farms are selected at high altitude in a region, whilst all (or most) of the non-organic farms are selected at low altitude. An observed difference in biodiversity indicator values cannot be attributed unequivocally to the farming system because altitude is correlated with the latter. It is then difficult to determine whether an observed difference in measurements of biodiversity indicators is due to the farming system, or to the altitude (Figure 3.1).

b) All (or most) of the selected organic farms grow crops, whilst all (or most) of the selected non-organic farms have mixed farming (or vice versa). An observed difference in biodiversity indicators cannot be attributed unequivocally to the farming system because the type of farm is correlated with the latter. In this example, it is difficult to determine whether an observed difference in biodiversity indicator measurements is due to the farming system, or to the type of farm.

In each case study region, 16–20 farms were randomly selected out of the 30–40 which were available for the evaluation of candidate biodiversity indicators, and which had been preselected with the aim of avoiding potential confounding factors.

In the case of heterogeneous regions, farms were selected in pairs, i.e. one organic and one non-organic farm in the same environmental conditions in each case.

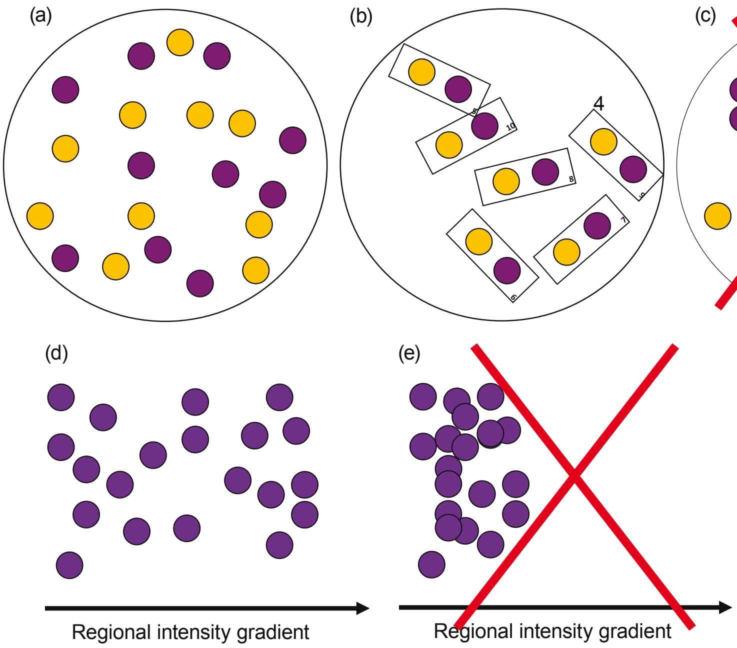

Figure 3.1: Acceptable patterns of farm selection for case studies with organic and non-organic farms (a) and (b), and for HNV regions with a gradient of intensity (d). Systematic bias in options (c) and (e) must be avoided.

3.2 Mapping a farm (habitat map)

A farm is a business that usually consists of several enterprises (economic activities such as crop production or animal husbandry) composed of several fields. Farms are often not consolidated, i.e. rather than being adjacent to one another; its individual plots may be dispersed over relatively large areas. As a first step, the farm boundaries were obtained either from cadastral maps or from the farmer. The survey area was defined by the farm property boundary. Habitats of the farm were provisionally identified based on interpretation of aerial photographs or satellite images available on the internet. Detailed habitat mapping was conducted in the field. Habitats were defined on the prepared base maps (e.g. aerial photographs) and described on standard forms. Site conditions were described according to a predefined code for geomorphology, geology, soil, etc.

Mapping the habitats of a farm is the first step of recording biodiversity indicators. BioBio has adopted a standard habitat mapping procedure for the European scale developed by Bunce *et al.* (2008). The habitat/land use classification method is based on a generic system of habitat definitions or so-called General Habitat Categories (GHCs); see Dennis *et al.* (2012) and EBONE (no date).

3.3 Selecting habitats for species diversity measurements

Once a farm had been mapped, habitats were grouped into types (Figure 3.2). Generally, each GHC or combination of GHCs represents a different habitat type except for grasslands, for which a finer classification is used. Grassland GHCs are further subdivided according to their moisture and nutrient levels as indicated by the environmental conditions.

Of each habitat type belonging to the farmed area, one habitat was randomly selected as a survey habitat for plant, bee, spider and earthworm species.
This random selection of habitats to represent all habitat types on a farm with a single example is the basic structure of the sampling design for assessing species diversity at farm level.

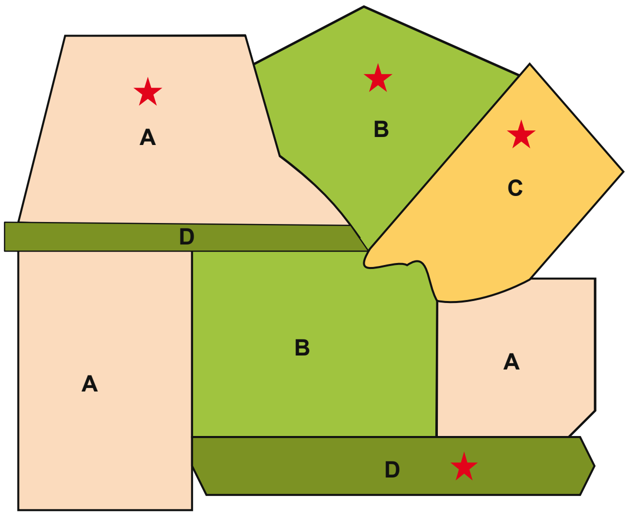

Figure 3.2: Schematic farm with six areal and two linear habitats belonging to four different habitat types (A, B, C, D). From each habitat type, one individual habitat (stars) is randomly selected for species diversity recording.

3.4 Species diversity recording

Species diversity recording methods are described in detail by Dennis *et al.* (2012). Basically, in each selected habitat for flora and fauna surveys, all of the following species indicators were sampled:

- Vascular plants of farmland habitats;
- Wild bees and bumblebees of farmland habitats (referred to later as 'bees');
- Spiders of farmland habitats;
- Earthworms of farmland habitats.

The spatial location for sampling areal and linear habitats is illustrated in Figure 3.3.

Vegetation – The procedure for recording vegetation used two types of plots, square and linear. Square plots were positioned in areal habitats (Figure 3.3) and linear plots were positioned in linear habitats. Vegetation was recorded in nested plots of 4 m^2, 25 m^2, 50 m^2 and 100 m^2 respectively in areal habitats, and of 10m x 1m in linear habitats. All vascular plants were recorded, but cryptogams (lichens or bryophytes) were not. Once the whole plot was recorded, the estimated cover percentage for the entire plot was listed against each species, using 5 %-cover categories.

This procedure provides basic information on the species composition of vegetation within the habitats, as well as allowing a rating of quality for assessing future change.

Wild and domestic bees and bumblebees: Bees were captured with an aerial net. Each habitat was surveyed by a slow walk along a 100-metre-long, 2-metre-wide transect crossing the centre of the vegetation plot. Where habitat length was shorter than 100m, 2 x 50m transects were surveyed. The transect walk lasted 15 minutes. While walking, the collector caught all individual bees seen within the 2m-wide 'belt' with a standard entomological aerial net. Captured specimens were immediately transferred into a killing jar charged with ethyl acetate, and taken to a taxonomist for identification if they could not be immediately identified in the field by the collector. The transect walk was repeated three times throughout the season.

Spiders: Spiders were caught with a modified vacuum shredder powered by a two-stroke engine. A suction sample composed of five subsamples was taken in each habitat selected from the habitat map of each farm. Each of the five suction subsamples was 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. Samples were stored in a cool-box, with plant material, dust and other arthropods separated out in the laboratory, and identified by a taxonomist. Sampling was repeated three times throughout the season.

Earthworms: Cool and wet seasons were the preferred time for sampling. Extraction by applying an expellant solution (diluted allyl isothiocyanate AITC) causing the earthworms to come to the soil surface was first performed in three samples of 30 x 30 cm each. After this, three soil cores (each 30 x 30 x 20 cm deep) were taken with a spade. Earthworms were extracted from the soil core, stored in alcohol, and identified by a taxonomist.

A total of 1490 plots were surveyed on 195 farms (Table 3.1).

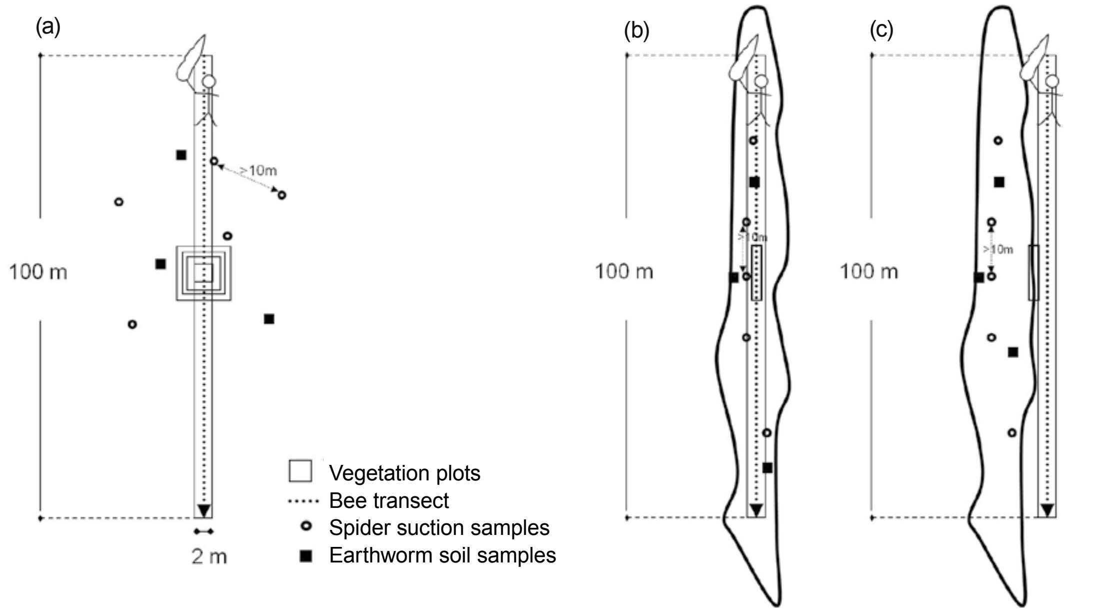

Figure 3.3: Flora and fauna sampling in areal (a) and linear habitats, without shrubs (b) and with shrubs (c). Source: Dennis et al. (2012).

Table 3.1: Number of farms and species plots per case study region. Data shown here is based on the 12 European case study regions. Preliminary results from Tunisia, Ukraine and Uganda are shown in Chapter 10. ARA = Arable, HOR = Horticultural, GRA = Grassland, DEH = Dehesa, MIX = Mixed farming, VIN = Vineyards, OLI = Olives.

Number of:	ARA Austria	ARA France	HOR The Netherlands[1]	GRA Bulgaria	GRA Switzerland	GRA Hungary	GRA Norway	GRA Wales [2]	DEH Spain	MIX Germany	VIN Italy	OLI Spain	Total
Farms	16	16	14	16	19	18	12	20	10	16	18	20	195
Plots	123	157	103	133	109	148	118	213	111	127	74	74	1490
Plot types	15	36	19	51	19	58	23	45	31	14	11	14	n.a.
Plot types per farm ø	7.7	9.8	7.4	8.3	5.7	8.2	9.8	10.7	11.1	7.9	4.1	3.7	7.6

[1] No sampling of fauna species on 6 farms
[2] No sampling of fauna species on 4 farms

3.5 Genetic diversity assessment

A comprehensive set of indicators for detecting biodiversity in farming systems must include measures of genetic diversity within species. However, reliable detection of genetic diversity is generally labour-intensive, often technically demanding, and can be difficult owing to the lack of information on e.g. breeding pedigrees and seed sources. In BioBio, the assessment of on-farm genetic diversity is based on a questionnaire surveying data on the number and abundance of different breeds per farm animal species, the number and abundance of different varieties per crop species, the origin of crops, and pedigree-based genetic diversity. Data were collected together with the farm management data. See Dennis *et al.* (2010) and Dennis *et al.* (2012) for detailed information and questionnaires.

3.6 Farm management interviews

The farm management questionnaire is the basis for farm management data collection. Designed to cover the management practices of farms with and without livestock, the questionnaire takes into account different land-use types such as grassland, arable crops and permanent crops (olives and vineyards), as well as semi-natural habitats (field margins, hedges etc.). Data were recorded on different scales of measurement: farm level, crop level (standard operations for each crop), and field level (selected habitats of the species survey). All data collected in the farm management questionnaire derived from the interviews based on farmers' operational knowledge of their farm and on basic farm accounting.

The farm management questionnaire was divided into 4 main sections (A, B, C and D) and several subsections:

- Form A surveyed general farm data collected at farm level, such as overall energy consumption, agri-environmental measures, organic matter fluxes, etc.;
- Form B yielded parameters describing the farm's plant production system. Standard operation data such as fertilization practices, plant protection measures and mechanised field operations were collected for each crop or grassland type. Data were used to calculate nitrogen input and nitrogen balances as well as to assess farming intensity based on grazing management, plant protection measures and mechanised field operations. The synthesis of data from all completed 'B' forms reflects the complete plant production system of the farm.
- Form C concerned the specific management of habitats where flora and fauna indicators are sampled (results not shown here).
- Form D provided information on livestock management and livestock numbers on the farm, broken down by livestock category, enabling the calculation of livestock units. Additional parameters were meat production (indicator for productivity), use of pastures and common grazing land.

Data were processed in spreadsheets, where further indicator calculation was performed, as well as in the online tool Dialecte (see box).

DIALECTE is an assessment tool taking into account the entire agricultural farming system. It was used in BioBio to produce two indicators (Total nitrogen input and Total direct and indirect energy input) and to cross-check the interview data (plausibility testing). DIALECTE indicators contribute to a quantitative assessment of the environmental impacts at farm level. The environmental performance is based on an analysis of farm diversity and farming practices (nitrogen management, use of pesticides, irrigation) with 43 indicators. Diversity is represented by crop diversity, the livestock system and the ecological infrastructure (semi-natural habitats). DIALECTE takes into account the impact of a farm on the main environmental components: water (quality and quantity), soil (erosion and fertility), biodiversity and non-renewable resource consumption. DIALECTE is provided in several languages and freely accessible via Internet (http://dialecte.solagro.org).

3.7 Why and how to relate habitat measurements to farm scale indicators

In agriculture, the farm is an important unit of consideration. Various important issues such as agri-environmental policy, the implementation of agri-environmental measures (objectives), evaluation of the measures (success), and overall management of the farming system including production, crop rotation, etc., address the farm level.

In BioBio, the farm level of analysis allows us to investigate relationships among biodiversity indicators, i.e. gene, species, habitat and management indicators, at a common spatial-unit level, i.e. the farm. Whereas habitat diversity, genetic diversity and farm management surveys yield indicators at farm level, species surveys are conducted in individual habitats and must be scaled up to the farm level, which is the common denominator for BioBio indicators. Measurements of indicator species in individual habitats must be aggregated into a farm-level value in order to be related to indicator measurements that only occur at farm level.

In BioBio, species data consisted of matrices with lists of species and the abundance of individuals (or cover in the case of plants), as well as habitat identification stating where individuals were collected or observed. Once the species lists are available, there are at least five different methods for aggregating species richness at farm level from species data obtained in habitats (section 6.3.2):

Gamma richness: Total number of species on the farm aggregated over the sampled habitats;

Alpha richness: Average number of species over the sampled habitats;

Area weighted richness: Total number of species over the sampled habitats weighted by the area of the habitat types to which each habitat belongs;

Rarefied richness: Average number of species calculated for the smallest number of habitats found on a farm (rarefaction);

Chao estimated richness: Estimated number of species on a farm based on the cumulative number of species and singletons found in habitats.

Given the approach of sampling one habitat per habitat type over the farm, the above five variables should likewise approximate the species richness of that farm. This approach for determining species richness at farm level has two main shortcomings: (1) the same number of species is implicitly attributed to all habitats of the same type, i.e. the possible and probable variability of species diversity among habitats of the same type (the so-called beta diversity within the habitat type) is not considered; and (2) the definition of the habitat types used for the habitat mapping is essentially based on vegetation types and geomorphological features, which possibly neglects important habitat features for e.g. bees which would lead to the definition of another habitat type; consequently, two habitats may be attributed to one habitat type in terms of the vegetation type found there, but might correspond to two different habitat types if bee habitat characteristics were being considered.

The above-mentioned approaches were used to conduct all five upscaling procedures as well as to calculate farm scale species richness. In most case study regions and for the four species groups, the gamma richness, i.e. the total number of species aggregated over the sampled habitats, correlated significantly with the other four richness indices (Jeanneret *et al.* 2012). Thus, information on the relationships between species groups, and with the management and habitat indicators is based on gamma richness.

3.8 Data analysis and indicator selection approach

The following criteria for indicator selection were applied:

1. Indicators must be reliably measurable across Europe;

2. There must be no correlations, or only minor ones with other indicators (except for management indicators);

3. Indicators should detect differences between farms;

4. Indicators must pass the stakeholder audit.

Several indicators were discarded at an early stage because they could not be measured and calculated in all case study regions. Examples of these are indicators based on Ellenberg values, which are not available for the plants in all countries across Europe, and the 'permanent grassland' indicator, because in many instances neither the farmers during the interviews nor the field staff during habitat mapping were able to distinguish reliably between permanent and sown grassland. Permanent grassland is also defined very differently in national agricultural census in different EU member state and EFTA countries.

If two indicators correlate they convey the same information, and only one of them need be measured. Within the four indicator groups (habitat, species, genetic diversity and farm management), correlating indicators were identified and one of them was discarded. In a second step, correlations across the themes were investigated, in particular between management, habitat and species diversity indicators. These correlations may indicate relationships which help us to understand the biodiversity findings, and in the case of strong and consistent correlations across case study regions, surrogate indicators may be identified. Examples of these analyses are given below.

The indicators should allow us to detect differences between farms within case studies because farms with a range of management intensities had been selected. Examples of this variability are shown in Figure 3.4, and the same graphs are provided on the indicator factsheets.

The remaining indicators underwent detailed screening with a view to identifying surrogate indicators, in particular between farm management indicators, which are based on easily recordable interview data, and actual biodiversity indicators. The analysis was performed within the farming types of the case studies.

3.8.1 Arable and horticultural case studies – Austria, France and The Netherlands

No general pattern could be derived for the arable case studies on the basis of the correlation analysis between the selected indicators. Nevertheless, there was a degree of similarity, e.g. the number and abundance of different varieties per species (genetic diversity indicator A4_1) correlated positively with the number of pesticide applications (D9), and the management indicators correlated significantly with each other (e.g. arable case study in Austria, Figure 3.5). In Austria, all species indicators correlated positively with one another, while in France only plant species richness correlated positively with bee and spider species richness.

Furthermore, most of the habitat diversity indicators correlated significantly with each other in France, but less so in Austria and The Netherlands. In addition, the number of

Farm-scale indicators

The species diversity measurements must be scaled up to the farm level in order to achieve a comprehensive and consistent indicator set because species diversity indicators were measured in plots representing each habitat, and other indicators – genetic, habitat diversity and farming indicators – were recorded for the entire farm.

	Level of measurement	Indicator level
Habitat diversity	Farm	Farm
Species diversity	Plot	Farm
Genetic diversity	Farm	Farm
Farm management	Farm	Farm

There are various ways to scale up species diversity to the farm scale. 'Gamma richness', the species richness index selected, yields the total number of species on the farm aggregated over the sampled habitats. The unit of measurement is then the number of species per farm. By contrast, habitat diversity and farm management indicators, e.g. the numer of habitat types (HabRich) and the number of livestock units (AvStock), are usually expressed on a per-hectare basis. Calculating values per hectare has the advantage of allowing comparisons between farms of various sizes, in particular when indicator values are a function of farm size. We may, for example, expect habitat richness to depend on farm size, i.e. larger farms may tend to consist of a greater number of different habitat types (and thus also possess greater species richness).

The correlation of species diversity, habitat diversity and farm management should be done on the same basis. Expressing gamma richness per hectare is an unsuitable approach, since it would require an extrapolation owing to the standard methods used to assess the species indicators on selected plots. Moreover, when calculating correlations between two indicators which are adjusted for farm size, i.e. where values are divided by the size of the farm to obtain values per hectare, correlation coefficients are artificially increased. For this reason, absolute 'per farm' values were used to analyse correlations across indicator groups (species, habitat, management).

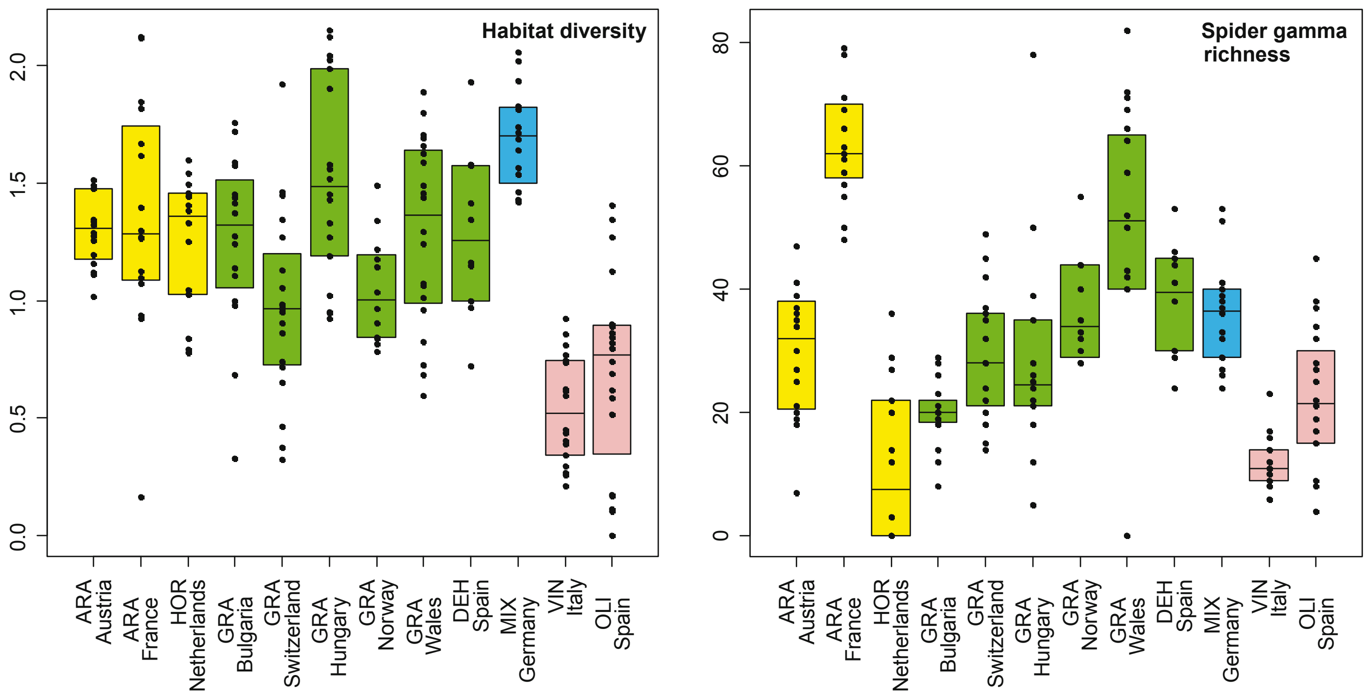

Figure 3.4: Examples of candidate indicator potential for distinguishing between farms within and between case study regions: Habitat diversity and spider richness per farm across the European case studies. Dots represent individual farms, boxes show median, 25 %, and 75 % of the values; colours differentiate between farm types (yellow: ARA = arable, HOR = horticultural; green: GRA = grassland, DEH = Dehesa; blue: MIX = mixed farming; red: VIN = vineyards, OLI = olives).

habitat types (C2a) on farms in Austria had strong positive correlations with species indicator richness, i.e. plants (B2_1.1), earthworms (B4_1.1), spiders (B8_1.1) and bees (B9_1.1), whilst this pattern did not occur in France. In both case studies, management indicators did not correlate with species indicators. In the horticultural case study, patterns of correlation were similar to those of the arable case studies, but usually weaker. Consequently, the number of pesticide applications (D9) could be taken as a surrogate for the other management indicators and for the number of varieties (A4) in arable case studies. However, no surrogate can be proposed between the indicator groups because no surrogates can be recommended either for species richness or for habitat diversity indicators due to contrasted results.

3.8.2 Grassland case studies – Bulgaria, Switzerland, Norway, Hungary and Wales

The general pattern in grassland case studies showed a few significant and weak correlations among the indicators. Significant correlations occurred mainly within indicator groups, i.e. within species, habitat and management indicators. For example, the species richness of vascular plants (B2_1.1) in Switzerland was significantly positively correlated with the three other species indicator groups (Figure 3.6), but this was not a general pattern in either Bulgaria, Hungary or Norway. In Wales, the correlations within indicator groups were often significant, and some habitat diversity indicators were correlated with species indicators as for Switzerland, where the number of habitat types (C2a) could be taken as a surrogate for the species richness (except in the case of earthworms). Based on these results, however, no surrogate nor additional elimination of indicators can in general be proposed for grassland case studies, as each indicator relates to specific conditions in these case studies.

3.8.3 Dehesa case study – Spain

In the Dehesa case study, significant correlations occurred between the management and habitat diversity indicators. In particular, the proportion of farmland with shrubs was significantly and negatively correlated with average stocking rate and grazing intensity, whilst the share of semi-natural habitats was negatively correlated with total nitrogen input. With increasing numbers of livestock, there were fewer linear elements per hectare. Species indicators were weakly correlated and not significantly correlated with any other indicators. Thus, a number of habitat diversity indicators could be represented by farming indicators in Dehesas.

3.8.4 Mixed farming case study – Germany

In the mixed farming case study, total nitrogen input was the management indicator with the highest correlation with all other management indicators (e.g. negative correlation with 'area without use of mineral N-fertiliser', and positive correlation with 'pesticide use'), excluding 'number of field operations' but including plant and bee species richness and 'crop richness' (negative correlation). Furthermore, the species richness of fauna indicators could be represented by plant species richness because of positive correlations between the two. No other indicators can be proposed as surrogates for habitat diversity indicators, however.

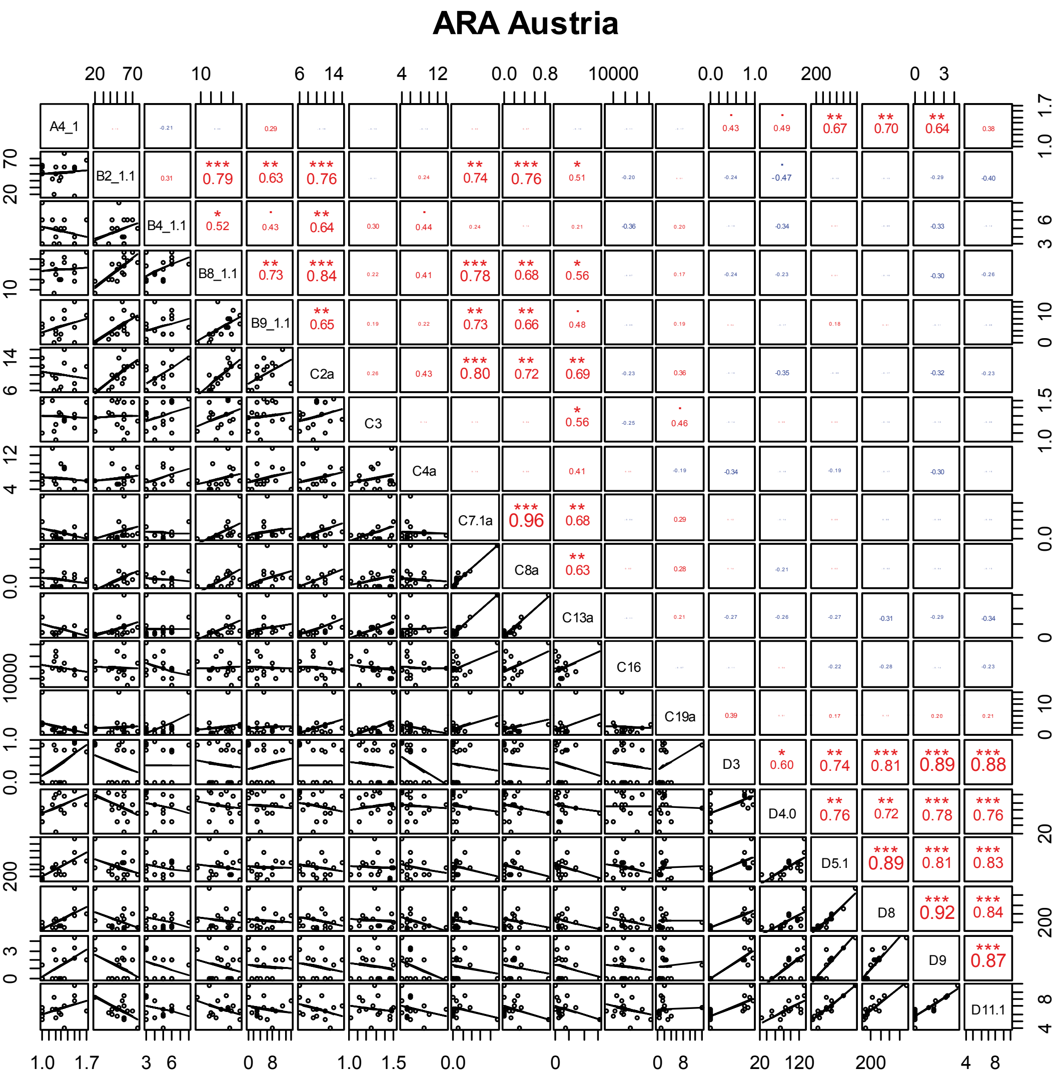

Figure 3.5: Example of Spearman correlations of BioBio indicators in the Austrian arable case study. The relationship between indicators is shown graphically below the diagonal. Positive (red) and negative (blue) correlation coefficients with significance (stars) are given above the diagonal. Font size is proportional to coefficient value.

A4_1	*Number and amount of different varietes (cultivar diversity)*
B2_1.1	*Vascular plants (gamma diversity)*
B4_1.1	*Earthworms (gamma diversity)*
B8_1.1	*Spiders (gamma diversity)*
B9_1.1	*Wild bees and bumblebees (gamma diversity)*
C2a	*Habitat richness*
C3	*Habitat diversity*
C4a	*Crop richness*
C7.1a	*Tree habitats*
C8a	*Percentage of farmland with shrubs*
C13a	*Length of linear elements*
C16	*Average size of habitat patches*
C19a	*Percentage of semi-natural habitats*
D2.2	*Average stocking rate*
D3	*Area with use of mineral N-fertiliser*
D4.0	*Total nitrogen input*
D5.1	*Total direct and indirect energy input*
D8	*Insensification/Extensification*
D9	*Pesticide use*
D11.1	*Field operations*
D12.1	*Grazing intensity*

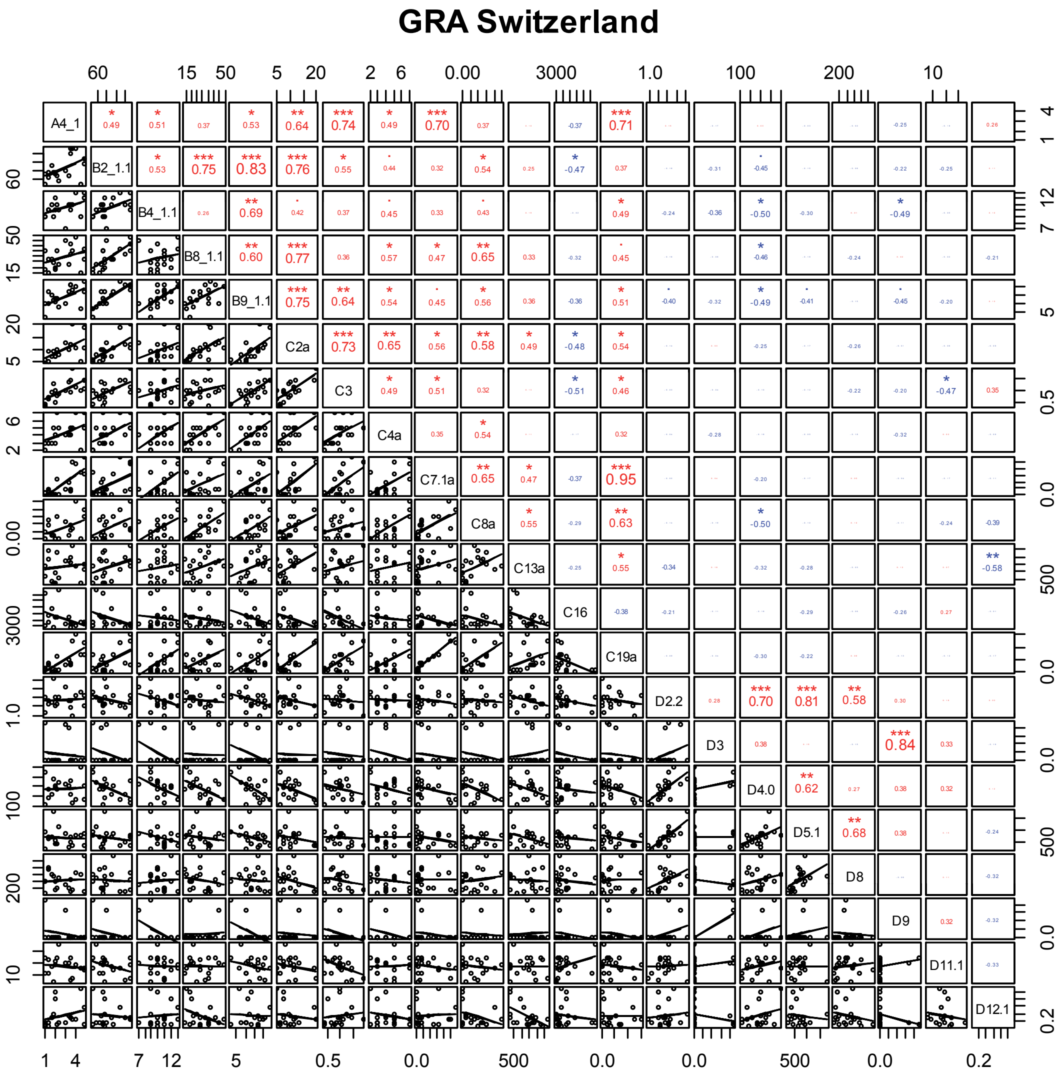

Figure 3.6: Example of Spearman correlations of BioBio indicators in Switzerland's grassland case study. The relationship between indicators is shown graphically below the diagonal. Positive (red) and negative (blue) correlation coefficients with significance (stars) are given above the diagonal. Font size is proportional to coefficient value. See Figure 3.5's legend for abbreviations.

3.8.5 Vineyard case study – Italy

In the vineyard case study, habitat indicators of farms represented by habitat indicators such as tree cover, proportion of farmland with shrubs, length of linear elements per hectare, average patch size, and the share of semi-natural habitats were significantly and positively correlated with each other, with the result that the most appropriate indicator could be assessed as a surrogate for the others. By contrast, management and species indicators were only marginally correlated with each other or with other indicators, except for plant species richness, for which habitat richness or diversity could be proposed as a proxy.

3.8.6 Olive plantation case study – Spain

In the olive plantation case study, most of the indicators correlated with each other within groups – i.e. species, habitats and management – as well as between groups. In fact, species indicators were highly and positively correlated with habitat diversity indicators such as habitat richness or diversity, as well as with management indicators such as total direct and indirect energy input and expenditures on fertiliser, crop protection and concentrate feed stuff. Biodiversity assessment in this type of farming system could therefore be approached with a relatively short list of indicators, including habitat diversity of farms, total nitrogen input, and number of field operations.

3.9 Interpretation of analysis and consequences for monitoring

Although correlations between farm management indicators and actual biodiversity indicators were observed in some case study regions, no general pattern emerged. The same applies to correlations within habitat, species and genetic diversity indicators, which were observed in some case study regions, but which were not consistent for types of farming, let alone for the whole range of case study regions. This shows that the remaining indicator set cannot be further reduced without losing information. Even in comparable farm types, biodiversity patterns and relation-

French Case Study: Arable Farming System

Valleys and Hills of Gascony is a typical agricultural landscape of the southwest of France, under both Sub-Atlantic and Sub-Mediterranean climate influences. This region is dominated by a mosaic of intensive to extensive crop production such as cereals, sunflowers, oilseed rape and natural and sown pastures, with small forest remnants. Agriculture is the main source of income for most of the farmers.

Number of farms surveyed: 8 organic, 8 non-organic
Average farm size: 79 ha
Average N-Input: 41 kg/ha
Average energy input: 266 kg fuel equivalents
Total number of habitat types: 52
Total number of plant species: 440
Total number of bee species: 171
Total number of spider species: 261
Total number of earthworm species: 16
Total number of crop species: 24
Total number of crop varieties: 74

ships between indicators are case specific. Consequently, all of the resulting biodiversity indicators should be monitored at the European scale. Despite this, not all indicators are applicable for all farm types (see Chapter 4). An additional argument for not reducing the indicator set further – even for specific farm types where indicators did correlate – is that these observed correlations may disappear over time. This is because disturbances occurring in the agricultural landscape may support some indicators (e.g. species) whilst adversely affecting others. Thus, each elimination of an indicator must be considered very carefully.
The resulting indicator set underwent a two-level stakeholder audit to determine whether it met the criteria formulated by the stakeholders at the outset of the project. Findings from individual case study regions were first discussed with local stakeholder groups. These groups then reported to the stakeholder advisory board, which then conducted an audit and overall assessment (see Chapter 2).

References

Andersen E., Baldock D., Bennett H., *et al.* 2003. Developing a High Nature Value Indicator. Report for the European Environment Agency, Copenhagen.

Bunce R. G. H., Metzger M. J., Jongman R. H. G., *et al.* 2008. A standardized procedure for surveillance and monitoring European habitats and provision of spatial data. Landscape Ecology 23,11–25.

Dennis P., Arndorfer M., Balázs *et al.* 2009. Conceptual foundations for biodiversity indicator selection for organic and low-input farming systems. Aberystwyth, Deliverable 2.1 of the EU FP7 Project BioBio. ISBN 978-3-905733-16-7. http://www.biobio-indicator.org/deliverables.php

Dennis P., Bogers M.M.B., Bunce R.G.H., Herzog F. & Jeanneret P. 2012. Biodiversity in organic and low-input farming systems. Wageningen, Deliverable 2.2 of the EU FP7 Project BioBio. ISBN 1566-7197. ALTERRA Report 2308. http://www.biobio-indicator.org/deliverables.php

EBONE (no date). http://www.ebone.wur.nl. [Accessed 24/7/12].

EC, 2007. Council Regulation (EC) No. 834/2007 of 28 June 2007 on organic production and labelling of organic products and repealing Regulation (EEC) No. 2092/91. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:189:0001:0023:EN:PDF [Accessed 30/04/2012]

EUROSTAT, Organic Farming in Europe – Country reports (no date). http://www.organic-europe.net/. [Accessed 25/7/12].

Jeanneret P., Lüscher G., Schneider M. *et al.* 2012. Report on scientific analysis containing an assessment of performance of candidate farming and biodiversity indicators and an indication about the cost of indicator measurements. Deliverable 4.1 of the EU FP7 Project BioBio. http://www.biobio-indicator.org/deliverables.php

4 The BioBio indicator system

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Scientific testing and the subsequent stakeholder audit yielded a complementary set of indicators with minimum redundancies within the components of habitat-, species- and genetic diversity as well as management indicators. Whereas some indicators are relevant for all farm types, others apply only to specific farm types. The BioBio indicator set focuses primarily on indicators of the 'state' of biodiversity.

4.1 Indicators for farm types

Based on the experience from the case-study regions, the set of candidate indicators was narrowed down by eliminating indicators which failed to meet scientific quality criteria, or which correlated within the four indicator categories of habitat diversity, species diversity, crop and livestock diversity, and farm management.

A second major criterion for selecting farm management and habitat indicators was their correlation with species diversity indicators. There are strong hypotheses as to the effect of e.g. management intensity or percentage of semi-natural habitats on the diversity of wild farmland species. These correlations were explored, and contributed to the selection of management and habitat indicators (Figure 4.1).

The remaining indicators were then submitted to a stakeholder audit in which their conformity with criteria such as practicability and communication were evaluated. This process resulted in the final BioBio indicator set (Table 4.1).

The resultant indicator set consists of 23 indicators of which 16 are generic (i.e. applicable for all farm types) and 7 are restricted to specific farm types (Table 4.2). Using crop-related indicators only makes sense on farms with a significant percentage of arable crops. Grassland- and farm-animal-related indicators can only be applied on specialist grazing or mixed crops/livestock farms. The 'Tree Cover' habitat indicator provides no useful information on farms dominated by fruit trees or vines, as these farms hardly differ from one other in this respect. By contrast, on farms where land use is predominately arable or grassland, tree habitats are usually rare and dispersed. There, a higher indicator value indicates greater potential habitat for species dependent upon permanent, woody structures.

Table 4.1: BioBio indicator set. These indicators have passed scientific and practical testing as well as the stakeholder audit.

Indicators for the Genetic Diversity of Livestock and Crops		**Species Diversity Indicators**	
Breeds	Number and amount of different breeds	Plants	Vascular plants
CultDiv	Number and amount of different varieties	Bees	Wild bees and bumblebees
CropOrig	Origin of crops	Spiders	Spiders
		Earthworms	Earthworms
Habitat Diversity Indicators		**Farm Management Indicators**	
HabRich	Habitat richness	EnerIn	Total direct and indirect energy input
HabDiv	Habitat diversity	IntExt	Intensification/Extensification Expenditures on fuel, pesticides, fertiliser and animal fodder
PatchS	Average size of habitat patches	MinFert	Area with use of mineral N-fertiliser
LinHab	Length of linear elements	NitroIn	Total nitrogen input
CropRich	Crop richness	FieldOp	Field operations
TreeHab	Tree habitats	PestUse	Pesticide use
ShrubHab	Percentage of farmland with shrubs	AvStock	Average stocking rate
SemiNat	Percentage of semi-natural habitats	Graze	Grazing intensity

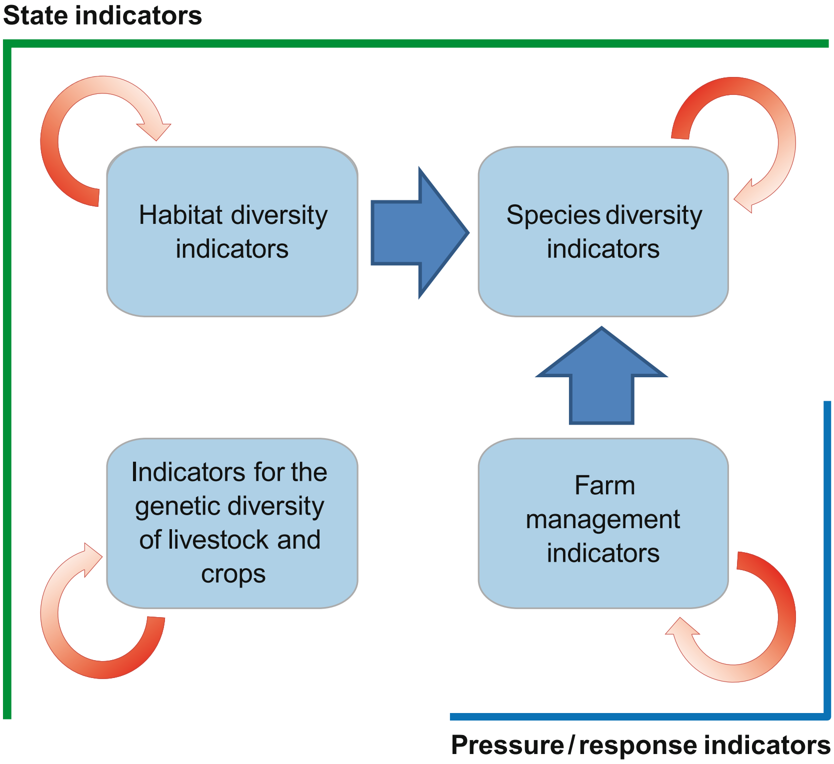

Figure 4.1: Correlations of indicators within the four main categories (red arrows) were tested and redundant indicators were discarded. Both habitat diversity and farm management were expected to influence species diversity (blue arrows), so indicators demonstrating this interaction were retained.

Table 4.2: The BioBio indicator set with generic indicators applicable for all farm types, and with indicators that are only relevant for specific farm types (sensu EC 1985). (See Table 4.1 for abbreviations).

All Farm Types	Genetic diversity	CultDiv			
	Species diversity	Plants, Bees, Spiders, Earthworms			
	Habitat diversity	HabRich, HabDiv, ShrubHab, LinHab, PatchS, SemiNat			
	Farm management	MinFert, NitroIn, EnerIn, IntExt, FieldOp			
Specific Farm Types		**Field Crops and Horticulture**	**Specialist Grazing Livestock**	**Mixed Crops/ Livestock**	**Permanent Crops**
	Genetic diversity	CropOrig	Breeds	Breeds CropOrig	
	Species diversity				
	Habitat diversity	CropRich TreeHab	TreeHab	CropRich TreeHab	
	Farm management	PestUse	AvStock Graze	AvStock PestUse Graze	AvStock PestUse

4.2 BioBio indicator set and other biodiversity indicator systems

The following features distinguish the BioBio indicator set from other biodiversity indicator systems:

- BioBio indicators relate to the farm scale (rather than to landscape scale or administrative units);
- BioBio indicators are limited to farmland (forest and wetland areas are not included);
- BioBio indicators focus on the state of biodiversity (response and pressure indicators were only retained if a link to species diversity was detected).

The paragraphs below discuss the similarities and differences between the BioBio indicator set and the two major European biodiversity indicator systems.

4.2.1 SEBI – Streamlining European Biodiversity Indicators

SEBI consists of 26 indicators which also relate to habitat-, species- and genetic diversity, as well as pressure and response indicators (EEA 2007). It focuses on the evaluation of biodiversity targets set by the Convention on Biological Diversity. The SEBI system is broader in scope, and is not limited to agricultural areas.

- Habitat diversity indicators: SEBI proposes five habitat indicators which are to some extent specific to agriculture. SEBI 5 (Habitats of European interest) and SEBI 8 (Sites designated under the EU Habitats and Birds Directives) relate to habitats listed in the Annexes of the 'Habitats' and 'Birds' Directives (92/43/EEC and 79/409/EEC, respectively), and thus also cover non-agricultural habitats. The indicator ValueHab – Percentage of valuable habitats on a farm – was tested in BioBio but not retained, since it hardly differentiated between the farms in the 12 case study areas – i.e. either there were hardly any 'Annexe I' habitats, or virtually the entire farm was considered 'Annexe I', as with the dehesa farms in Spain. SEBI 7 (Nationally designated protected areas) was tested but discarded, as it showed correlations with species diversity in only two case-study regions. SEBI 20 (Agriculture: area under management practices potentially supporting biodiversity) was also tested but discarded owing to similar considerations. As defined by SEBI, this category contains (i) High Nature Value farmland areas (based on the indicator IRENA 26), (ii) Area under organic farms (IRENA 7), and (iii) Area under biodiversity-supportive agri-environmental schemes (IRENA 1). Criterion (i) was not tested in BioBio because it tends to relate to the regional level and does not allow for differentiation within and between farms. Moreover, there is no universally accepted definition of HNV, or at least one which would be applicable at the on-site habitat level. Criteria (ii) and (iii) were tested, but a lack of consistent correlations with species diversity led to these indicators being discarded. SEBI 13 (Fragmentation of natural and semi-natural areas) is based on the "average size of patches of natural and semi-natural areas", and is derived from CORINE Land Cover. In BioBio, the indicator PatchSize – Average size of habitat patches on the farm also addresses patch size, but of the entire farm. A sub-indicator for semi-natural habitats can be calculated, but would tell us nothing about the fragmentation of semi-natural habitats owing to the dispersed nature of many farms. Several additional habitat diversity indicators are proposed by BioBio because they relate to farmland species diversity.
- Species diversity indicators: SEBI lists three species indicators which are relevant for agriculture. SEBI 1 (Abundance and distribution of selected species: (a) common birds and (b) butterflies) covers species groups other than the selected BioBio species indicators. For birds, an index for farmland birds is calculated. The indices are based on national monitoring programmes, many of which are limited to selected bird species. The BioBio species indicators are based on the full species lists for plants, bees, spiders and earthworms. SEBI 2 (Red List Index for European species) and SEBI 3 (Species of European interest) address the status of endangered species (IUCN Red List, birds only) and of European Habitats Directive (92/43/EEC) species, respectively. The percentage of Red List species is also proposed by BioBio as a sub-indicator of Plants, Bees, Spiders and Earthworms, based on national Red Lists.
- Genetic diversity indicators: SEBI 6 (Livestock genetic diversity) takes a different approach to that of the BioBio indicator Breeds – number and amount of different breeds per species. Whereas SEBI 6 aims to record the proportion of native breeds in relation to introduced breeds, the BioBio indicator Breeds evaluates the overall diversity of livestock breeds. A sub-indicator, Rare breeds, is also proposed, however. BioBio has also developed two further indicators (Varieties, CropOrigin) addressing the genetic diversity of crops.

In addition, SEBI lists several pressure indicators which either evaluate nitrogen in particular (SEBI 9 and 19) or nutrients in general (SEBI 15). Unlike the respective BioBio indicators which are based on farm nutrient evaluations, these indicators are based on national / regional data.

4.2.2 IRENA operation – 'Indicator Reporting on the Integration of Environmental Concerns into Agriculture Policy'

The IRENA operation captures the 'big picture' of environmental issues relating to agriculture (IRENA 2005). Five to ten of its 35 main indicators have a more or less direct link to farmland biodiversity (see http://epp.eurostat.ec.europa.eu/portal/page/portal/agri_environmental_indicators/documents/ for indicator factsheets). As with the SEBI

indicators, they tend to address the (sub-)national, regional or continental scale rather than the farm scale. BioBio specifically tested and retained IRENA 15 (Intensification/extensification: BioBio indicator IntExt) as part of the final indicator set, in spite of some reservations by stakeholders owing to the fact that it is based on monetary values. IRENA 25 (Genetic diversity) consists of three sub-indicators addressing the diversity of livestock and crop varieties. In this, they are similar to the BioBio indicators Breeds and Varieties, although the IRENA indicators are defined/measured at national rather than at farm level. IRENA 9 (Consumption of pesticides) is based on the quantity of pesticides sold (kg per country) and applied (kg per ha). BioBio proposes PestUse (Pesticide use), which consists of the number of pesticide applications, with sub-indicators for categories such as herbicides and fungicides. This information is easily obtainable from the farmer, and has been shown to correlate with species diversity. The BioBio indicators MinFer (Area with use of mineral N-fertiliser) and NitroIn (Total nitrogen input) have similar objectives to IRENA 8 (Mineral fertiliser consumption) and IRENA 18 (Gross nitrogen balance), but IRENA indicators are based on national statistical data rather than being calculated at the farm scale. The same applies to IRENA 11 (Energy use), with the analogous BioBio indicator EnerIn (Total direct and indirect energy input) being measured at farm scale. Despite some methodological difficulties in indicator measurement, EnerIn constitutes a universally applicable measure of farming intensity and has shown some correlation with species diversity indicators, and was therefore retained.

In addition to the IRENA pressure and driving-force indicators, which primarily address issues of nutrients, pesticides, water and land-use, BioBio proposes the following indicators:

- FieldOp (Field operations), which measures the average number of field operations;
- Graze (Grazing intensity), which measures the number of livestock units per hectare of grazing area;
- AvStock (Average stocking rate per ha forage area).

IRENA 28 (Population trends of farmland birds) is the only IRENA species diversity indicator, whilst four different species groups (plants, bees, spiders, earthworms) are proposed in BioBio.

4.3 Operational aspects

In addition to scientific considerations, entirely practical aspects must also be borne in mind when implementing the indicator system on a farm. Essentially, the four categories of the BioBio indicator set are measured using three mutually complementary approaches (Figure 4.2):

- Habitat diversity indicators are obtained via habitat mapping at farm scale;
- Species diversity indicators are obtained by specific field-recording methods;
- Crop- and livestock genetic diversity indicators and farm management indicators are obtained through interviews with farmers.

German Case Study: Mixed Farming System

Located in southern Germany, the Tertiary Hills of Lower Bavaria form part of the Alpine Foothills. This region is typical of intensively managed areas, with mixed farming systems (arable land, grassland and forests) and an increasing number of organic farms. Milk is the main product of all of the surveyed dairy farms, but all sell grain too.

Number of farms surveyed: 8 organic, 8 non-organic
Average farm size: 61 ha
Average N-Input: 215 kg/ha
Average energy input: 456 kg fuel equivalents
Total number of habitat types: 14
Total number of plant species: 211
Total number of bee species: 34
Total number of spider species: 110
Total number of earthworm species: 11
Total number of crop species: 29
Total number of crop varieties: 140
Total number of livestock species: 1
Total number of breeds: 2

The indicator campaign starts with the selection of the farms. Depending on the purpose of the campaign, selection criteria must be carefully applied in order to ensure that the sample is representative. The farmer is then contacted and an initial general interview is conducted, during which the farmer's consent, other necessary information, and a map of the farm should be obtained.

The map defines the area whose habitats are to be mapped. The selection of plots for species sampling is based on the habitat map, with one plot per habitat type being selected at random. This means that species sampling can only begin once habitat mapping is complete. In BioBio, data recording in its entirety took place within a year, but spreading the data recording over two years is also an option. Whilst vegetation can be recorded shortly after habitat mapping and selection of plots is available, arthropod sampling must be conducted three times – in the spring, summer, and late summer – in order to cover the entire season and record both early species and those emerging later. Depending on the region, the first sampling round should possibly be done at about the same time as the habitat mapping, although this would lead to constraints in terms of the availability of labour and how quickly the field campaign could be conducted. Spreading the recording over two years would resolve this conflict. On arable farms, however, and owing to crop-rotation dynamics, the habitat map will change – at least in part – from one year to another, and would require updating.

The field campaign is concluded by a farmer interview, during which the parameters are recorded which are needed to compute indicators for genetic diversity and for farm management. See Dennis *et al.* (2012) for practical advice on implementing a field campaign.

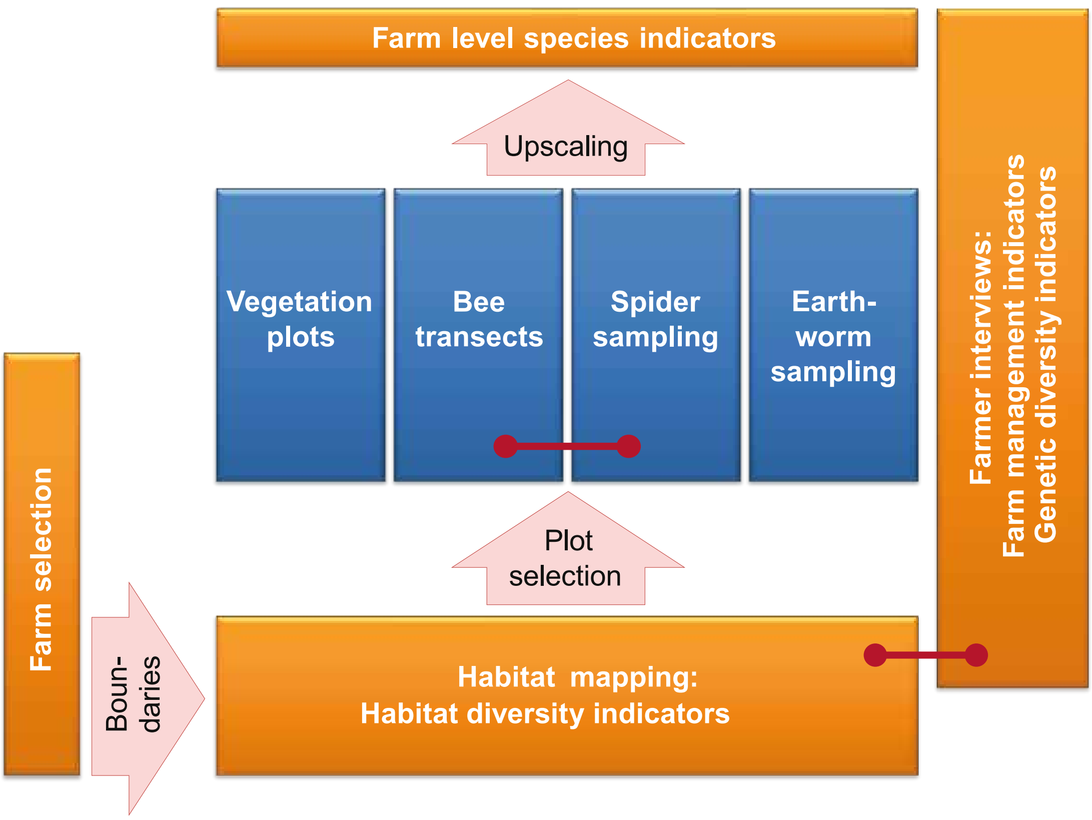

Figure 4.2: BioBio indicator measurement starts with contacting the farmer, who provides a map of farm boundaries. These boundaries delimit the extent of the habitat mapping. One specimen of each habitat type is then randomly selected for species recording. According to weather conditions spider and bee sampling can be combined. Farm interviews and habitat mapping yield indicators at farm scale. Species are recorded at plot level and then scaled up to farm level. The survey concludes with a detailed farm interview on the genetic diversity of crops and livestock, and on farm management.

Hungarian Case Study: Semi-Natural Low-Input Grassland

The case-study area is situated in Central Hungary between the Danube and Tisza rivers. The region forms part of the Homokhatsag High Nature Value Area, its landscape being a result of natural phenomena and human activity. Regulation of the Tisza and Danube rivers in the 19th century resulted in secondary alkaline pusza landscapes. The Homokhatsag is characterised by an abundance of wildlife in connection with traditional ranching known as tanya farming. All of the farms surveyed can be classified as low-input farms.

Number of farms surveyed: 7 organic, 11 non-organic
Average farm size: 170 ha
Average N-Input: 50 kg/ha
Average energy input: 140 kg fuel equivalents
Total number of habitat types: 58
Total number of plant species: 384
Total number of bee species: 100
Total number of spider species: 163
Total number of earthworm species: 8
Total number of crop species: 15
Total number of crop varieties: 34
Total number of livestock species: 2
Total number of breeds: 8

References

Dennis P., Bogers M.M.B., Bunce R.G.H., Herzog F. & Jeanneret P. 2012. Biodiversity in organic and low-input farming systems. Wageningen, Deliverable 2.2 of the EU FP7 Project BioBio. ISBN 1566-7197. ALTERRA Report 2308. http://www.biobio-indicator.org/deliverables.php

EEA, 2007. Halting the loss of biodiversity by 2010: proposal for a first set of indicators to monitor progress in Europe. European Environmental Agency, Technical Report 11/2007. Available at: http://www.eea.europa.eu/publications/technical_report_2007_11 [Accessed 16/03/ 12].

EC, 1985. Commission Decision of 7 June 1985 establishing a Community typology for agricultural holdings (85/377/EEC). http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:1985D0377:20030523:EN:PDF [Accessed 23/02/12].

IRENA, 2005. Agriculture and environment in EU-15 – the IRENA indicator report. European Environmental Agency, EEA Report 6/2005. Available at: http://www.eea.europa.eu/publications/eea_report_2005_6 [Accessed 16/03/12].

5 Habitat indicators

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Habitats are an important component of biodiversity in their own right, as well as providing possible indicators of biodiversity at the species level. Monitoring habitat diversity at the farm scale starts with habitat mapping. The farm habitat map forms the basis for generating habitat indicators, and is also required for selecting plots for species recording. At the farm scale, habitat indicators provide information about the composition of on-farm habitats, such as their richness, diversity and percentage cover. We have identified eight habitat indicators which as a set reflect the composition of the farm, and to some extent its potential for hosting wild species.

5.1 What is a farm habitat?

A habitat is an area with relatively homogeneous environmental conditions, occupied by plants and animals that are adapted to those conditions. On farmland, the term 'habitat' is sometimes associated with 'semi-natural habitats' or elements of 'ecological infrastructure'. Wild species also occur in fields of crops, however, and some wild species such as ruderal plant species or seed-feeding birds are even specifically adapted to these environmental conditions. Farm habitat indicators should therefore also relate to arable- crop fields, sown and permanent grasslands, intensively managed vineyards and orchards, etc. At the other end of the spectrum, they must also account for less intensively managed parts of the farm such as marginal grasslands, hedgerows, or grazed forest (Figure 5.1). The BioBio method for measuring biodiversity indicators therefore starts by establishing a habitat map of the entire farm, i.e. the utilised agricultural area (UAA) that is managed by a specific farmer. The farm is defined as the legal / economic unit owned or rented by the farmer. Spatially, farm fields are not necessarily adjacent to each other but can be quite far apart, depending on the historical evolution of farming in the region in question.

The boundaries between farmed and unfarmed land can sometimes fluctuate. They can be specifically defined in given regions to ensure the inclusion of all habitats potentially affected by farm activities. In BioBio the extent of the farm relates to the UAA, and in addition to agricultural fields also comprises:

- Hedgerows, lines of trees, shrubby, grassy and herbaceous strips, water margins, stone walls managed by the farmer;
- Grazed forest (even if not legally part of the UAA);
- Small woods (<800 m^2);
- Aquatic habitat (<800 m^2).

The following, however, were excluded:

- Farmhouses and gardens;
- Large ungrazed forests (>800 m^2), even if managed by the farmer (since this represents a different economic activity);
- Shrubby habitats (>800 m^2);
- Nature protection areas if no longer part of the UAA – even if managed by the farmer;
- Commonly grazed lands such as summer pastures or outfields (Switzerland, Norway), out-bye (northern England), and ffridd (Wales), that cannot be assigned to a specific farm. The fodder produced (and consumed) on this land, however, must be estimated and included in the calculation of a number of farm management indicators;
- Aquatic habitats (>800 m^2).

Figure 5.1: Farm habitats range from intensively managed crop fields (a), to linear features such as hedgerows (b), to extensively managed marginal grasslands (c). Photos: (a) G. Lüscher, (b) G. Brändle, (c) S. Buholzer, all Agroscope

5.2 Mapping the habitats

The habitat mapping method follows the EBONE (no date) approach, which has been adapted to farm-scale mapping. This method of habitat / land-use classification is based on a generic system of habitat definitions, the so-called 'General Habitat Categories' (see Dennis *et al.* (2012) for a description of the method). Each areal and linear habitat is delineated on a map, an aerial photograph, or a satellite picture (e.g. Google Maps or Google Earth). Areal elements should have a minimum size of 400 m^2 to be mapped, while linear elements (from 0.5 to 5m wide) should have a minimum length of 30m. Areal elements are further characterised by environmental qualifiers expressing moisture conditions and variations in acidity. Site conditions are described according to a predefined code for geomorphology, geology and soil. Visible effects of management recognisable in the field are also recorded.

The size of areal habitats and the length of linear habitats are required in order to calculate the habitat indicators. Areas and lengths can be most accurately and consistently measured if the farm maps are digitised using a geographical information system (GIS). Digitising guidelines are proposed in Dennis *et al.* (2012). The width of linear elements can be noted individually in order to calculate their area, or general estimates can be used. See Figure 5.2 for an example of a resultant habitat map.

If no geographical information system (GIS) is available, the area and length of habitats can either be obtained from the farmer (provided he or she has this information) or estimated in the field. Since it is only the farm area that is mapped and many farms have widely dispersed, non-contiguous fields, none of the BioBio indicators involves landscape-level spatial analysis. Indicators of e.g. connectivity or fragmentation can therefore not be meaningfully calculated, and the use of GIS is not indispensable.

Mapping habitats in the field requires botanical knowledge, because the boundaries between habitat types are – amongst other criteria – also determined by dominant plant-species cover. GIS knowledge is also useful for preparing maps for use in the field, and for digitising the mapped habitats and managing the resultant database. For routine mapping, the use of field computers will reduce time, effort and error rate.

Figure 5.2: Habitat map for one of the farms in the arable case study in France, showing the observed linear and areal habitats. Areal habitats consist mainly of different crop types (see Table 5.1 for crop typology). 'Tested areas' refers to habitats which were selected for species sampling.

5.3 Habitat categories

BioBio proposes a system for classifying the farm habitats (Figure 5.3, see Jeanneret *et al.* 2012 for the detailed classification using the EBONE terminology). Common lands, forest and aquatic habitats not used for agricultural purposes, and urban habitats are excluded.

At the first hierarchical level, the farm area is subdivided into (1) Intensively farmed land, including all crop fields and grasslands managed for the primary purpose of agricultural production, and (2) Semi-natural habitats.

5.3.1 Intensively farmed land

Intensively farmed land (1) is then subdivided into (1.1) Crops and sown & productive permanent grassland and (1.2) Intensive agriculture involving trees. In the process of habitat mapping, Crops and grassland (1.1) were differentiated into various habitats in order to allow for a stratified (representative) sampling of species of the different habitat types. Grasslands consist of three major habitat types: grass-dominated, herb-dominated and mixed grass/herbs. These are further subdivided according to environmental qualifiers describing nutrient and moisture status, thus enabling classification of numerous grassland-habitat types. Productive, intensively managed permanent grasslands are included in this category (Figure 5.4). Crops were aggregated into four categories depending on how attractive they were expected to be for pollinating insects, and whether they were annual or perennial crops (Table 5.1). Rotational (sown) grassland was considered a perennial crop (Fodder crops in Table 5.1). This typology was related to the bee species indicators investigated in BioBio. This typology may be re-considered and other criteria may be applied (e.g. agronomic criteria such as winter cereals / summer cereals, etc.). Ideally, crops should be considered as individual habitat types. On arable farms this will, however, considerably increase the number of habitats to be sampled for species.

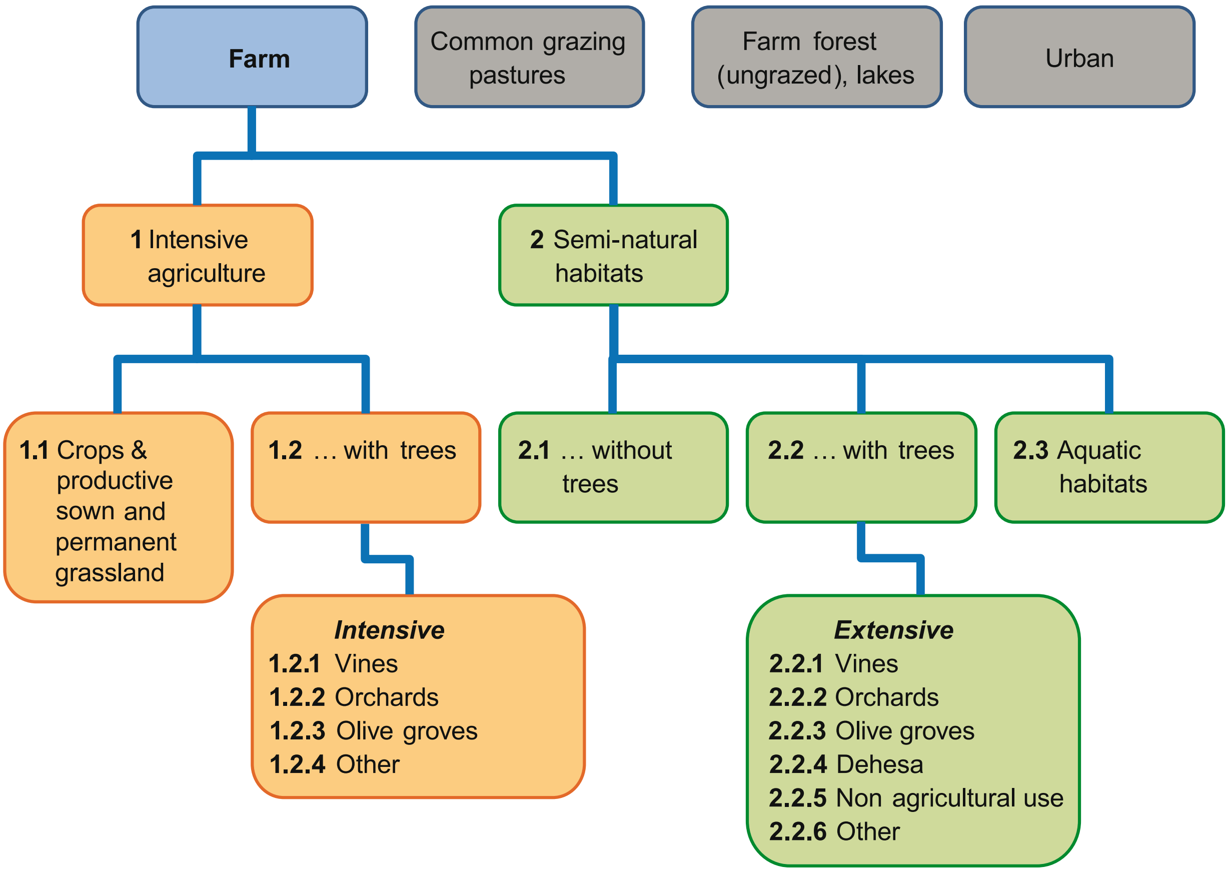

Figure 5.3: Farm habitat types are classified into categories. The majority of the farmland of most farms consists of category-1 land – 'Intensive agriculture' – interspersed with 'Semi-natural habitats' (category 2) consisting mainly of linear elements with or without trees or shrubs. In some European regions, farms are dominated by large areas of semi-natural grassland or agroforestry systems.

Figure 5.4: Depending on their level of intensity, permanent grasslands occur in both habitat categories, (1) Intensive agriculture and (2) Semi-natural habitats. Semi-natural permanent grasslands are mainly characterised by a vegetation composition reflecting less-intensive management. Because permanent grasslands (> 5 years) cannot always be differentiated in the field from more recently sown ones, the actual share of the former on the farms could not be measured reliably. These grasslands are examples of a gradient running from intensive in Germany (left) to intermediate intensity in Switzerland (centre) to extensive in France (right). Photos: (1) S. Wolfrum, TUM, (2) G. Lüscher, Agroscope, (3) J.P. Sarthou, INRA

Table 5.1: Crop types used in BioBio. Other types can be defined, depending on the objectives of the survey and on the species groups to be observed on the plots.

Non-Entomophilic and/or Non-Bee-Attracting Annuals		Entomophilic and/or Bee-Attracting Annuals	Perennials
Winter crops	**Spring crops**		
Winter oats	Spring oats	Oilseed rape	Fodder crops
Winter barley	Spring barley	Sunflower	Alfalfa
Winter wheat	Spring wheat	Maize	Asparagus
Rye	Lettuce	Soya	
Triticale	Peas	Cucumber	
Beans	Beans	Tomatoes	
		Potatoes	
		Strawberries	

Category (1.2), Intensive agriculture with trees, involves intensively managed vines and fruit orchards. In the BioBio case study sites this was the case for the vineyards in Italy, while the (extensively managed) olive groves in Spain and Tunisia were grouped with the semi-natural habitats.

5.3.2 Semi-natural habitats

Category (2), Semi-natural habitats, comprises all linear habitats and areal habitats managed as farmland where the species composition of the vegetation reflects less-intensive farming practices. Hedgerows, grazed forest, lines of trees, etc. belong to this category, which also includes all habitats listed in Annex I of the European Habitats Directive (EC 1992). Thus, for example, Spain's dehesas have been assigned in their entirety to this category. Extensively managed permanent grassland comes under this category if plant composition reflects the semi-natural character of the grassland. We strived for an overall classification of semi-natural habitats across all case study regions by establishing general rules (see Jeanneret *et al.* 2012). The classification was cross-checked individually by case study leaders.

Category (2.1), Semi-natural habitats without trees, relates to sparsely vegetated habitats, permanent grasslands, vegetated banks associated with stone walls and herbaceous linear elements. Category (2.2), Semi-natural habitats with trees, consists of extensively managed vines and fruit orchards (e.g. traditional high-stem orchards, olive groves < 200 trees / ha), small woods (< 800 m^2), larger forests if grazed, and woody linear habitats (hedgerows, lines of trees or scrub). Category (2.3), Semi-natural aquatic habitats, refers to water plots < 800 m^2 if they are used for agricultural purposes (e.g. aquaculture, seasonal ponds), as well as to water margins.

What is a semi-natural habitat?

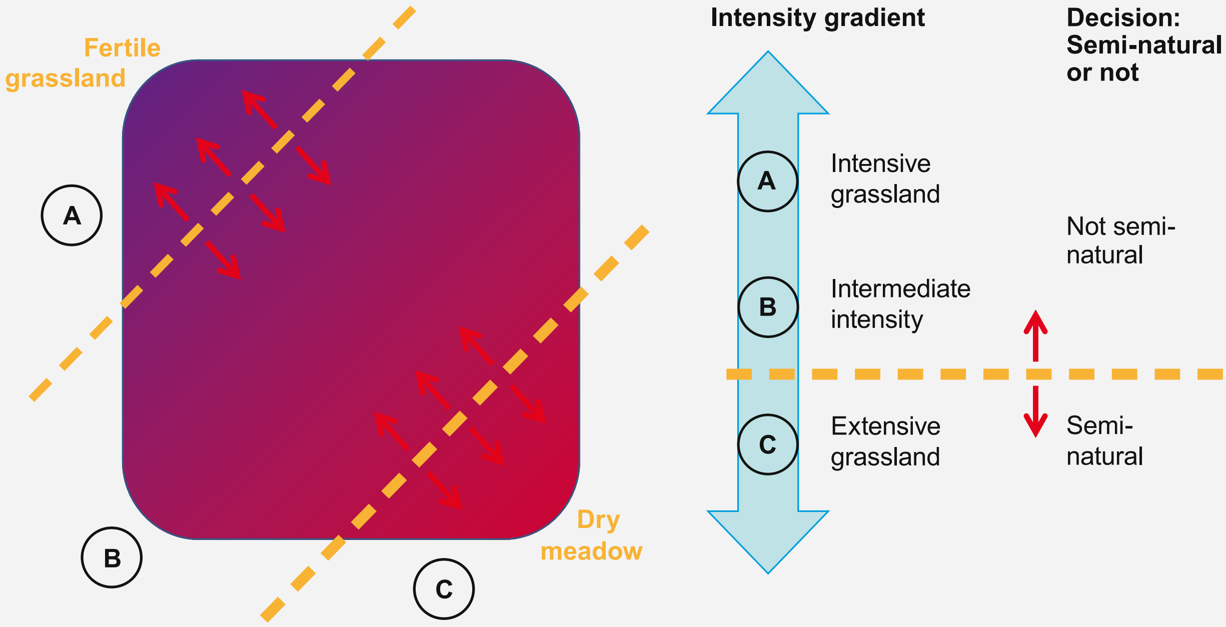

Figure 5.5: Conceptual graph illustrating the difficulties when classifying habitats as semi-natural or not. Grassland is taken as an example but similar problems occur in other habitat types.

Assigning the label 'semi-natural' to a habitat is not a straightforward matter, involving as it does decisions at a minimum of two stages. This can be difficult if the shifts from one habitat type to another are gradual, as often occurs in an agricultural context in permanent grassland (see Figure 5.5). A first decision must be made in order to separate the different vegetation types and classify them into distinct habitats labelled A, B and C in Figure 5.5. The EBONE (no date) habitat mapping method consists of a tested European-scale habitat-mapping methodology providing rules that help distinguish different habitat types. In a gradient-dominated landscape, however, deciding where exactly to separate the habitats from each other is still a long, drawn-out exercise.

Once the habitats have been identified and indicated on a map, a second decision – i.e. which of these habitats should be labeled 'semi-natural' – must be made. This is a clear-cut matter for habitats A and C in the figure, but a somewhat arbitrary decision for habitat B. Labeling a habitat 'semi-natural' is a 'black-and-white' decision in a situation where there are numerous intermediate ('grey') habitats. The definitions adopted in BioBio are detailed by Jeanneret *et al.* (2012), and attempt to create a classification which is applicable across Europe. What is perceived as 'semi-natural', however – both in terms of agricultural practices and the species pool for a given region – may vary from country to country. Depending on the aim and geographical extent of a monitoring programme, these definitions should be revised and adapted to local requirements. In Switzerland, for example, whilst the ecological compensation areas extensively managed by farmers under the cross-compliance regulation (e.g. unfertilised grassland with late cut) are not considered semi-natural in the European (BioBio) context, they are regarded locally as semi-natural areas. If possible, semi-natural habitats that meet local requirements should be distinguished during habitat mapping.

5.4 Habitat indicator set

Eighteen habitat indicators – most of them based on the habitat mapping – have been tested in the BioBio case studies. Of these, eight passed the test, as well as the BioBio Stakeholder Advisory Board audit (Figure 5.6, indicators in boxes). Six indicators were not considered sufficiently developed for standard application, and were felt to merit further research and testing (indicators in bold without boxes in Figure 5.6). The remaining four indicators were discarded, either because they could not be measured reliably, or because they yielded information that was redundant when other habitat indicators were employed.

a) Farm composition based indicators

- **Habitat Richness**
- **Habitat Diversity**
- **Average Size of Habitat Patches**
- **Length of Linear Elements**

Aggregation
Habitat density

b) Indicators relating to specific habitat types

- **Crop Richness**
- **Percentage of Farmland with Shrubs**
- **Tree Habitats**

Tree density
Weed
Crop flower
Percentage of arable land
Percentage of permanent grassland

c) Normative indicators

- **Percentage of Semi-Natural Habitats**

Valuable habitats
Multigrass swards
Ellenberg value

Figure 5.6: Habitat indicators tested in BioBio case studies. Indicators in boxes have been retained, indicators in bold with no box require further research, and the remaining indicators (non-bolded, no box) have been discarded.

Four of the recommended indicators are based on the composition and geometry of the farm habitats (Group (a) in Figure 5.6). Taken together, they enable an interpretation of the diversity and distribution of the different habitats on the farm. The BioBio grassland case-study farms in Switzerland, for example, had a relatively high Habitat Richness (many different habitat types), but the indicator values for Habitat Diversity were low, suggesting that the majority of the area of the farms is covered by just a few dominant habitat types (see indicator factsheets for the indicator values). The relatively high values for Linear Habitats indicate that the high Habitat Richness is mainly due to various linear elements. In the arable case study in Austria, Habitat Richness was low but Habitat Diversity was high, supporting the comparatively high Patch Size and low values for Linear Habitats. This indicates that in Austria the farms consist of relatively few habitats with more even quantities of each habitat type, in comparatively large fields, with just a few linear (semi-natural) elements.

Three indicators (Group (b) in Figure 5.6) relate to specific habitat types. Crop Richness is of interest mainly for arable farms, and is expected to correlate with species richness in crop fields. The Percentage of Farmland with Shrubs can indicate both a valuable habitat for species which depend on habitat structure (e.g. spiders), as well as the abandonment of marginal farmland, and therefore must be interpreted in context. The share of farmland with Tree Habitats is of interest on intensively managed arable and grassland farms, where (fruit) trees are often among the few habitats for farmland wildlife, e.g. birds. The Percentage of Semi-Natural Habitats (Group (c) in Figure 5.6) is a normative indicator revealing the overall potential of a farm for hosting wild species (see Chapter 6).

Italian Case Study: Vineyards

In a region where wine production plays an important economic role in both agriculture and the overall economy, the vineyards of the Veneto in northeastern Italy have a long tradition of organic wine production. The Veneto is famous for its Prosecco sparkling wines, its high-quality table wines, and its aromatic high-quality wines (e.g. Amarone and Valpolicella from the Verona hills). The farms surveyed specialise in wine production, with grapes being the only, or the main, crop. The vineyards sampled are mature, and hence in full production. The farms surveyed are also private businesses whose income derives mostly from farming activities. Some farms also run B&Bs and agro-tourism activities, but this accounts for only a limited part of their income.

Number of farms surveyed: 9 organic, 9 non-organic
Average farm size: 27 ha
Average N-Input: 24 kg/ha
Average energy input: 1415 kg fuel equivalents
Total number of habitat types: 11
Total number of plant species: 246
Total number of bee species: 64
Total number of spider species : 86
Total number of earthworm species: 16
Total number of crop species: 4
Total number of crop varieties: 55

Table 5.2: BioBio habitat indicator set: recommended indicators, research indicators, and indicators which were discarded for failure to meet the selection criteria.
***: low, **: medium, ***: high, n.a.: not applicable / not tested in BioBio.**

	Name	Unit	Data Source	Cost	Scien-tifi-cally Sound	Prac-tica-ble	Attrac-tive	Sub-Indicators	Comments
Recommended Indicators									
HabRich	**Habitat richness**	N° of habitat types per hectare	Habitat mapping	**	***	***	***	1) Habitat richness of cultivated forage and food crops 2) Habitat richness of semi-natural habitats	Further division into sub-indicators is possible
HabDiv	**Habitat diversity**	Shannon diversity	Habitat mapping	**	***	***	***	1) Habitat diversity of cultivated forage and food crops 2) Habitat diversity of semi-natural habitats 3) Habitat diversity of areal habitats 4) Habitat diversity of linear habitats	Further division into sub-indicators is possible
PatchS	**Average size of habitat patches**	ha	Habitat mapping	**	***	***	***	1) Patch size of cultivated forage and food crops 2) Patch size of semi-natural habitats	Can also be calculated for further sub-categories
LinHab	**Length per hectare of linear elements**	m / ha	Habitat mapping	**	***	***	***	1) Length of grassy linear features 2) Length of woody linear features 3) Length of auqatic linear features 4) Length of wall linear elements	Can be individually calculated for mapped categories
CropR	**Crop richness**	N° of crops per farm / per hectare	Interviews	*	***	***	***	Most relevant for arable systems	
ShrubHab	**Percentage of farmland with shrubs**	% of farmland	Habitat mapping	**	***	***	***		Interpretation in context. Can be positive in intensively cultivated areas, but negative in areas of agricultural abandonment
TreeHab	**Tree cover**	% of farmland	Habitat mapping	**	***	***	***	1) Share of cultivated forage and food crops with trees (%) 2) Share of semi-natural habitats with trees (%) 3) Share of area with trees (%) 4) Share of lines with trees (%)	Further division into sub-indicators is possible
SemiNat	**Percentage of semi-natural habitats**	% of farmland	Habitat mapping	**	***	***	***	1) ... without trees 2) ... with trees 3) Semi-natural aquatic habitats	Includes all linear habitats and areal habitats classified as semi-natural. Can also be calculated for further sub-categories
Research Indicators									
TreeDens	**Tree density**	N° of trees per ha	Habitat mapping	** / *	***	***	n.a.		Can be used to differentiate between intensive and extensive orchards and olive plantations. Cannot be tested in BioBio, as only extensive plantations observed

Weed	**Cover of non-crop plants on arable fields, at the plot level**	Share of crop field covered by weeds	Vegeta-tion relevé or habitat mapping	*** / **	*	**	n.a.		Could be derived from vegetation sample or noted during habitat mapping but would require several visits per season
ValueHab	**Percent-age of valuable habitats on the farm**	% of farmland	Habitat mapping	**	**	*	n.a.		Annexe I habitats are easy to measure but hardly differentiate between farms. Addi-tional quality criteria could be used, e.g. national priority habitats, target habitats, etc.
Multigrass	**Area covered by multi-grass swards**	% of farmland	Vegeta-tion sample	***	*	*	n.a.		European definition not meaningful, would require regional defini-tions
Aggre-gation	**Ratio of total farm size to minimum bounding polygon, i.e. the smallest polygon that en-closes all patches belonging to the farm**		Habitat mapping	**	**	***	n.a.		Easy to compute from farm plot maps but more relevant for classifying farm types, rather than having direct ecological significance
CropFlower	**Ratio of non-flow-ering to flowering crops on the farm**	%	Habitat mapping	**	**	***	n.a.		For arable farming systems. Crop categories in habitat mapping defined as flowering / non flowering; test against arthropod data
Discarded Indicators									
HabDensity	**Habitat density**	N° of habitat patches per ha of farm	Habitat mapping	**	***	***	*		Consistent correlation with patch size (consist-ent also for sub-indica-tors), therefore redundant and not needed.
ArableArea	**Percent-age area of arable land**	% of farmland	Habitat mapping	**	**	*	n.a.		Cannot be reliably measured. The difference between permanent and sown grassland is difficult to detect in the field (survey); farmers have difficulties in differentiat-ing between the two categories (interview)
Grass Area	**Percent-age area of permanent grassland**	% of farmland	Habitat mapping	**	**	*	n.a.		Cannot be reliably measured. The difference between permanent and sown grassland is difficult to detect in the field (survey); farmers have difficulties in differentiat-ing between the two categories (interview)
Ellenberg	**Ellenberg values indicating environ-mental conditions of farm grasslands**	Ellenberg scores	Vegeta-tion relevé	***	**	*	n.a.	For differerent character-istics (soil moisture, pH, nutrient status, etc.)	Discarded because Ellenberg values are not systematically available across Europe

References

Dennis P., Bogers M.M.B., Bunce R.G.H., Herzog F. & Jeanneret P. 2012. Biodiversity in organic and low-input farming systems. Wageningen, Deliverable 2.2 of the EU FP7 Project BioBio. ISBN 1566-7197. ALTERRA Report 2308. http://www.biobio-indicator.org/deliverables.php

EBONE (no date) http:// www.ebone.wur.nl. [Accessed 24/12/12]

EC, 1992. Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX: 31992L0043:EN:html [Accessed 24/4/12]

Jeanneret P., Lüscher G., Schneider M. *et al.* 2012. Report on scientific analysis containing an assessment of performance of candidate farming and biodiversity indicators and an indication about the cost of indicator measurements. Deliverable 4.1 of the EU FP7 Project BioBio. http://www.biobio-indicator.org/deliverables.php

6 Species diversity indicators

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In farmland monitoring, it is essential to collect information on the minimal set of species groups in order to represent the biodiversity of different trophic levels and functional groups. Good species diversity indicators are sensitive to agricultural management. They may operate at different scales, e.g. at local, farm and landscape levels. Direct measures of species diversity are also essential for corroborating the effects of changes in indirect indicators and revealing lag times in responses that would not be determined from changes in indirect or habitat-based indicators.

6.1 Introduction

Species diversity is typically viewed as synonymous with biodiversity by the general public, who are often less aware of the genetic and habitat diversity components of biodiversity. Information on species is also essential in order to characterise actual changes in biodiversity. A basic indicator set of species is essential for increasing confidence in the impression of change given by monitoring information derived from habitat surveys (which only indicate a potential for species diversity) or indirect evidence from farm-management surveys (which yield pressure indicators for species). For instance, habitat extent can be readily mapped, but the ecological status of habitats (quality) can only be assessed if there are complimentary data on plant species and fauna. The speed of species' response to changes in farm management practices or habitat diversity and extent is an essential property of indicators, since there are time lags between observed changes in mapped habitats or management on the one hand, and the recruitment or loss of species or changes in their population sizes on the other.

Recommended species indicators are widely recognised as an effective means of assessing general environmental conditions. They can include emblematic species which engage public interest, and may respond at a different rate to environmental or management changes than the more easily measured general (habitat) or indirect indicators (Büchs 2003, Billeter *et al.* 2008). In the BioBio project, the selection procedure described in Chapter 2.2 was further progressed with reference to the essential qualities of species diversity indicators (Table 6.1).

6.1.1 Legal obligations related to biodiversity conservation at the species level

International conventions, EU Natura 2000 legislation and national conservation designations for nature conservation all emphasise the need for species level information. Species listed in Annex II of the EC Habitats Directive typically suffer from a rapid rate of population decline, or rapid reductions in the occupancy of grid squares in their former geographic range. When considering target-driven payments to landowners (Gibbons *et al.* 2011), objective evidence of the status of species is essential in order to avoid agri-environmental schemes' previous failure to contribute to biodiversity targets for plant and animal species that are rare or of restricted range (Reidsma *et al.* 2006). The Strategic Goals of the Convention on Biodiversity Conservation, Nagoya 2010, included the wording "C. To improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity", and the resulting Aichi Targets for 2020 included "Target 7: Areas under agriculture … are managed sustainably, ensuring conservation of biodiversity".

Table 6.1: Properties for the selection of species diversity indicators (adapted from Pearson & Carroll 1999).

Consideration	Desirable characteristics
Familiarity with biology and ecology of taxonomic group	Biology and life history well understood
	At higher taxonomic levels (order, family, etc.), occurrence over a broad geographical range and breadth of habitat types so that results will be broadly applicable
	At lower taxonomic levels (species), specialisation of each population within a narrow habitat to detect habitat change
	Evidence that the pattern observed in the indicator taxon is reflected in other taxa
Practical sampling and identification	Populations readily surveyed
	Well known taxonomy and easy identification
	Large random samples encompassing all species variation are possible
	Predictable, rapid, sensitive, analysable and linear response to disturbance
	High taxonomic and ecological diversity (many species in each location or system)
	Potential economic importance of some populations (agricultural relevance)

6.2 Process of reducing indicator numbers

With the countless taxa, the challenge is to select the ones to be used as indicators, assuming that they are – to some extent at least – representative of species diversity as a whole. The selection process (see Dennis *et al.*, 2009) reduced the number of possible plant and animal taxa from 36 to 11 (Figure 6.1). These were presented in December 2009 to the Stakeholder Advisory Board at a workshop in Brussels. Since it was desirable to represent the local to landscape conditions and trophic levels of organisms, there were generally choices between pairings of earthworms vs. ants, spiders vs. beetles, butterflies vs. bees, and wasps and birds vs. small mammals. The subsequent selection process, based on the perceived interest and relevance of each potential indicator to stakeholders, led to a further reduction in the list of candidate species indicators to 4 plus 1. The "plus one" represented birds. It was agreed that bird diversity was an established and widely recorded measure of species diversity (European Bird Census Council, no date) and that it was not necessary to invest further research effort in this group. The species groups of plant diversity (field and semi-natural habitat combined), earthworms, wild bees and spiders were taken forward for field evaluation in the case study regions in 2010.

6.3 Selected indicator species groups

The emphasis on invertebrates in addition to vascular plants reflects the contribution of the former to overall species diversity, with arthropods alone accounting for about 65 % of the species number of all multicellular organisms (Hammond 1994) and probably even higher percentages in cultivated areas (Duelli & Obrist 1998, 2003). In addition to the fact that invertebrates are relatively easy to monitor, provide relevant information on general environmental conditions (including emblematic species), and react quickly to environmental changes, substantial datasets on this group are available in a number of European countries (Dennis *et al.* 2009).

6.3.1 Ecological functions represented by the species groups

Flowering, vascular plants are the essential primary producers in agricultural ecosystems. In addition to species richness, sub-indicators were calculated (function of the number of species times the relative ground cover of each species) in order to provide information on the plants coexisting with agricultural management in fields or free-range grazing areas and those present in remnant semi-natural habitats in more intensive farmland. PlantLife In-

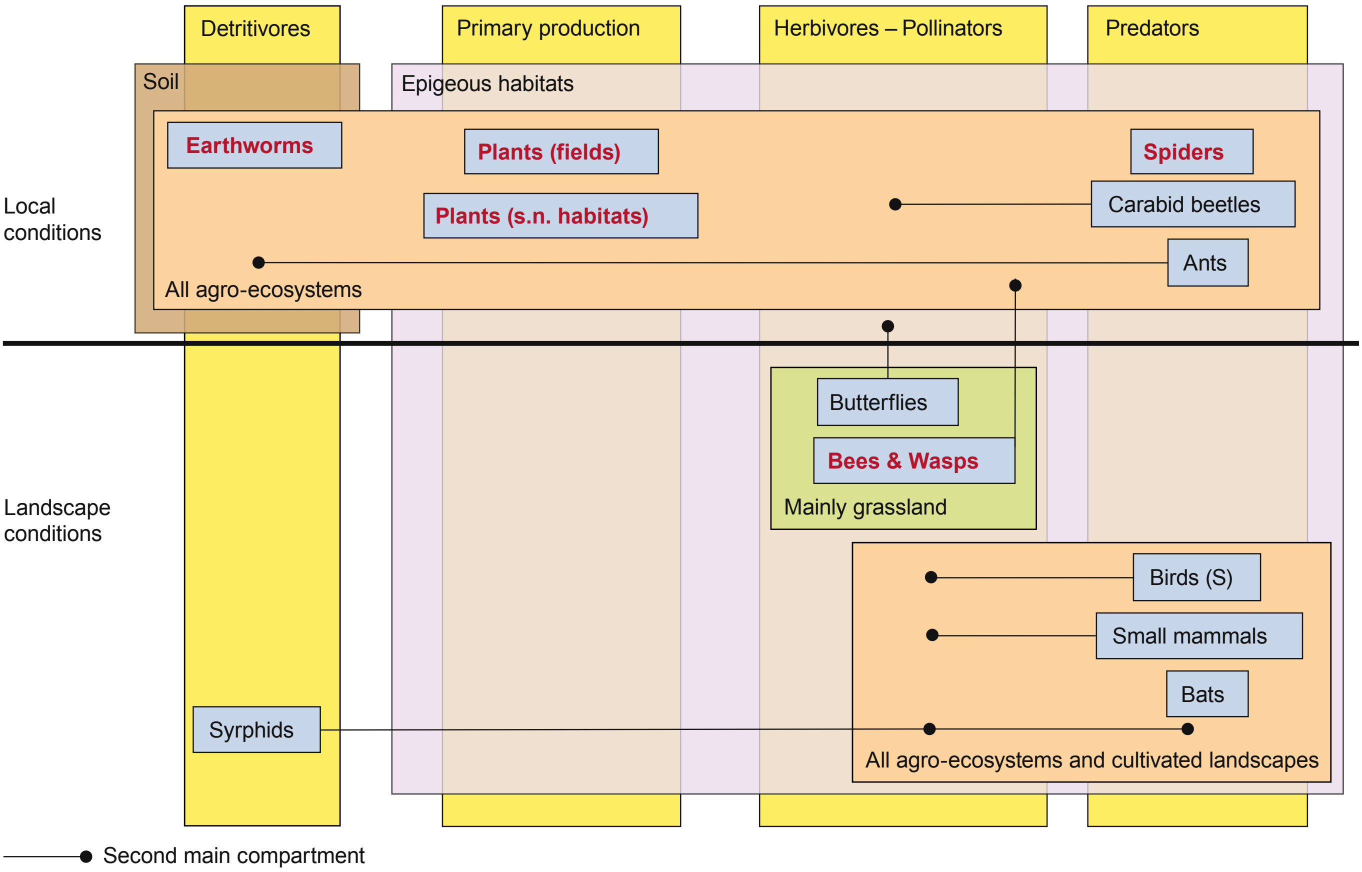


Figure 6.1: Rationale for selection of species indicators based on scale of spatial distribution, range of activity and trophic level (position in food chain). Selected indicator groups are printed in red.

ternational (no date) points to the decline and loss of many former common field plants under intensive agriculture, and the dicotyledonous flowering plants in particular have a high public and policy profile (Figure 6.2). Many bird species and pollinators have been excluded from farmland owing to the disruption of the flower succession and associated declines in host plant leaves, pollen and nectar and seeds.

Figure 6.2: The Pheasant eye, Adonis annua L. is now a rare plant of cultivated farmland (Source: Game and Wildlife Conservation Trust).

Earthworms are essential detritivore organisms of soils and their functions include aeration and increased fertility from the composting, recycling and redistributing dead plant material, directly affecting the productivity of farm soils. Soil fertility and structure (formation of stable aggregates) benefits from high populations of earthworms, facilitating soil aeration and water infiltration (soil pore formation through their burrowing activities). Different earthworm species contribute to three ecophysiological categories: (1) leaf litter/compost dwelling worms (epigeic, Figure 6.3), (2) topsoil or subsoil dwelling worms (endogeics); and (3) worms that construct permanent deep stable burrows through which they visit the surface to obtain plant material for food, such as leaves (anecic).

Figure 6.3: The widespread earthworm species Allolobophora chlorotica (Source: British Natural History Museum).

Wild bees are a species rich taxonomic group and are essential pollinators in natural ecosystems and for many agricultural and orchard crops. Widespread public concern is apparent for both the significant, recent decline in the domestic honey bee and also for wild pollinators, such as the bumblebees (Figure 6.4) which are the subject to campaigns by several food retail companies. Scientific research has demonstrated that the decline is complex, partly driven by parasitism and disease and partly by discontinuities in the flowering succession and associated availability of nectar and pollen throughout the year.

Figure 6.4: The bumblebee species Bombus monticola, recorded at upland, semi-natural summer pastures (Source: P. Dennis).

Spiders (Figure 6.5) represent a predatory group consisting of a large number of species, several of which play a role in regulating potential pest insect populations in cultivated crops. Several groups have long distance dispersal capabilities by ballooning and passive airborne distribution and

the detection of large numbers of species may represent selection of habitats with favourable botanical composition, architecture of vegetation for web anchorage or abundant prey populations. Larger species can be more restricted and larger population sizes and diversity of these species may reflect favourable habitat structure over longer periods than the smaller species will be able to indicate.

Figure 6.5: The money spider species Silometopus elegans (Linyphiidae), typically recorded in grasslands (Source: P. Dennis).

Despite the restriction to four candidate species indicators, bird diversity was assumed as a fifth indicator following the evaluation of further candidate species indicators (Figure 6.6). This was justified on the basis that bird monitoring is already well established and implemented across several European countries, in which the general population trends of a list of common, including farmland bird species is used as an OECD National Environmental Quality of Life indicator. Data are collected using the Pan-European Common Bird Monitoring Scheme (European Bird Census Council no date).

Birds are limited as an indicator for habitats below the scale of individual farms due to their size and mobility, hence could only realistically be used as an indicator for consolidated farms as the smallest unit for comparison unless surveys of breeding populations of territorial birds were compared at smaller spatial scales (i.e. at plot and field scale). Birds cannot be measured within the stratified

Figure 6.6: Lapwing Vanellus vanellus, typical of grazed, damp grasslands in the hills and lowlands (Source: P. Dennis).

sampling design conceived for the other BioBio species indicators based on the mapping of habitats.

6.3.2 Appropriate parameters of species for monitoring functions

The principle of diversity places emphasis on the number of species, rather than on other parameters such as incidence of rarity, species composition, or abundance of selected species. Species richness (the count of species recorded in a particular habitat or accumulated at the farm scale) or various measures of species diversity (weighting species richness by the relative abundance of each species) are appropriate agreed parameters for the assessment of biodiversity. Section 3.7 describes the options available for representing the different groups of species indicators with particular parameters for long-term or geographic comparison (species by habitat type or at the farm scale):

- Gamma richness: Total number of species of the farm pooled over the sampled habitats;
- Alpha richness: Average number of species over the sampled habitats;
- Area weighted richness: Total number of species over the sampled habitats weighted by the area of the habitat types to which each habitat belongs;
- Rarefied richness: Average number of species calculated for the smallest number of habitats found in a farm (rarefaction);
- Chao estimated richness: Estimated number of species on a farm based on the accumulated number of species found in habitats.

Once the species lists are available from field surveys, one or more of the five parameters can be calculated according to local requirements. As a rule, for most BioBio case study regions and for all four species groups, the gamma richness – i.e. the total number of species pooled over the sampled habitats of a farm, was significantly correlated with the other four richness indices (Jeanneret *et al.* 2012). Hence, gamma richness is the main expression of species diversity for each species group related to habitat (this section) and management indicators (section 8) in this guidebook.

The correlations between species indicators on the one hand and habitat and farm management indicators on the other are of particular interest, because (i) the latter are usually easier to record, and could potentially serve as surrogate indicators for species; and (ii) they allow us to test hypotheses about causal relationships between habitat quantity, habitat quality and farm management on species diversity. Some preliminary results are presented in the following two sections.

Dutch Case Study: Horticulture

This case-study region is situated in the eastern part of the provinces of Gelderland and Noord Brabant. The landscape is characterised by intensively managed arable dairy and horticulture systems. Irrigation is routinely used on two-thirds of the farms in vegetable production. All farms surveyed are horticultural systems without greenhouse cultivation.

Number of farms surveyed: 11 organic, 3 non-organic
Average farm size: 18 ha
Average N-Input: 151 kg/ha
Average energy input: 1998 kg fuel equivalents
Total number of habitat types: 19
Total number of plant species: 207
Total number of bee species: 22
Total number of spider species: 76
Total number of earthworm species: 16
Total number of crop species: 18
Total number of crop varieties: 58
Total number of livestock species: 2
Total number of breeds: 4

6.4 Correlations among indicator species groups

When searching for indicators, an important question concerns the degree to which one indicator or another is representative of the whole set. In the case of species groups, surrogates may be identified that are indicative of the diversity of other groups. As primary producers, plants are expected to play this role by forming habitats with various ecological niches that in turn may provide suitable conditions for faunistic groups. The consequence for monitoring programs is that two correlating indicators convey the same information, and only one of them need be measured. The correlations among the four species groups in the BioBio case studies were highly diverse, and followed no general pattern, ranging from a majority of the correlations being highly significant (Austria, Switzerland, Olive groves in Spain) to there being just a few significant correlations (France, Bulgaria, Germany), to the existence of one or no significant correlations (The Netherlands, Hungary, Norway, Wales, Dehesa in Spain, Italy). One example of each case is illustrated in Figure 6.7.

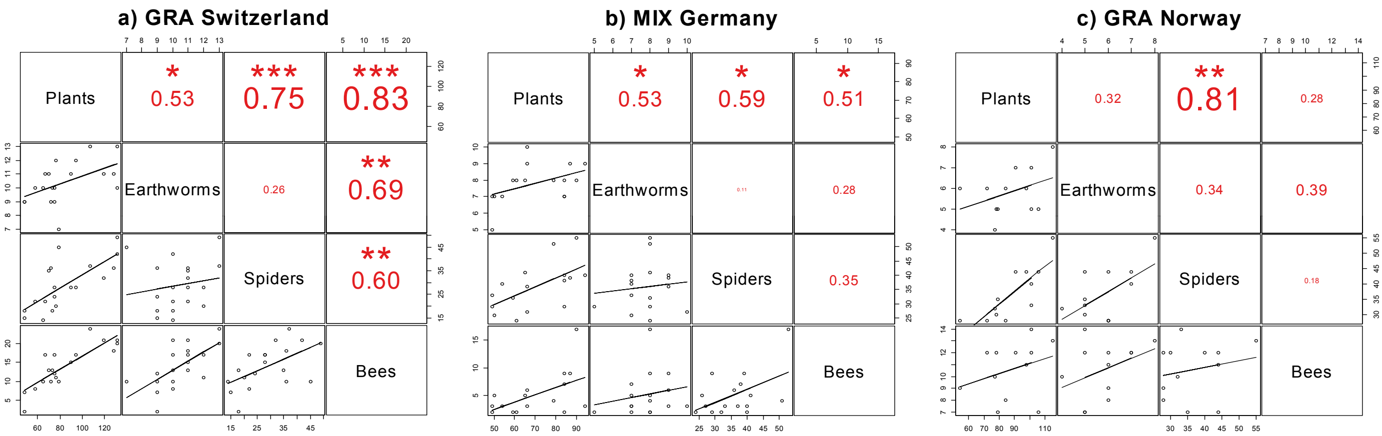


Figure 6.7: Spearman correlations of the gamma richness on farms of the four species indicator groups in (a) the grassland case study region in Switzerland, (b) the mixed farming region of Germany, and (c) the grassland case study region in Norway. The relationship between indicators is graphically shown below the diagonal. Correlation coefficients with significance (stars) are given above the diagonal. Font size is proportional to coefficient value.

6.5 Species diversity, number of habitat types on farms, and the contribution of semi-natural habitats

Table 6.2 summarizes the number of species per case study region and per farm. There are considerable differences between the total numbers of species recorded between case study regions, due to both bio-geographical differences and to different farm types. Therefore, comparisons across case study regions are not very meaningful. Still, it is interesting to note that, on average across all case studies, 50 – 160 different plant species per farm were recorded. For bees the range is between 3 and 34 species per farm (excluding the honey bee); for spiders it is 12 – 65 species per farm and for earthworms 2 – 10 species per farm.

Table 6.2: Average number of specimen and of species recorded per case study region and per farm.

		ARA Austria	ARA France	HOR The Netherlands	GRA Bulgaria	GRA Switzerland	GRA Hungary	GRA Norway	GRA Wales	DEH Spain	MIX Germany	VIN Italy	OLI Spain	Total
	Farms	16	16	14	16	19	18	12	20	10	16	18	20	195
	Habitat types	15	36	19	51	19	58	23	45	31	14	11	14	n.a.
	Habitat types per farm	7.7	9.8	7.4	8.3	5.7	8.2	9.8	10.7	11.1	7.9	4.1	3.7	7.9
Plants	Species	247	360	207	364	269	388	200	321	403	211	246	288	1 581[a]
	Species per farm	50.4	101.2	49.6	78.0	84.5	90.9	88.0	84.0	164.1	70.1	60.4	71.9	82.8
Bees (Apis mellifera excluded)	Individuals	101	2 127	73	356	570	298	812	588	485	115	453	252	6 230
	Species	49	153	22	91	64	101	23	13	51	34	64	44	382 [a]
	Individuals per farm	6.3	132.9	5.2	22.3	30.0	16.6	67.7	29.4	48.5	7.2	25.2	12.6	403.8
	Species per farm	5.2	33.6	2.6	11.4	14.0	10.4	10.6	5.7	12.2	5.1	9.4	6.6	10.6
Spiders	Individuals	1 470	4 879	500	770	2 200	1 816	3 175	9 214	2 921	4 272	466	1 446	33 129
	Species	128	215	76	106	125	163	104	158	116	110	86	123	603 [a]
	Individuals per farm	91.9	304.9	35.7	48.1	115.8	100.9	264.6	460.7	292.1	267.0	25.9	72.3	2 079.9
	Species per farm	30.2	64.5	11.6	19.8	28.9	29.3	36.8	45.8	38.0	35.9	12.2	22.5	31.3
Earthworms	Individuals	1 164	7 962	671	293	2 321	474	928	4 226	2 337	2 664	219	924	24 183
	Species	10	16	16	8	17	8	10	18	17	11	14	19	49
	Individuals per farm	72.8	497.6	47.9	18.3	122.2	26.3	77.3	211.3	233.7	166.5	12.2	46.2	1 532
	Species per farm	4.7	10.4	4.4	3.4	10.4	2.3	5.8	8.6	6.4	7.8	3.4	4.5	6.0

[a] *Checking for synonyms across case studies still ongoing (only complete for earthworms)*

Across the BioBio farms, the decisive issue with respect to species richness at farm level (gamma diversity) was the overall number of habitat types, i.e., more habitat types accumulate more species (Figure 6.8). The results also showed that there are usually more semi-natural habitats than represented by cultivated forage and food crop fields on the BioBio farms across regions (Table 6.3). The consequence was that more semi-natural habitats were sampled for species on farms as a result of the sampling rules, i.e. one habitat sampled per habitat type recorded for each farm. In all BioBio case studies, plant and spider species richness on farms increased with the number of habitat

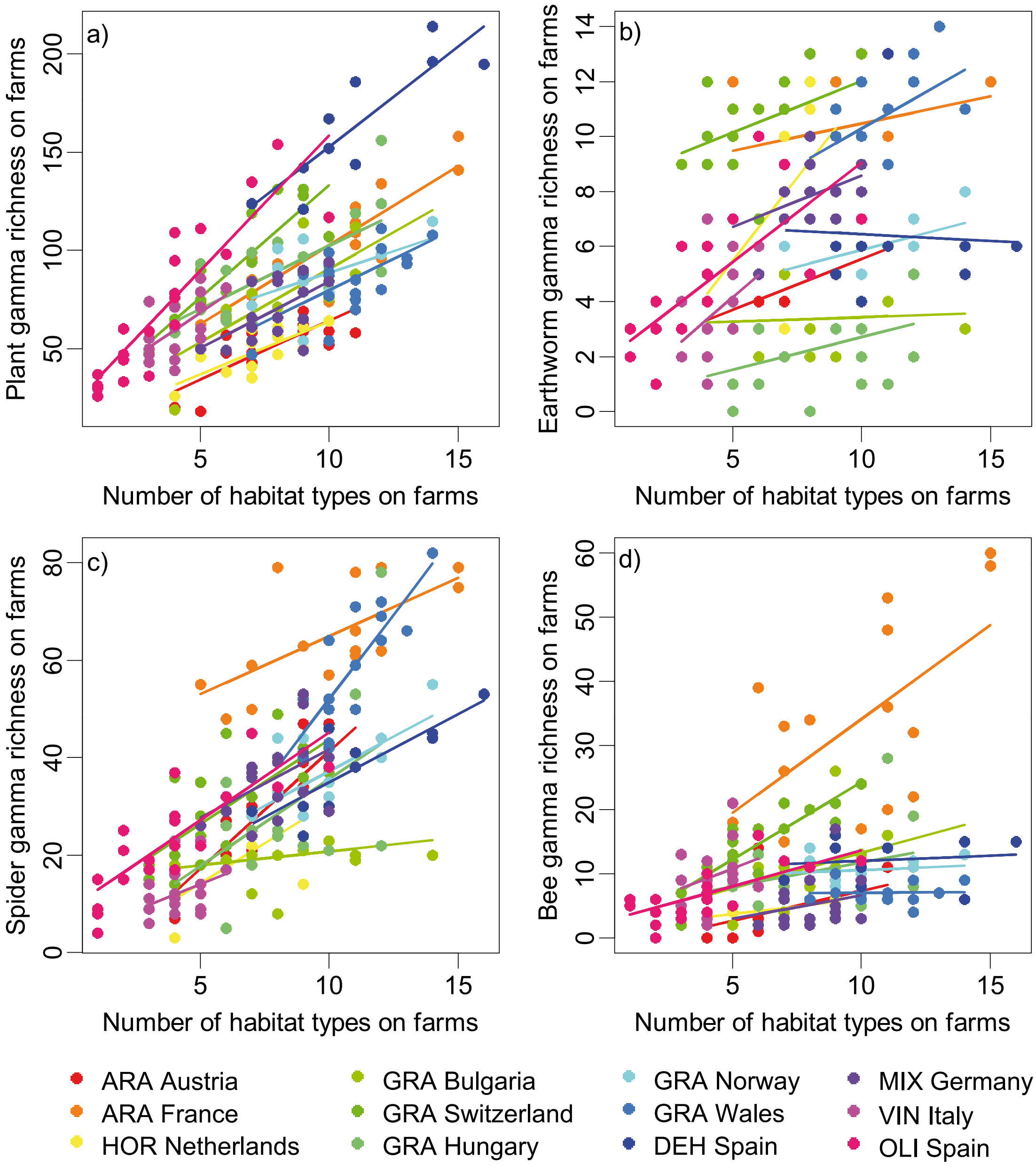


Figure 6.8: Gamma richness of (a) plants (b) earthworms (c) spiders and (d) bees on farms (overall species richness) related to the number of habitat types in 12 BioBio case study regions. ARA = arable CS, HOR = horticulture CS, GRA = grassland CS, DEH = Dehesa CS, MIX = mixed farming CS, VIN = vineyard CS, and OLI = olive plantation CS.

types recorded, and this trend also held good for nearly all case studies of earthworms and bees. Even so, the variability among farms within case studies was high.

On farmland, semi-natural habitats are recognised as playing an important role in the conservation of species diversity. On the BioBio farms, species diversity was investigated in semi-natural habitats, as well as in typical fields managed for agricultural production. One of the important questions arising with respect to species diversity in farmland relates to the proportion of the species effectively occurring in semi-natural habitats as opposed to intensive agricultural fields. The answer provides useful information on the relative contribution of these features to overall species richness (gamma diversity) in a biodiversity monitoring programme. The relative contribution is summarized in Figure 6.9 expressed as the percentage of species found exclusively in semi-natural habitats (definition in Chapter 5) or in cultivated forage and food crop fields, or shared over both in the BioBio case study regions. Semi-natural habitats generally make a greater contribution to species richness than cultivated forage and food crop fields.

The significant influence of number of habitat types found on farms, combined with the generally greater contribu-

Table 6.3: Number of semi-natural habitats, cultivated forage and food crop fields, and share (percent area) of semi-natural habitats in the BioBio case studies. ARA = arable CS, HOR = horticulture CS, GRA = grassland CS, DEH = Dehesa CS, MIX = mixed farming CS, VIN = vineyard CS and OLI = olive plantation CS. See Chapter 5 for the definition of semi-natural habitats.

Case study	Average no. of semi-natural habitats / cultivated forage & food crop fields found and sampled per farm	Average share (percent area) of semi-natural habitats per farm
ARA Austria	4.1 / 3.6	3.5
ARA France	6.6 / 3.2	7.5
HOR Netherlands	4.7 / 2.6	11.1
GRA Bulgaria	8.2 / 0.06	99.4
GRA Switzerland	3.4 / 2.3	4.7
GRA Hungary	3.7 / 4.5	19.5
GRA Norway	8 / 1.8	24.5
GRA Wales	9.7 / 0.9	48.6
DEH Spain	10.8 / 0.3	99.0
MIX Germany	2.5 / 5.4	3.0
VIN Italy	2.5 / 1.5	2.9
OLI Spain	3 / 0.6	95.0

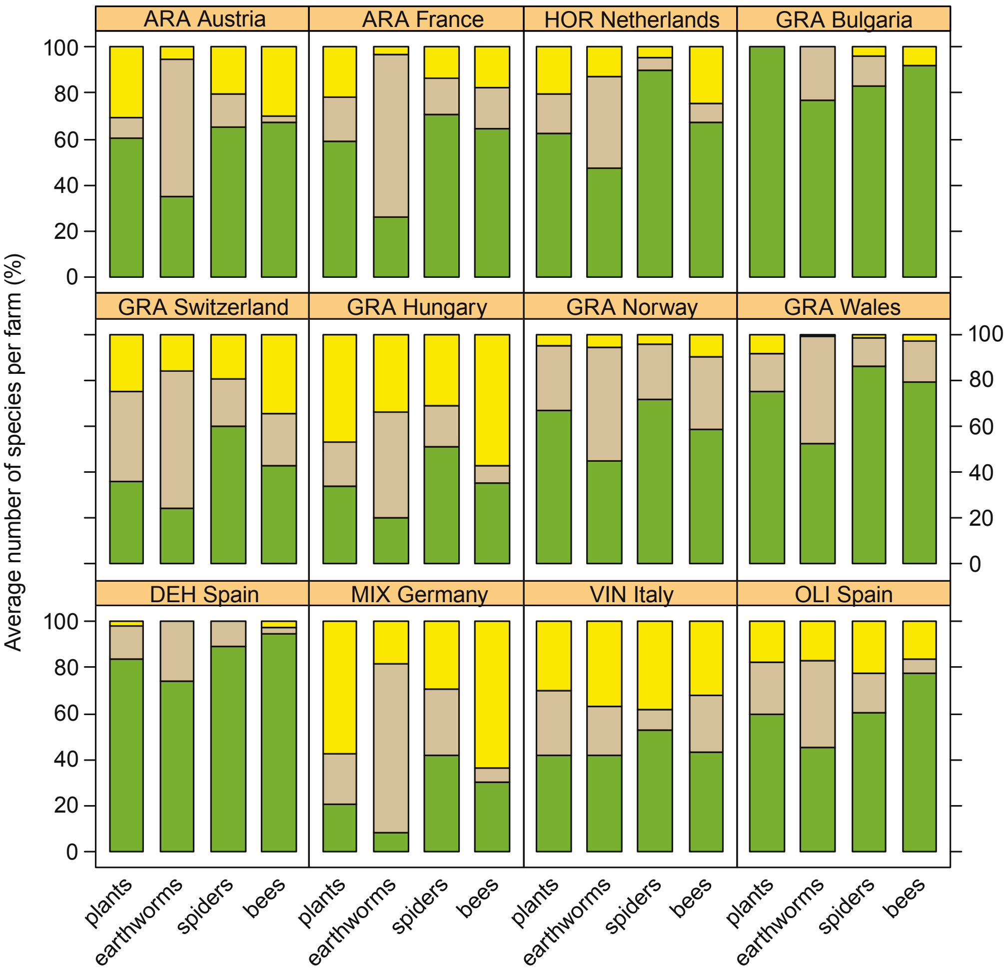


Figure 6.9: Percentage of plant, earthworm, spider and bee species found exclusively in semi-natural habitats (green stack), in cultivated forage and food crop fields (yellow stack) or in both (grey stack), based on the average number of species across farms in each case study (CS). ARA = arable CS, HOR = horticultural CS, GRA = grassland CS, DEH = Dehesa CS, MIX = mixed farming CS, VIN = vineyard CS, and OLI = olive plantation CS.

tion of semi-natural habitats to species richness illustrated above (Figure 6.9) demonstrated the importance of habitat diversity – as opposed to habitat surface area – in supporting biological diversity on farms. Earthworms, which appear to be less sensitive to this distinction, are perhaps the exception to the rule here. In absolute terms, semi-natural habitats make a greater contribution to species richness at the farm level than those habitats under direct agricultural management. For the most part, the species richness of farms did not correlate with the percentage of farmland classified as semi-natural habitats (Figure 6.10). This is because a small number of semi-natural habitat types may predominate on a farm, accounting for a large proportion of its area, without necessarily increasing species richness at farm level. In terms of the percentage of farmland accounted for by semi-natural habitats, case studies can be divided into three groups: those with high percentages (> 80 %, e.g. olive plantations in Spain), those with low percentages (< 20 %, e.g. arable land in Austria), and those accounting for a wide range of shares (0 % < share < 100 %, e.g. grassland systems in Norway) (Figure 6.10). Except for plants in olive plantations in Spain, farms with a high proportion of semi-natural habitats did not in general exhibit greater species richness. Most positive associations were observed in grassland systems accounting for a wide range of percentages, e.g. in Norway and Wales for plants and spiders. In case studies with a low proportion of semi-natural habitats, significant positive associations were observed for earthworms in the vineyard systems of Italy and the mixed systems of Germany. In conclusion, in order to increase the number of species on a farm, habitat diversity should be increased (i.e. more habitats of different types should be created), instead of increasing solely the area of existing (semi-natural) habitats but it should of course consider the minimum area requirements of habitats to sustain species.

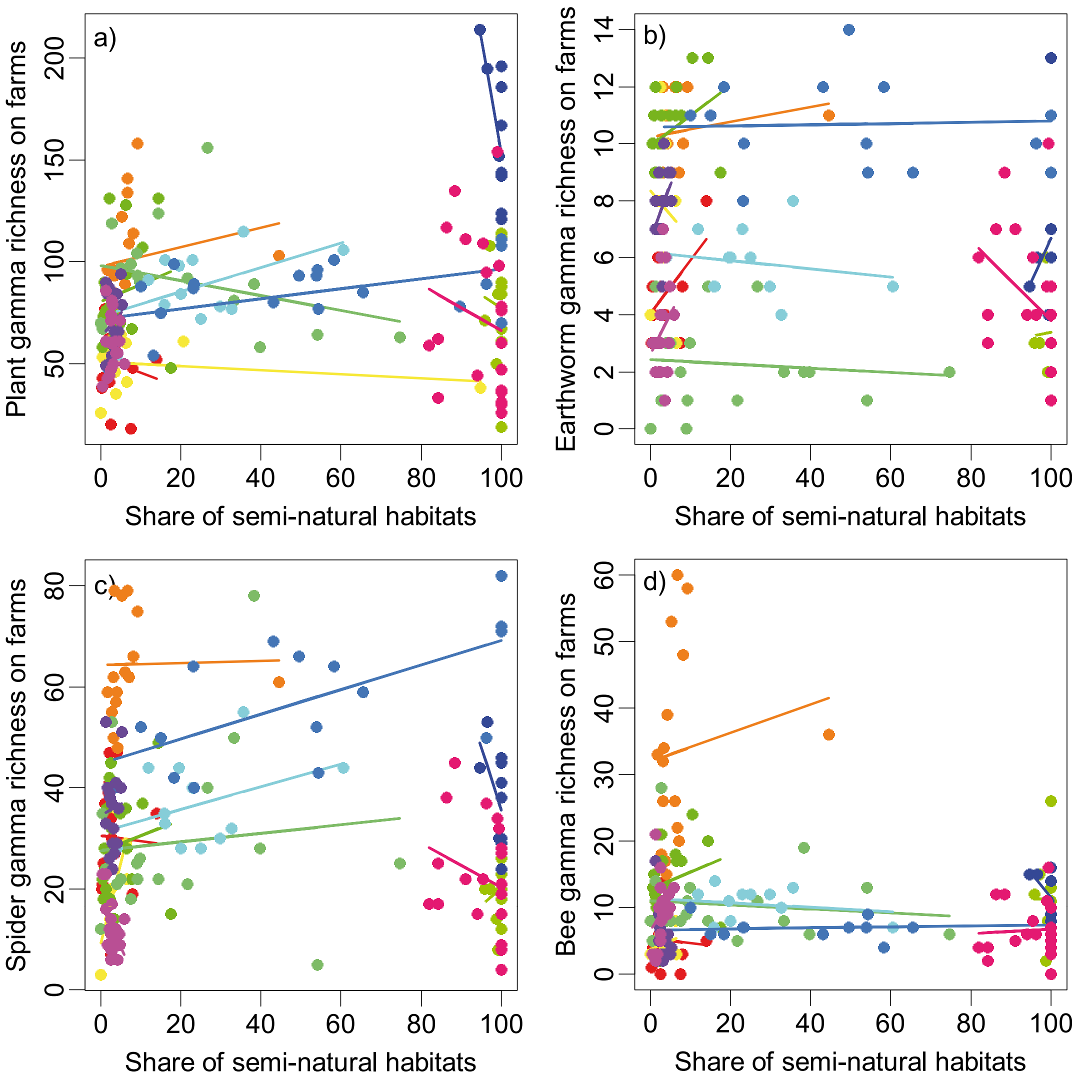


Figure 6.10: Gamma diversity of (a) plants (b) earthworms (c) spiders and (d) bees on farms (overall species richness) related to the share of semi-natural habitats (area per ha) in 12 BioBio case study regions. As with Figure 6.8, colours of points and lines refer to the case studies.

6.5.1 Arable, mixed and horticultural case studies – Austria, France, Germany and The Netherlands

In these farming systems, although the reaction of all four species indicators with respect to semi-natural habitats was not uniform, the response of particular species groups showed similarities across case studies. Indeed, whereas about 60 % of the plant species were found exclusively in semi-natural habitats, a large number of earthworm species were captured in both semi-natural habitats and in those managed for agriculture (Figure 6.9). Over 65 % of the spider and bee species occurred exclusively in semi-natural habitats. Germany's mixed farming system showed the highest impact of habitats directly managed for agriculture on species found there exclusively, owing to the high number of such habitat types in this region. Despite this, the number of species generally increased with the number of semi-natural habitat types. The arable case study in France showed the highest numbers of spider and bee species of any European case study.

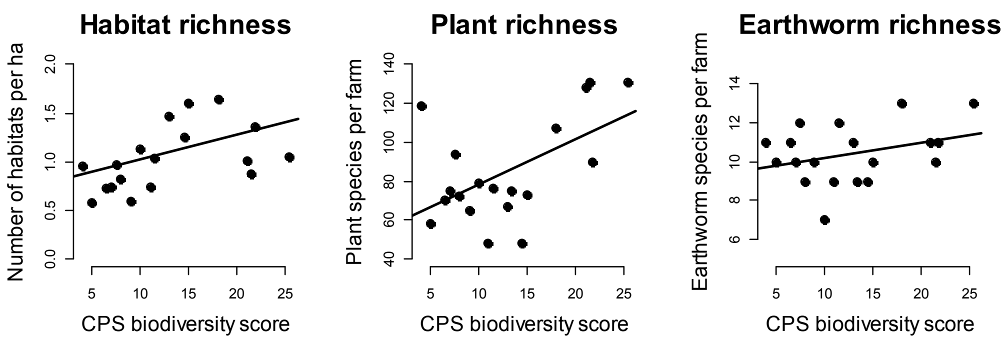
6.5.2 Grassland case studies – Bulgaria, Switzerland, Norway, Hungary and Wales

In grassland case studies, the role of semi-natural habitats differed since it was largely dependent upon the number of semi-natural habitat types. In Bulgaria, for example, whilst 132 habitats investigated across farms were considered semi-natural, only one intensive agricultural field was reported. In Hungary and Switzerland – countries with fewer semi-natural habitats – the number of species found exclusively in both semi-natural and intensive agricultural habitats was similar. With high numbers of semi-natural habitat types in Wales and Norway, the percentage of species found exclusively in semi-natural habitats also increased. In Bulgaria, semi-natural habitats accounted for over 80 % of farmland. Consequently, there was little variation in the number of species, which was lower here than in some other areas (Figure 6.10).

In Switzerland, the farmers' association "IP-SUISSE" strives to increase habitat and species diversity on the farms of their members (see Box). Positive trends between their biodiversity score and Habitat richness as well as the species indicators were observed on the Bio-Bio farms (Figure 6.11).

6.5.3 Case studies: Dehesa in Spain, Vineyard in Italy, and Olive plantation in Spain

With very high levels of semi-natural habitat types, the Dehesas and olive plantations in Spain also had a high level of species found exclusively in these habitats, in particular bees (Figure 6.9). The Dehesas were also exceptionally rich in plant species, with no repercussion on faunistic groups (Figure 6.8). In vineyards in Italy, both semi-natural and intensive agricultural habitats exhibited a similar number of exclusive species, and only the number of earthworm species increased with a higher number of semi-natural habitat types.



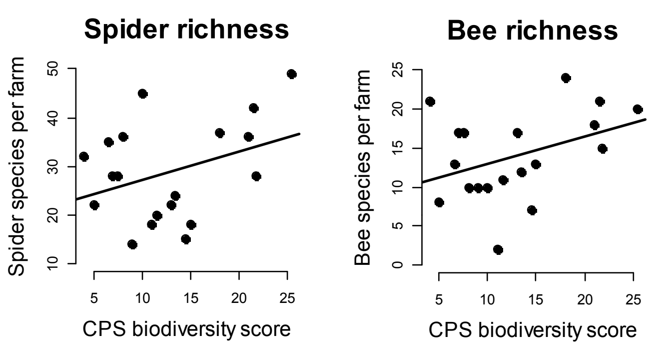


Figure 6.11. Correlations between farm scale CPS biodiversity scores (see Box) and biodiversity indicators in the Swiss case study. Habitat richness: Spearman's rho 0.63, p=0.0045; Plants: Pearson's cor 0.54, p=0.0160, Earthworms: Pearson's cor 0.33, p=0.1735; Spiders: Pearson's cor 0.36, p=0.1334; Bees:. Pearson's cor 0.39, p=0.1030.

Norwegian Case Study: Grassland with Sheep

The study area is located in Nord-Østerdal, in northern Hedmark County. One of the biggest sheep producers in Norway, it is also a leading region for organic agriculture, with about 20 % by area of the sheep farms being organic. Most of the sheep grazing is on communal land in the mountains.

Number of farms surveyed: 6 organic, 6 non-organic
Average farm size: 15 ha
Average N-Input: 93 kg/ha
Average energy input: 345 kg fuel equivalents
Total number of habitat types: 23
Total number of plant species: 200
Total number of bee species: 23
Total number of spider species: 104
Total number of earthworm species: 10
Total number of crop species: 6
Total number of crop varieties: 16
Total number of livestock species: 1
Total number of breeds: 5

Scoring with Biodiversity – A scientific evaluation of species diversity indicators at farm-scale

Judith Zellweger-Fischer, Lukas Pfiffner, Oliver Balmer & Simon Birrer

For the project "Scoring with biodiversity – farmers enrich nature", the Swiss Ornithological Institute and the Research Institute of Organic Agriculture FiBL have developed a Credit Point System (CPS) as an indicator system for biodiversity at farm-scale. Farmers can score points by applying 34 different biodiversity-favouring measures. The CPS point score serves as a proxy for the biodiversity efforts made on a given farm.

The effectiveness and applicability of the CPS is currently evaluated on 133 farms in the Swiss lowlands. Plants, grasshoppers, butterflies and breeding birds have been assessed at each farm and are now compared with the farms' point scores. Preliminary results indicate significant positive correlations between the CPS scores and richness/abundance of all observed organism groups. It thus seems that the CPS score is an adequate and powerful farm scale biodiversity indicator for the Swiss lowlands (see figure 6.11 for the CPS scores of the Swiss BioBio farms).

http://www.vogelwarte.ch/scoring-with-biodiversity-farmers-enrich-nature.html
http://www.fibl.org/de/schweiz/forschung/pflanzenschutz-biodiversitaet/pb-projekte/punktesystem.html.

The CPS has already been implemented by the farmers' organisation IP-SUISSE, producing for a consumer label and adding a market-based approach. One fourth of the Swiss farmers are members of IP-SUISSE, the Swiss Organisation for Integrated Farming. They obtain a higher price for their products, which are (amongst others) marketed under the wildlife-friendly brand "TerraSuisse" – provided that they reach a minimum CPS biodiversity score. The Swiss organic farmers' association BIO-SUISSE (10 % of the Swiss farmers) is currently implementing a very similar approach derived from the CPS, thus actively promoting species diversity on their members' farms.

www.ip-suisse.ch
http://www.migros.ch/generation-m/de/konsum/oekologische-faire-produkte-labels/terra-suisse.html).
www.bio-suisse.ch/

Table 6.4: BioBio species indicator set: Recommended indicators, research indicators, and indicators discarded for not meeting the selection criteria. *: low, **: medium, *: high, n.a.: not applicable / not tested in BioBio.**

	Name	Unit	Data Source	Cost	Scientifically Sound	Practicable	Attractive
Recommended indicators							
Plants	Vascular plants	N° of species per farm	Field survey	***	***	***	***
Earthworms	Earthworms	N° of species per farm	Field survey	***	***	***	***
Spiders	Spiders	N° of species per farm	Field survey	***	***	***	***
Bees	Wild bees and bumblebees	N° of species per farm	Field survey	***	***	***	***
Birds [a]	Birds of farmland habitats	N° of species per farm – Specialist species	Field survey	n.a.	n.a.	n.a.	n.a.

Sub-indicators for all four indicator species groups:
1) Gamma diversity – species of cultivated forage, food crops and semi-natural habitats
2) Alpha diversity – species of cultivated forage, food crops and semi-natural habitats
3) Area weighted diversity – species of cultivated forage, food crops and semi-natural habitats
4) Rarefied richness – species of cultivated forage, food crops and semi-natural habitats
5) Chao estimated richness – species of cultivated forage, food crops and semi-natural habitats

1.1) Gamma diversity – species of cultivated forage and food crops
1.2) Gamma diversity – species of semi-natural habitats
2.2) Alpha diversity – species of semi-natural habitats
2.1) Alpha diversity – species of cultivated forage and food crops
3.1) Area weighted diversity – species of cultivated forage and food crops
3.2) Area weighted diversity – species of semi-natural habitats

Comments:
Gamma diversity: Total number of species aggregated over the habitats
Alpha diversity: Average number of species over the habitats
Area weighted diversity: Number of species over the habitats weighted by the area of the habitats
Rarefied richness: Average number of species over the smallest number of plots found in a farm
Chao estimated richness: Extrapolated number of species based on the accumulated number of species found in plots

Discarded indicators	Name	Unit	Data source	Comments
Butterflies	Rhopalocera of farmland habitats	N° of species per farm	Field survey	Much data available. Observations are weather dependent (as for bees). Indicators of grassland conditions.
Hymenoptera-Ants	Ants of farmland habitats	N° of species per farm	Field survey	Lack of information. Require much laboratory work. Require further consideration due to functions (ecosystem engineering, biological properties of soils, pest control).
Small mammals	Small mammals of farmland habitats	N° of species per farm	Field survey	Lack of data. Difficult to survey. Include pests.
Carabid beetles	Carabids of farmland habitats	N° of species per farm	Field survey	Biocontrol agent. Well investigated in agro-ecosystems. Require much laboratory work.
Diptera, Syrphidae, Hoverflies	Hoverflies of farmland habitats	N° of species per farm	Field survey	Biocontrol agent. Require much laboratory work.
Bats	Bats of farmland habitats	N° of species per farm	Field survey	Lack of information. Difficult to survey.

[a] *Birds were not tested in BioBio, but should be part of a species indicator set for monitoring*

References

Billeter R., Liira J., Bailey D. *et al.*, 2008. Indicators for biodiversity in agricultural landscapes: a pan-European study. Journal of Applied Ecology 45(1), 141–150.

Buchs W., 2003. Biotic indicators for biodiversity and sustainable agriculture - introduction and background. Agriculture Ecosystems & Environment 98(1–3), 1–16.

Chao A., 1987. Estimating the population size for capture-recapture data with unequal catchability. Biometrics 43, 783–791.

Dennis P., Arndorfer M., Balázs K. *et al.*, 2009. Conceptual foundations for biodiversity indicator selection for organic and low-input farming systems. Aberystwyth, Deliverable 2.1 of the EU FP7 Project BioBio. ISBN 978-3-905733-16-7. http://www.biobio-indicator.org/deliverables.php

Duelli, P. & Obrist, M.K., 1998. In search of the best correlates for local organismal biodiversity in cultivated areas. Biodiversity and Conservation, 7, 297–309.

Duelli P. & Obrist M.K., 2003. Biodiversity indicators: the choice of values and measures. Agriculture, Ecosystems and Environment, 98(1–3), 87–98.

European Bird Census Council (no date). Available at: http://www.ebcc.info/index.php. [Accessed 14/02/12].

Gibbons J. M., Nicholson E., Milner-Gulland E.J. & Jones J.P.G., 2011. Should payments for biodiversity conservation be based on action or results? Journal of Applied Ecology 48(5), 1218–1226.

Hammond P.M., 1994. Practical Approaches to the Estimation of the Extent of Biodiversity in Speciose Habitats. Philosophical Transactions of the Royal Society of London Series B-Biological Sciences, 345(1311), 119–136.

Pearson D.L. & Carroll S.S., 1999. The influence of spatial scale on cross-taxon congruence patterns and prediction accuracy of species richness. Journal of Biogeography, 26, 1079–1090.

PlantLife International (no date). Available at: http://www.plantlife.org.uk/international. [Accessed 14/02/12].

Reidsma P., Tekelenburg T. van den Berg, M. & Alkemade, R., 2006. Impacts of land-use change on biodiversity: An assessment of agricultural biodiversity in the European Union. Agriculture, Ecosystems and Environment 114, 86–102.

Sier A.R.J., Monteith D. & Brooks S., 2010. Beyond 2010: Strategies for understanding and responding to longterm trends in UK Biodiversity. Proceedings of the workshop held in the Natural History Museum London, 16–17 November 2010. NERC Centre for Ecology and Hydrology, Lancaster Environment Centre.

UK NEA, 2011. The UK National Ecosystem Assessment: Synthesis of the Key Findings. UNEP-WCMC, Cambridge.

7 Indicators for crop and livestock genetic diversity

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Genetic variability is the basis of life. Farmers and breeders have developed a multitude of crop varieties and animal breeds to suit their needs, and to stabilise and increase productivity. Based on huge genetic variation, this diversity can be characterised with molecular genetic methods. These methods are technologically demanding, expensive, and require further development for general application. Three simple, indirect indicators – based on crop-cultivar and livestock-breed information collected in farmer interviews – are therefore proposed to assess such genetic resources.

7.1 Genetic diversity

Genetic diversity, i.e. the heritable variation among individuals within one species, represents biodiversity at its most fundamental level. Differences in the sequences of nucleotides provide variation within DNA which drives all morphological and physiological differences among individuals that are based on genetic inheritance. Genetic diversity within and among populations is influenced by four principle factors that represent the basic mechanism of evolution (Table 7.1). Genetic variation, evolutionary processes and environmental factors account for the enormous diversity of species which assemble as ecological communities, the living component of habitats and ecosystems.

Table 7.1 Key factors influencing genetic diversity

Factor	Description
Mutation	Changes in genomic sequence caused by errors during recombination or DNA replication, radiation, transposons, mutagenic chemicals or viruses. Mutations are the basis for genetic variation and speciation.
Reproduction and gene flow	Exchange and recombination of genetic material among individuals through reproduction leading to novel genotypes. Within and among populations, allele frequencies are changed through gene flow, which enhances genetic variability and prevents inbreeding, thus increasing chances of survival.
Genetic drift	Random changes in genotype frequencies between generations due to migration, availability of reproductive partners, or geographic constraints.
Natural selection	Selection of favourable or elimination of detrimental alleles. Individuals whose genotype provides better adaptation to the environment will thrive and spread their genetic material. Mutations leading to reduced fitness will lead to extinction of the respective genotypes.

Continuous changes in genetic diversity within and among populations of wild and domesticated species are influenced by various natural and anthropogenic factors. Genetic structure within populations is affected by natural factors such as breeding system (mating system), seed-dispersal mechanism, life form, geographic range, and taxonomy. Intensification of agricultural production represents one of the main anthropogenic threats to genetic diversity. Rapid increase of the world's human population has led to ecological degradation and fragmentation of (semi-) natural habitats due to agricultural production. Intensification causes genetic erosion within natural populations, as well as affecting the genetic diversity of primary food sources, i.e. crops and livestock. Assessing genetic diversity is crucial to understanding population structure and dynamics, as well as the effects of environmental and anthropogenic factors on genetic diversity now and in future. Such information is required for maintaining and exploiting genetic diversity as the primary food-production resource.

7.2 Genetic diversity in agriculture

The genetic diversity of crop varieties and livestock breeds plays a major role in agriculture, and is an essential part of agrobiodiversity, and hence of biodiversity as a whole. Agrobiodiversity is defined as "the variety and variability of animals, plants and micro-organisms that are used directly or indirectly for food and agriculture, forestry and fisheries, including crops and livestock" (FAO 1999a), and relies heavily on the interaction between the surrounding environment, plant and livestock genetic resources, and management systems and practices, which are highly variable.

The domestication of crop and animal species has historically led to tremendous variation in breeds and cultivars. More recently, however, the number of plant varieties and animal breeds providing for the world's food resources has fallen drastically (Schröder *et al.* 2007).

The growing world population demands increased agricultural production and efficient, sustainable use of environmental resources. People's and organisations' awareness of crop and livestock genetic resources has become more important, resulting e.g. in increased efforts to conserve germplasm. Genetic resources are conserved and protected either ex situ (plants) / in vitro (animals) in gene banks, or in situ / in vivo in their natural environment or on farms. For ex situ conservation, worldwide gene banks contain 7.4 Mio. plant accessions from 612 genera and 3446 species. In situ or in vivo conservation basically refers to the direct protection of farmers' varieties, landraces, or valuable wild relatives in natural and agricultural ecosys-

tems. With regard to livestock genetic resources, 7616 breeds are recorded in global databases. The majority of these breeds constitute cattle, pig, sheep, goat and chicken species (FAO 2007).
Crop and livestock genetic-diversity resources are an important asset which must be sustainably used and actively conserved. Within the BioBio project, genetic diversity assessments of arable, vegetable, tree and forage crops as well as of livestock breeds focused exclusively on in situ / in vivo genetic resources.

7.3 Crop and livestock genetic diversity

The FAO Commission on Genetic Resources for Food and Agriculture has recently highlighted concerns over the loss of recognised livestock breeds and the risk that the reduction in livestock genetic resources poses for future adaptation of livestock production to environmental change. This is recognised in Aichi Target 13: "By 2020, the genetic diversity of cultivated plants and farmed and domesticated animals and of wild relatives, including other socio-economically as well as culturally valuable species, is maintained, and strategies have been developed and implemented for minimizing genetic erosion and safeguarding their genetic diversity" (CBD Nagoya 2010).

The genetic diversity of domesticated species and their wild relatives is crucial for world food security, for the survival of individuals and populations in their environment, and for the sustainable development of agriculture. Despite the massive number of 250,000 to 300,000 known edible plant species in the world, only 7000 have been cultivated and used – and of these 7000, only 150 crop species, e.g. *Malus domestica* (Figure 7.1) are in general use by humans. A mere 12 species contribute 80 per cent of the nutrition and calories for feeding the world's human population (Schröder *et al.* 2007; FAO 1997). Although the number of high-yielding cultivars and breeds has increased over the last century, their gene pool remains small or limited due to standardisation, specialisation, intensification and the demands of the market. Estimates of worldwide plant genetic resources have shown a decline of about 75 percent in crop genetic diversity over the past century (FAO 1997). In agrarian countries, the replacement of local farmers' varieties and landraces with improved cultivars and breeds – despite the fact that the former still consti-

Figure 7.1. Selected Malus domestica cultivars recorded on farms participating in the BioBio project case studies: (a) Weisser Klarapfel (Switzerland); (b) Jonathan (Switzerland). Photos: Markus Zuber

Figure 7.2. Selected livestock breeds recorded on farms participating in the BioBio project case studies. (a) Sheep: Spael / Old Norwegian Short Tail (Norway). (b) Cattle: Welsh Black (Wales, UK). Photos: Hanna Timmermann & Peter Dennis

tute the major staple foods in developing countries – still continues at the expense of genetic variation.

In the seven case-study regions with livestock husbandry, 26 cattle and 30 sheep breeds were recorded (Figure 7.2). Rare and local breeds were represented in 6 case studies (Figure 7.3). The average number of breeds per farm was 1–2, irrespective of production system, and was characteristic of the specialisation of individual farms in particular enterprises, regardless of management system.

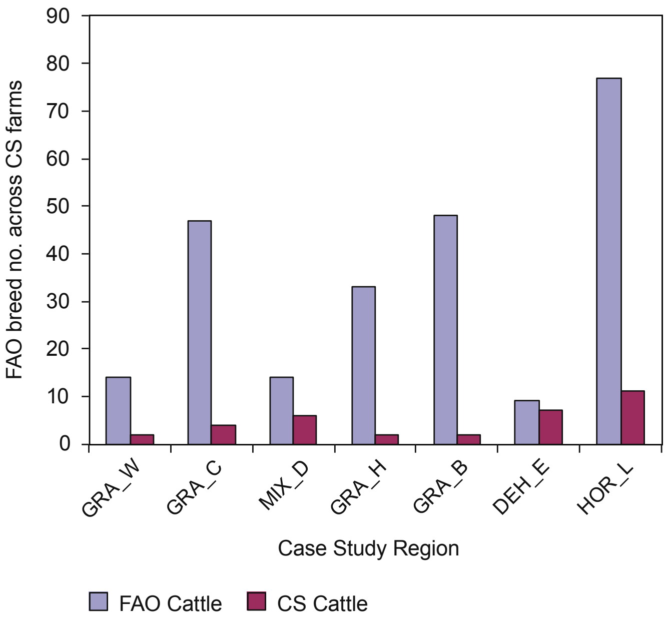

Figure 7.3. Number of FAO DAD-IS (Domestic Animal Diversity Information System) (DAD-IS online), -listed species of cattle and sheep represented in case-study regions.

7.4 Genetic diversity indicators

Recent decades have seen an increase in the recognition of the importance of genetic diversity given its fundamental contribution to biodiversity. Whereas genetic diversity and its assessment receive plenty of attention, however, general tools for assessing genetic diversity in agricultural environments remain scarce and in need of further investigation, validation and development. Various options for measuring genetic diversity do indeed exist, but all have their advantages and disadvantages and must be chosen carefully according to the aim of a specific investigation.

Information on livestock breeds and cultivars used on each farm was tested as a surrogate for genetic diversity, i.e. information that can be collected as part of a farmer questionnaire on farm management. These tools are very simple, addressing neither diversity on the gene level nor environmental influence. Cross breeds were included, since genetic diversity is effectively introduced by an off-farm sire breed in the form of artificial insemination or loan of a single bull or ram. The main assumption that animal breeds or crop cultivars associated with equal genetic distance is not validated by widespread studies in molecular biology, and probably does not hold true. These indicators are compared at whole-farm level, since e.g. grazing animals use the full extent of the land which is grazed or used for forage crops throughout the year. In the BioBio case studies, only cattle and sheep were significantly represented on the specialised and mixed livestock farms (Fig. 7.3).

Genetic diversity estimates can also be made on the basis of morphological, physiological or agronomic characteristics used in the basic description of individuals, with regard to relationships existing between single genotypes and their environment. The assessment of genetic diversity in terms of e.g. agronomic traits is of great interest for plant and livestock breeders as well as for monitoring or management processes. Measuring genetically complex (i.e. quantitative) traits such as yield and stress tolerance can reveal genotypic differences among individuals or populations. Unlike with molecular analysis, such measurements are not at the gene level, with measurements of genetic variation based on phenotypic traits being highly influenced by the environment.

Pedigree analysis provides yet another tool for analysing genetic diversity on a farm. The genetic relatedness of breeds and cultivars can be calculated according to the proportion of genes contributed by a specific number of ancestors to a cultivar – the coefficient of parentage. This approach requires detailed information on selection and breeding processes, as well as an adequate software tool. Such a tool represents a very basic approach, used in breeding programmes worldwide which address genetic diversity on a gene level but ignore the influence of environment.

The use of molecular tools, e.g. molecular markers or genotype sequencing, allows a much more detailed insight into the diversity of individuals or population structures by addressing genetic variation directly on a DNA-level and excluding environmental factors. These tools enable the measurement and evaluation of genetic diversity in both ex situ / in vitro and in situ / in vivo genetic resources. They allow for the investigation of the variability of genetic material and the detailed analysis of potential breeding material, as well as the investigation of the genetic structure of populations and the detection and preservation of valuable alleles, allele sequences, genotypes, individuals of wild relatives, and populations. The continued development of molecular tools, e.g. genotyping methods as next-generation sequencing, enables rapid, precise and efficient investigation.

7.5 Selection of genetic diversity indicators

The assessment of on-farm genetic diversity within the BioBio project is divided into two parts which deal respectively with in-situ crop genetic diversity and livestock genetic diversity at farm level. The major genetic diversity in-

dicators are based on a questionnaire assessing data for arable, vegetable, tree and forage crops, as well as livestock data for breeds found on farms across all BioBio case-study regions. Another single indicator is based on field and laboratory work assessing the genetic diversity of a model grass species within three selected BioBio grassland case studies via molecular analysis.

Of the eight genetic indicators tested, three have been proposed as genetic diversity indicators (Table 7.2), while another two have been tested and validated within the BioBio project, but are classified as research indicators requiring further development. Although basic data was successfully collected within the BioBio case studies, either data-analysis tools or common lists or registers enabling international assessment were lacking, or the overall analysis was in need of improvement in terms of cost-effectiveness and time efficiency. Another three indicators were discarded because the relevant data could Indefinite antecedent not be reliably collected via farm interviews.

Table 7.2

	Name	Unit	Data source	Cost	Scientifically sound	Practicable	Attractive	Sub-indicators	Comments
Recommended Indicators									
Breeds	Number and amount of different breeds	Mean no. of breeds per farm	Farm interview	low	*	***	***	Rare breeds	
CultDiv	Number and amount of different varieties (cultivar diversity)	No. of varieties per species and farm	Farm interview	low	*	***	***	1) Average number of varieties across all crop species per farm 2) Percentage of endangered crop varieties per species per farm	Additional information and lists required
CropOrig	Origin of crops	Percentage of landraces (across all crop species and varieties) per farm	Farm interview	low	*	**	**	Percentage of landraces per farm	Very few landraces found
Research indicators									
CroPedDiv	Pedigree-based genetic diversity	Coefficient of parentage (index) per CS	Farm interview plus additional information	medium	**	*	***	Coefficient of parentage per case study	Low pedigree-data availability (i.e. only for major crops on case-study level) is limiting
GrassGenDiv	Genetic diversity of model grassland species	Genetic diversity index, Gene diversity (He) per plot/farm	Laboratory analysis	high	***	*	***	Gene diversity	Tested for one grass species in 3 CS, far from routine application
Discarded indicators									
Seedmulti	On-farm seed multiplication				*	*	**		Precise data cannot be gathered with questionnaire
CropCuPheDiv	Crop-cultivar phenotypic diversity				*	*	**		Data not available from questionnaire, field work required
ReSeed	Amount of re-seeding				*	*	**		Precise data cannot be gathered with questionnaire

References

FAO, 1999a. Agricultural biodiversity, multifunctional character of agriculture and land conference, Background Paper 1. Maastricht, Netherlands. September 1999.

FAO, 2007. The State of the world's animal genetic resources for food and agriculture in brief, edited by Dafydd Pilling & Barbara Rischkowsky. Rome.

Schröder S., Begemann F. and Harrer S. (2007). Agrobiodiversity monitoring – documentation at European level. Journal of Consumer Protection and Food Safety Vol. 2, Supplement 1, pp. 29–32.

FAO, 1997. The state of the world's plant genetic resources for food and agriculture. FAO, Rome.

FAO, 2010. Report of a workshop on indicators to measure trends in genetic diversity of domesticated animals, held in Rome, 9–10 February 2010. Edited by D. Pilling & B.D. Scherf. Rome.

Eaton D., Windig J. & Hiemstra S.J., 2004. Indicators of Biodiversity for Livestock and Crops in Agriculture. Wageningen University & Research Centre.

CBD Nagoya, 2010. Implementation of Strategic Plan for Biodiversity 2011–2020, including the Aichi Biodiversity Targets. http://www.cbd.int/sp/targets/ [Accessed 25/11/11).

DAD-IS (online). Domestic Animal Diversity Information System. http://www.fao.org/dad-is [Accessed 25/11/11].

8 Management related indicators

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Farm management affects farmland biodiversity. Eight management indicators relating to energy and nutrient input, pesticide applications and disturbance by mechanical operations have been identified. They allow the assessment of intensity of farm management and can be correlated with direct indicators of habitats and species.

8.1 Categories of farm management indicators

BioBio farm management indicators are conceptualised as indirect indicators of biodiversity. They reflect the level of farming intensity, and hence the major impact (pressure) exerted on habitats in agricultural landscapes. By affecting habitat structure, farming methods determine the conditions for species diversity, which is assessed by direct biodiversity indicators (state indicators), mainly on the managed area of the farms. Farming practices are therefore key for maintaining and restoring biodiversity.

BioBio farm management indicators represent different categories of pressure indicators.

- Consumption of energy and external inputs:
  Total direct and indirect energy input (EnerIn); *Intensification/Extensification* (IntExt).
  Intensification of agricultural production is accompanied by progressive mechanisation and increased external inputs. Non-organic and organic farming systems differ in their use of external inputs, with organic farms striving to minimise them (Hülsbergen and Schmid 2010). The BioBio indicators quantify this dependency both in energy units (EnerIn) and in monetary terms (IntExt).

- Nutrient input and management:
  Area on which mineral N-fertiliser is used (MinFert)[1]; *Total nitrogen input* (NitroIn).
  Nutrients are a limiting factor in plant production. They define the growth conditions for plant species, and hence the differentiation of habitats. Nitrogen is a key element facilitating biomass production. Whereas environments that are limited in nitrogen generally favour plant species diversity, high nitrogen availability promotes a rather limited number of highly competitive plants. In order to increase yields, farmers strive to raise the nutrient level of the soil, changing the trophic conditions of the habitats for wild species. Through runoff and leaching, excess nutrients also impact adjacent ecosystems (Flade *et al.* 2006).

- Application of pesticides:
  Pesticide use (PestUse) *with* sub-indicators *Herbicide treatments, Insecticide treatments, Fungicide treatments.*
  The application of pesticides has been identified as a constraining factor for species diversity on farmland (Geiger *et al.* 2010). Pesticides have direct effects on non-target organisms, as with herbicides that reduce the abundance of arable flowers, or insecticides and fungicides that have negative impacts on various invertebrate species. Indirect effects are the disruption of food webs through the reduction of both plant and animal food sources (Hole *et al.* 2005).

- Field operations:
  Field operations (FieldOp) *with the sub-indicators Mowing frequency, Mowing time, Ploughing.*
  These indicators are measures of disturbance caused by mechanised operations on farmland. The sub-indicators address specific farming operations with proven effects on species diversity.

- Livestock system:
  Average stocking rate (AvStock) *with sub-indicator Average stocking rate per ha forage area; Grazing intensity.*
  Livestock affects grassland composition via treading on the soil and grazing, and through the input of manure into farmland. In livestock systems, stocking density is a good indicator of land-use intensity (Dennis *et al.* 2009).

Generally speaking, the pressure on biodiversity rises with increasing farm management indicator values, which signify increased nutrient input to the farmland, progressive mechanisation of farm operations, more frequent pesticide applications, or higher livestock densities on the farm. However, the Grime curve (Grime 1973) demonstrates that there is a response curve with maximum species richness at an optimal management value. Intermediate management values are most often related to maximum biodiversity. This is why HNV farming supports a richer diversity than abandoned farms in the same areas.

8.2 Data quality of farmer interviews

The quality of data from farm interviews depends on the documentation and accessibility of the requested data in farm accounts and field data records. Key questions are:

- Does documentation exist for such data on the farms?

- Can the data be easily provided for the interviews? (e.g. data structure, document formats)

[1] N.B.: Here the indicator is the area with use of mineral nitrogen fertiliser, whilst in BioBio deliverable D2.2 'Handbook for recording key indicators', the opposite – i.e. the area without use of mineral nitrogen fertiliser – is described.

Several approaches might be considered to safeguard data quality – for instance, the inclusion of only those farms which have sufficiently documented the required data. This, however, may place severe limitations on the choice of farms and introduce unwanted biases. We suggest instead to ask farmers to keep track of certain data for a period of time at the outset of the survey. Furthermore, it is advisable to focus data collection on a limited set of indicators in order not to ask too much of the farmers.

Information on both the land cover of different crops and on livestock numbers is generally provided by the CAP declarations. Some data can also be provided by the farm accounts. Fuel consumption and fertilisation are generally recorded in vulnerable zones.

Many farm-level indicators are defined in relation to farm land use variables, such as 'utilised agricultural area', 'forage area' and 'grazing area'. When asking farmers for such data, it is advisable to cross-check for consistency against the background of the data collected for farm-level indicators, e.g. the total of the surface areas used for crops and grassland should add up to the 'utilised agricultural area', and the total of the grazed surface area should equal the 'grazing area'.

To limit the effort involved and avoid problems in obtaining reliable plot-level data in grazing systems, grazing intensity in BioBio was assessed on a general farm level only. Differences in grazing intensity within the farm were disregarded. Grazing outside the farm was assessed by estimating the time spent by grazing livestock on areas outside of the farm.

8.3 Organisational aspects of interviews

In order to safeguard and improve the availability and reliability of data, it is recommended that farmers be informed about data requirements in advance. During initial contact with the farmers, when they are asked whether they are willing to participate in the project, a list of the data requirements for future interviews can be provided.
The duration and methodology of farm interviews depend on both the number of indicators to be recorded and the complexity of the farming system. The more diversified farm production is, the higher the effort required in the data collection process for farm-level indicators. The presence of animals requires an additional set of questions. Data collection for genetic diversity indicators (cultivated plants, livestock) was included in the farm interviews.

General farm information can be requested via telephone or the mailing of questionnaires. For management information, a face-to-face interview is more appropriate, both to improve the reliability of the data and to sustain the attention of both interviewer and interviewee. In on-farm surveys, repeated direct contact between farmers and researchers is indispensable for establishing confidence and facilitating feedback. Elements of farm-indicator data collection can be part of this continuous exchange (e.g. recording the specific management of plots throughout the year). Furthermore, it is advisable to budget additional time for cross-checking uncertain data with farmers over the course of data processing and indicator calculation (telephone contacts).

Spanish Case Study: Mediterranean Low-Input Dryland Tree Crops

The Extremadura region is characterised by hot, dry summers. Dehesa is a Mediterranean silvopastoral system based on scattered oaks with native pasture and rainfed crops as an understorey. Dehesas are among the best-preserved low-intensity farming systems in Europe, and the combination of traditional land-use and biodiversity conservation found in these systems has been cited as an example of wise management of the countryside as a whole, and a model for sustainable land use in Europe.

Number of farms surveyed: 10 low-input
Average farm size: 485 ha
Average N-Input: 58 kg/ha
Average energy input: 20 kg fuel equivalents
Total number of habitat types: 31
Total number of plant species: 439
Total number of bee species: 63
Total number of spider species: 130
Total number of earthworm species: 17
Total number of crop species: 12
Total number of crop varieties: 17
Total number of livestock species: 4
Total number of breeds: 3

Interview length was the shortest (1 to 1.5 hours per farm) in certain specialist crop systems (e.g. olive plantations) and in very extensive production systems (e.g. Dehesas). The more complex a farming system (mixed farms, diverse arable farms), the longer the interview lasted. For some case studies, a comprehensive BioBio interview took more than 3 hours.

For communication with farmers in an interview setting, it is advisable to provide a set of documents to ensure that the recorded data are consistent and complete, e.g.:

- A list of crops on the farm for recording management practices
- Maps from the habitat survey, e.g. for discussing patterns of grassland management on the farm. It is recommended that aerial photographs be used in order to provide landmarks for orientation.

Indicating the position of sampling sites on maps is particularly important for recording plot-specific management practices, as it ensures that the correct areas are dealt with.

8.4 Relating management to species indicators

When interpreting the relationship between farm management and species indicators, it must be borne in mind that the above-mentioned pressure effect of farm management on species may be direct or indirect. The level of *Total nitrogen input* on a managed grassland site, for example, will directly affect the composition of the plant community, although perhaps with a certain time lag. The higher the amount of fertiliser applied, the more it will change from legumes and less-nitrogen-demanding herbaceous vegetation to a sward dominated by grasses and nitrogen-demanding herbaceous vegetation. The effect of management measures such as *Total nitrogen input* on faunistic indicators such as bees will be predominantly indirect, via nitrogen pressure on the vegetation and the resultant change in the latter's composition. This indirect effect can be expected to be less immediate than a direct effect. The indicators *Total direct and indirect energy input* and *Intensification/Extensification* evaluate the use of external inputs such as nitrogen fertiliser, pesticides, and fuel for field operations, and therefore integrate their individual effects. The total effect is indirect via the effect of one or more of these means of production.

The impact of management indicators on species indicators becomes visible when the whole spectrum of farming intensity can be examined (e.g. Billeter *et al.* 2008, Kleijn *et al.* 2009). Since the majority of BioBio case study regions fall within the extensive-to-medium-intensive range and do not cover the whole intensity range, the relationship between management and species indicators indicated in the scientific literature (e.g. Grime 1973) is not always very strong.

In BioBio, the values for *Total nitrogen input* largely varied among and within cases studies. With increasing inputs, trends showed a decrease of gamma species richness of all four species indicator groups observed in cultivated forage and food crops (Figure 8.1). However, the negative linear relationship was only significant ($p < 0.05$) for plant richness in the case study regions of Austria, Germany and Italy, and for bee richness in Switzerland. For earthworm richness in Hungary, the linear relationship was significantly positive. Further individual analysis within organic and non-organic farms showed that the plant richness on non-organic farms of Austria and of Switzerland was significantly and negatively related to the *Total nitrogen input* but not on the organic ones. Earthworm richness was further significantly and negatively related to the *Total nitrogen input* on the organic farms of Austria. As for all farms together, the organic and non-organic farms did not show significant relationship between *Total nitrogen input* and the spider richness in any case study region. In Switzerland, bee richness dependence on *Total nitrogen input* was significant in non-organic farms but not in organic ones.

BioBio case studies were designed to represent a variety of farming types, among them arable and mixed farms, specialist grazing livestock farms, and farms with permanent crops, such as vineyards and olive farms. Correlations between farm management and the state indicators of biodiversity differed from case study to case study. As it has been demonstrated for the indicator *Total nitrogen input*, there was no consistent correlation pattern across farming types. For each case study, the analysis revealed distinctive combinations of farm management indicators correlating with state indicators of biodiversity.

8.5 Example: German Mixed Farms

Farm management indicators distinguished between the management intensities of the mixed farms investigated in the German BioBio case study. Farms were best characterised by the following indicators:

- *Average stocking rate per ha forage area*
- *Total nitrogen input*
- *Area on which mineral N-fertiliser is used*
- *Total direct and indirect energy input*
- *Intensificaton/Extensification: Expenditures on fuel, pesticides, fertiliser and animal fodder*
- *Number of pesticide applications.*

Because these indicators correlated with one other, they are good indicators of overall farming intensity (Figure 8.2). With respect to direct indicators of biodiversity, they

showed negative correlations with species diversity indicators in cultivated habitats, particularly with plant and bee species richness, and to a lesser degree with earthworm and spider richness (Table 8.1). The sub-indicator *Mowing time* (date of first cut) was positively correlated with plant and bee diversity. This result is in line with the observation that early cuts promote grass species and suppress flowering herbs that could attract pollinators. Clearly the relationships between farm management and species indicators presented for German mixed farms provided evidence for increased biodiversity on farmland that is managed less intensively.

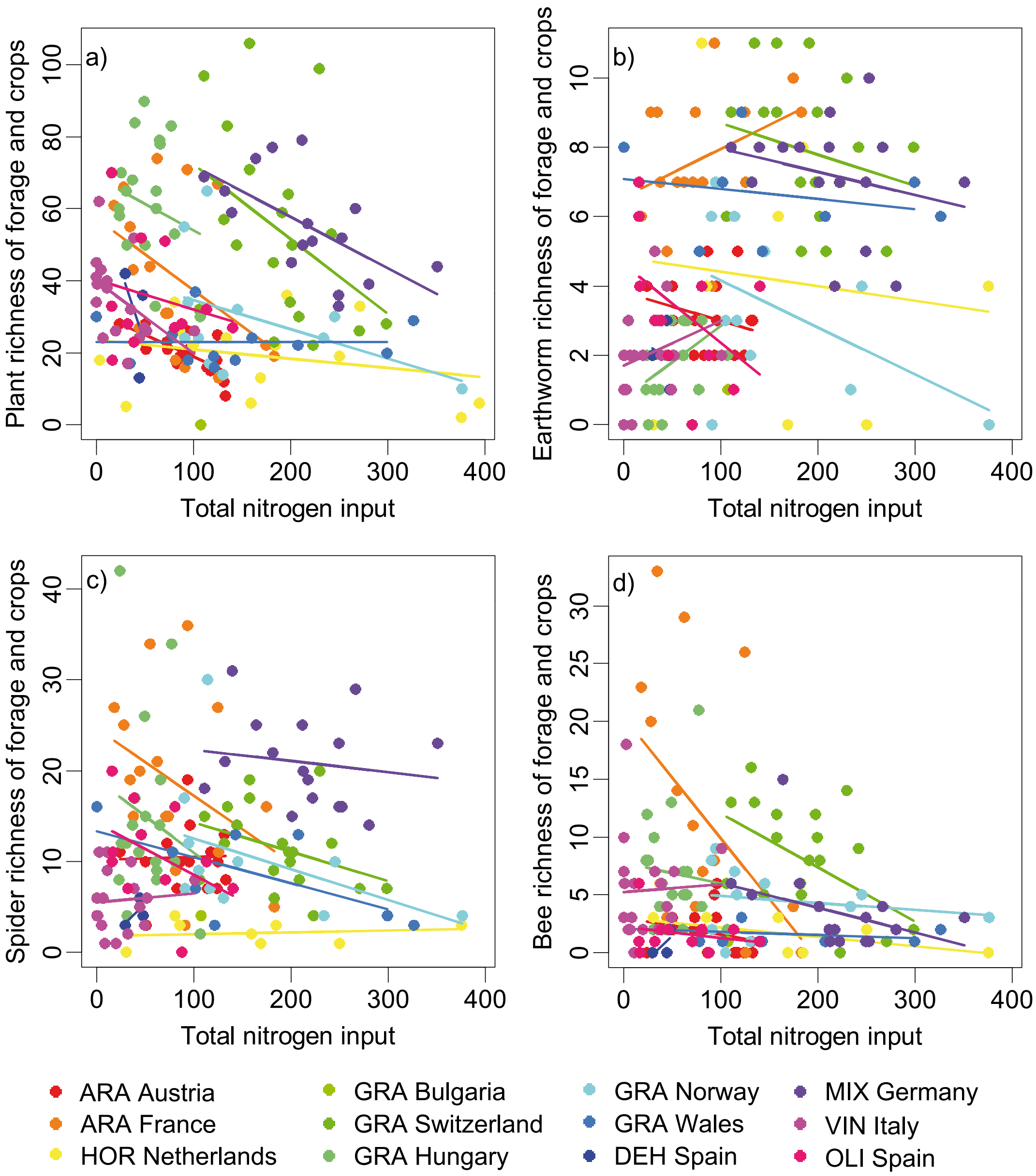

Figure 8.1: Gamma diversity of plants, earthworms, spiders and bees on farms (overall species richness) collected or observed in cultivated forage and food crops, related to the Total nitrogen input in 12 BioBio case study regions. ARA = arable CS, HOR = horticulture CS, GRA = grassland CS, DEH = Dehesa CS, MIX = mixed farming CS, VIN = vineyard CS and OLI = olive plantation CS.

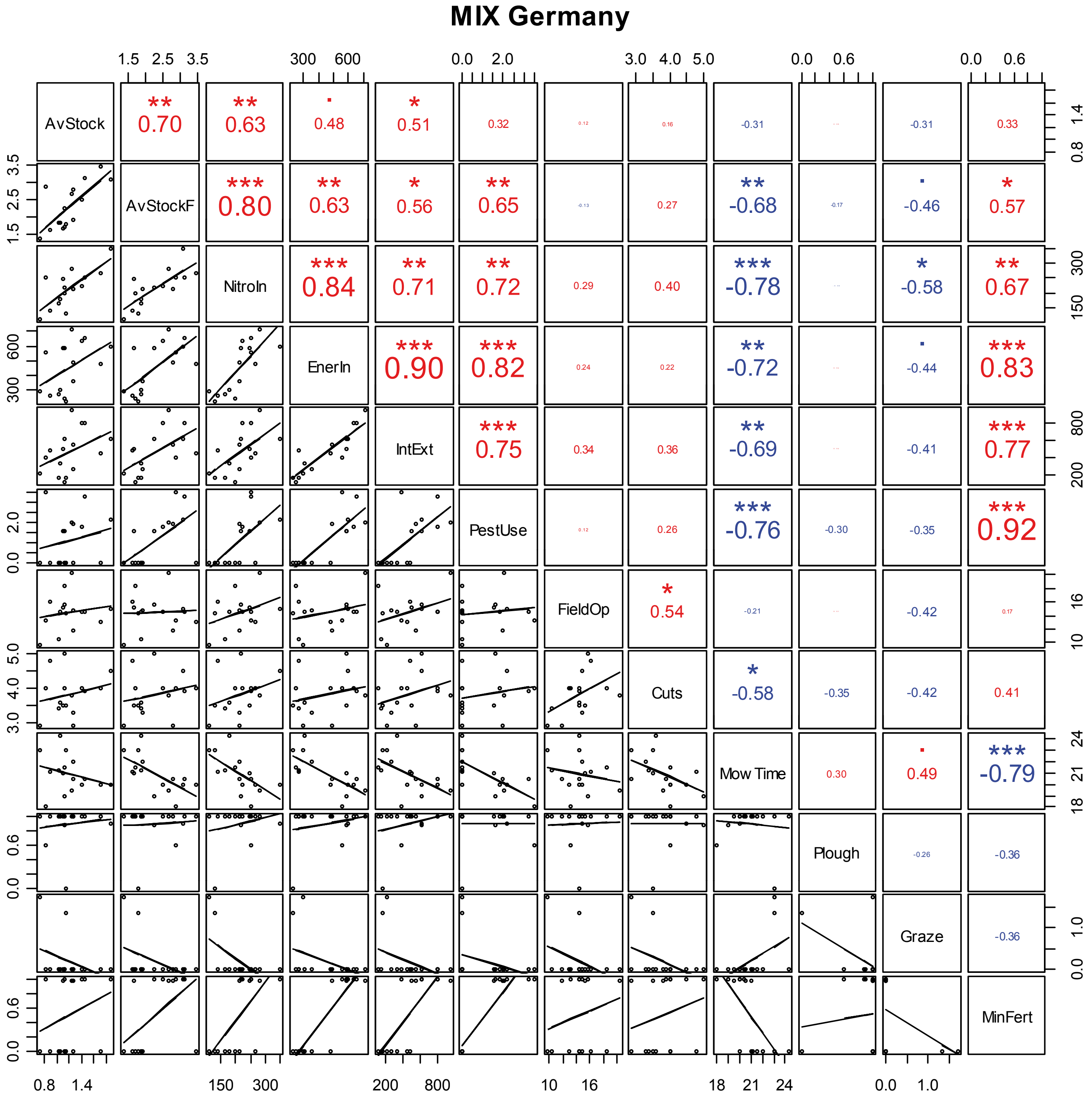

*Figure 8.2: Analysis of correlations between farm management indicators in German mixed farms (Spearman's rho: *** p < 0.001, ** p < 0.01, * p < 0.05). AvStock = Average stocking rate per ha UAA. AvStockF = Average stocking rate per ha forage area, NitroIn = Total nitrogen input, EnerIn = Total direct and indirect energy input, IntExt = Intensification/Extensification, PestUse = Pesticide use, FieldOp = Field operations, Cuts = Mowing frequency, Mow Time = Mowing date of first cut, Plough = Soil cultivation, Graze = Grazing intensity, MinFert = Area with use of mineral N-fertiliser.*

Table 8.1: Correlation between farm management indicators and Y-diversity of cultivated forage and food crops of species indicators on German mixed farms (Spearman's rho *** p<0.001, ** p<0.01, * p<0.05).

	Correlation			
Indicator	**Plants**	**Earthworms**	**Spiders**	**Bees**
Average stocking rate per ha UAA	-0.15	0.09	0.00	-0.26
Average stocking rate per ha forage area	-0.26	0.12	-0.15	-0.40
Area on which mineral N-fertiliser is used	-0.65**	-0.33	-0.45	-0.64**
Total nitrogen input: kg N/ ha UAA	-0.63**	-0.28	-0.22	-0.41
Total direct and indirect energy input: GJ/ha UAA	-0.56*	-0.26	-0.37	-0.53*
Intensification/Extensification: Expenditure on external inputs	-0.50*	-0.18	-0.25	-0.66**
Pesticide use: Frequency of applications	-0.72**	-0.21	-0.52*	-0.66**
Mowing time: Date of first cut	0.65**	0.42*	0.29	0.60*

Table 8.2: BioBio management indicator set: Recommended indicators, research indicators, and indicators which were discarded for failure to meet the selection criteria.
***: low, **: medium, ***: high, n.a.: not applicable / not tested in BioBio.**

	Name	Unit	Data source	Cost	Scien-tifi-cally sound	Practi-cable	Attrac-tive	Sub-indicators	Comments
Recommended indicators									
EnerIn	Total direct and indirect energy input	GJ/ha UAA	Farm inter-views	Low	***	***	***		Alternatively, the unit Equivalent litres of fuel/ha UAA can be used for communication.
IntExt	Intensification/ Extensification: Expenditures on fuel, pesticides, fertiliser and animal fodder	€/ha UAA	Farm inter-views	Low	***	***	***		
MinFert	Area with use of mineral nitrogen fertiliser	% of UAA	Farm inter-views	Low	***	***	***		
NitroIn	Total nitrogen input	kg N/ha UAA	Farm inter-views	Low	***	***	***		
FieldOp	Field operations	N° of field opera-tions	Farm inter-views	Low	***	***	***	1) Cuts Mowing frequency (No. of cuts); 2) MowTime Mowing timing (Date of first cut); 3) Plough Ploughing (% arable land)	
PestUse	Pesticide use	N° of applica-tions	Farm inter-views	Low	***	***	***	1) PestH Herbicide use; 2) PestI Insecticide use; 3) PestF Fungicide use	
Av Stock	Average stocking rate	N° of livestock units/ha UAA	Farm inter-views	Low	***	***	***	AvStockF Average stocking rate per ha forage area	

Graze	Grazing Intensity	N° of grazing livestock units/ha grazing area	Farm inter-views	Low	***	***	***		
Research indicators									
Norg	Organic nitrogen fertiliser input	kg N/ha UAA	Farm inter-views	Low	***	***	***		A subindicator of 'Total nitrogen input›. Of potential relevance for earthworm indicator.
	Energy output	GJ per kg grain sold	Farm inter-views	Low	***	***	***		To be tested as case study specific indicator (arable case studies).
Irrig	Irrigation	% of UAA	Farm inter-views	Low	***	***	***		Relevant for few case studies only. A candidate for merging with 'Irrigation' indicator to form new 'Intensity water manage-ment' indicator (working title).
Drain	Drainage	% of UAA	Farm inter-views	Low	***	***	***		See Irrigation.
Discarded indicators									
DivEnt	Diversity of enterprises	N° of enter-prises	Farm inter-views	Low	*	***	*		No consistent trends, so indicator was dropped.
CertOrg	Certified organic farming	yes/no	Farm inter-views	Low	*	***	*		Specific farm management characteristics are more reliable indicators. But CertOrg can be an important additional explanatory variable.
AgrEnv	Agri-environ-mental measures on the farm	No of agri-envi-ronmen-tal measures	Farm inter-views	Low	*	***	*		Correlations with biodiver-sity indicators for 2 case studies only (France – plants: positive, Italy – bees: negative). No consistent trend, so indicator was dropped.
AeNa-ture	Agri-environ-mental support related to nature conservation	% of UAA under nature conserva-tion measures	Farm inter-views	Low	*	***	*		Correlations with biodiver-sity indicators for 2 case studies only (Germany – habitats: positive. Austria – plants: negative.). No consistent trend, so indicator was dropped. But perhaps worthwhile for specific analysis of German CS.
PestUse-Area	Reduced use of chemical pesticides	% of UAA without use of chemical pesticides	Farm inter-views	Low	***	***	*		Correlates strongly with PestUse.
Zero	Soil cultivation: Zero tillage	% of UAA	Farm inter-views	Low	***	***	*		Relevant in one BioBio case study (France) only.

References

Billeter R., Liira,J., Bailey D. *et al.* 2008. Indicators for biodiversity in agricultural landscapes: a pan-European study. Journal of Applied Ecology 45, 141–150.

Dennis P., Arndorfer M., Balázs *et al.* 2009. Conceptual foundations for biodiversity indicator selection for organic and low-input farming systems. Aberystwyth, Deliverable 2.1 of the EU FP7 Project BioBio. ISBN 978-3-905733-16-7. http://www.biobio-indicator.org/deliverables.php

Dennis P., Bogers M.M.B., Bunce R.G.H., Herzog F. & Jeanneret P. 2012. Biodiversity in organic and low-input farming systems. Wageningen, Deliverable 2.2 of the EU FP7 Project BioBio. ISBN 1566-7197. ALTERRA Report 2308. http://www.biobio-indicator.org/deliverables.php

Flade M. Plachter H., Schmidt R., & Werner A. (Eds.) 2006. Nature conservation in agricultural ecosystems. Results of the Schorfheide-Chorin Research Project. Quelle & Meyer Verlag, Wiebelsheim. 706 pages.

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

Grime J. P., 1973. Competitive Exclusion in Herbaceous Vegetation. Nature 242, 344–347.

Hole D.G., Perkins, A.J., Wilson, J.D. *et al.* 2005. Does organic farming benefit biodiversity? Biological Conservation, 122(1), 113–130.

Hülsbergen K. & Schmid H., 2010. Treibhausgasemissionen ökologischer und konventioneller Betriebssysteme. In: Emissionen landwirtschaftlich genutzter Böden. KTBL-Schrift 483, pp. 229 – 244.

Kleijn D., Kohler F., Bàldi A. *et al.* 2009. On the relationship between farmland biodiversity and land-use intensity in Europe. Proc. R. Soc. B 276, 903–909.

9 Implementing a biodiversity monitoring scheme for European farms

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The BioBio indicator set consists of a toolbox which could be used to implement a European farm scale biodiversity monitoring. Europe has been subdivided into 55 regions, each with up to eight coarse farm types. The cost of implementing the BioBio indicators has be evaluated based on effort data recorded during the case study investigations. Investing 0.25 % of the annual CAP expenditure would allow to evaluate the policy's effectiveness on 50'000 farms in a rolling survey over five years.

9.1 From survey to monitoring

There are several steps which have to be taken before results from a once-off experimental pilot study such as BioBio can be extrapolated to a long term monitoring scheme. These steps include:

- Setting the objective of the monitoring scheme;
- Determine the unit that should be monitored;
- Decide the criteria of the monitoring program to deliver required data and indicators, i.e. sensitivity of indicators for the expected drivers and changes;
- Determine a sampling design to achieve spatial representativeness and the required frequency of sampling to detect trends;
- Adapting the methodologies;
- Provide cost estimates.

This chapter provides an outline for a European wide monitoring of biodiversity at the farm scale based on the 23 indicators identified in the BioBio project. It draws on the experience from the case studies, which included detailed recording of the costs for indicator measurement.

9.1.1 Objectives of monitoring schemes

The objective of a monitoring scheme determines the choice of indicators and how they will be applied. Objectives can relate to specific indicators (e.g. birds or semi-natural habitats), to regions within Europe (e.g. vineyards are only found in specific countries), to specific farm types (e.g. horticultural farms) or to specific farming systems (e.g. organic farming). Monitoring for biodiversity conservation tends to focus on rare habitats and rare species, whereas the monitoring of functional biodiversity, for instance earthworms and their relation with soil fertility, is more targeted towards the more common habitats within and around the production areas of the farms.

The aim of the BioBio project was to provide a monitoring scheme for the detection of general trends in the biodiversity of farmland throughout Europe. Therefore the BioBio consortium decided to focus on the land owned and/or managed by farmers. This definition excludes some sensitive nature habitats. Additionally, different farm types were selected throughout Europe to serve as pilot studies.

9.1.2 Monitoring a moving target

The aim of a monitoring scheme as investigated by BioBio is to provide information on the presence and direction and magnitude of the trends in farmland biodiversity, and link these to changes in farming practises and specific regions. These are the strengths of a farm based approach which addresses the farm as the central management and decision unit. However, farms and farming enterprises are dynamic in many of their characteristics. Farmers may choose to change enterprises / farm type (e.g. from mixed to solely arable farming), production management system (e.g. from non-organic to organic) or to sell the land when there is no son or daughter to continue the succession of ownership of the farm. The flexibility and dynamics of European farms has to be accounted for in a long term monitoring.

This leads to difficulties of farm-based monitoring in yielding a representative picture of changes at a regional scale. It should therefore be complemented with a monitoring design that is independent of the farm unit, i.e. one at a regional scale such as the approach developed in EBONE (no date).

9.1.3 Requirements for data and indicators

Monitoring schemes should provide data and indicators that enable appropriate analysis. This means that indicators have to be sensitive to drivers of change and the impact should be measurable. These were important selection criteria for the BioBio indicators. Stakeholders' interest and budget restrictions were additional important criteria. Measuring too many indicators would lead to increased cost for only little additional information. The 23 BioBio indicators are considered to be the minimum necessary baseline for estimating trends in farmland biodiversity. A further reduction would lead to a significant loss of information. E.g. omission of faunal sampling would exclude groups which provide vital functions in the agro-ecosystem, also represent a large share of overall species diversity and are highly sensitive to farming practices. Various stakeholders even argued that additional in-

Spanish Case Study: Olive Plantations

The northern part of Tierras de Granadilla in the Extremadura region of west-central Spain is highly specialised in olive production. Agricultural practices are strongly influenced by a severe water deficit that usually lasts four months a year. The crop is mainly used to produce olive oil.

Number of farms surveyed: 10 organic, 10 non-organic
Average farm size: 8 ha
Average N-Input: 62 kg/ha
Average energy input: 425 kg fuel equivalents
Total number of habitat types: 14
Total number of plant species: 283
Total number of bee species: 44
Total number of spider species: 123
Total number of earthworm species: 19
Total number of crop species: 16
Total number of crop varieties: 17

dicators should be included (e.g., butterflies, carabid beetles).

9.1.4 Requirements for sampling design and schemes

A sampling design must ensure that data are gathered which are representative of regions, farm types, farming systems or specific biodiversity, dependent on the precise objective of the monitoring scheme. Based on existing agricultural and environmental databases a sampling design was sketched. This is presented in section 9.2.

Trends can only be detected if datasets are collected in a time series. Depending on the drivers and sensitivity and variability of the collected data, the frequency of the monitoring scheme has to be determined. In terms of the frequency of the sampling there are several options. Data collection can be episodic at ca. ten year intervals, such as in the UK Countryside Survey or it can be organized in a rolling survey such as in the Swiss Biodiversity Monitoring, in which 20 % of the sampling is conducted annually and the full survey completed every five years. The frequency depends on the requirement for up-to-date information and the variability of indicators within and between years. It will strongly affect the resources (e.g. budget, expertise) to be allocated. This analysis was not done within the BioBio project and will have to be included in a supplementary study or evaluation before a routine programme would be started.

9.1.5 Cost estimates

Development of a one-off survey into a long term monitoring scheme has (positive) consequences for the average costs. In section 9.3 we provide coarse cost estimates for a BioBio monitoring scheme. The estimates are based on records of effort used in the BioBio case studies and on assumptions for cost reductions in routine monitoring. Section 9.4 provides an estimate of the number of farms to be sampled in Europe and the costs involved, expressed as a share of the budget of the Common Agricultural Policy (CAP).

9.2 Sampling design for farm types and European regions

To construct a representative sample pool, preliminary analysis has to be done of which farm types can be found at different locations in Europe. Subsequently, homogeneous regions need to be identified. For each region a number of farms per farm type has then to be determined that will be representative for that region. Detailed computations can be found in Jongman *et al.* (2012), this section gives a summary of the findings.

9.2.1 Farming types in Europe

In the SEAMLESS project a farm typology has been built on (i) specialisation, (ii) land use, (iii) scale of production and (iv) intensity (Anderson *et al.* 2010). This links best with the data from FADN as this is the only data set covering the entire EU territory including information on all the dimensions. An analysis based on the FADN database provides an overview of the main farming systems in Europe. From this analysis, it can be concluded that the BioBio case studies do cover the major European farm types in Europe, except for specialist poultry and specialist fruit and citrus fruit production farms.

In general, in landscapes with the same dominant land use the landscape patterns will not change within a country, but might be different between countries such as between the Netherlands and Germany (Jongman *et al.* 1996), where the landscapes across borders reflect the different heritage of ownership and tenure, land-use practices and

policies due to historical developments and national regulations for land management. Therefore NUTS-2 regions have been chosen as first entrance because the highest level they can reach is the country level (e.g. Luxemburg, Denmark, Latvia).

9.2.2 Homogeneous regions within Europe

To design more or less homogeneous regions use has been made again of the SEAMLESS database. Based on FADN it covers much of Europe, but some gaps remain for Switzerland and Norway concerning the underlying agricultural data and there is incomplete coverage for Bulgaria and Romania. However, if this regionalisation works then the other countries could be added in a later phase. The database and its farm types were used for the analysis.

For the regionalisation the variables intensity and scale did not discriminate well at the European scale, but typology was an effective initial discriminator. The following steps were taken:

1. At the level of NUTS2 all regions have been analysed for area covered by different farming scale, farming intensity and farm type;
2. Farming scale and intensity have not been used further they do not sufficiently discriminate between regions;
3. Farm types have been aggregated into major types;
4. Dominant farm types have been aggregated until 75 % area cover of the UAA was reached; this varied from 1–4 farming types;
5. For all regions the location in an environmental zone (Metzger *et al.* 2005) has been identified;
6. Within a country, comparable NUTS regions have been merged based on categories >75 %, 50–75 % and 15–50 % coverage of farm types.

Care has been taken not to mix contrasting biogeographical regions by using a layer of the environmental zones that is included in the SEAMLESS database. This ensured that the differences in species diversity between Mediterranean and non-Mediterranean countries remain in different groups.

Figure 9.1 (see page 82) shows the resulting homogeneous zones. The composition in terms of farm types per zone can be found in Jongman *et al.* (2012).

9.2.3 Proposed sampling protocol

The BioBio consortium proposes to select farms by probability sampling within the regions (Figure 9.1) and divided over the main farm types. This enables model-free, unbiased and valid estimation of target parameters and their standard errors (De Gruijter and TerBraak 1990). This is impossible with non-probability sampling, like haphazard sampling, targeted sampling or convenience sampling. Valid quantification of the uncertainty of the monitoring result is important to avoid discussions on the statistical significance of estimated time-trends in quality indicators and other target parameters (Brus *et al.* 2011).

As the farms within the regions vary considerably in size and intensity, each region has a different optimum sampling design for collecting a representative dataset. Some regions may need only few samples, whereas others may need many. Therefore, the sampling design must be tailored to the needs of each region. Determining factors for this design will include the degree of variation in the composition of the farm population (number of farms, farm types) in this region and the variability in biodiversity indicators.

9.2.4 Number of farms to be sampled

For selecting the samples we must know the total number of farms and their distribution. To arrive at a sample estimate we compare several different approaches:

- In the EBONE project (no date), it was proposed to sample European rural landscapes by means of 10,000 1 km squares in a rolling system of 2000 per year in subareas of the Environmental Stratification (Metzger *et al.* 2005). The total area of Europe under consideration was in this case 4,027,947 km^2 and the sample covers 0.25 % of this area.
- In a case study for Portugal on representativeness of land cover for the (land cover) population of the region, a pool of 10–40 sampling units have been used to represent a region of 3000 km^2, being 0.3–1,33 % of the area. Already 10 sample squares appeared sufficient for proper estimates, while mainly the SE and the %CV are being reduced by increasing the sample (Mateus 2004, Jongman *et al.* 2006).
- In the Seamless study 15 sample farms per FADN region has been considered the minimum for characterising farm types for a region (Andersen *et al.* 2006). However, testing is required to verify the viability of the proposed sample size.

If BioBio is adopting the procedure that has been followed in Seamless, then the number of farms in a region should be set at 15. This is also the minimum aggregation level for FADN data. Following the approach in the Portuguese study the number of farms is dependent on the area of the region. This means that smaller areas with less farms should contain proportionally less sample farms, but always with a minimum of 15. Whether 1 %, 1.4 % or 2 % of the farms need to be surveyed is an issue that is determined by homogeneity of a region, the available budget for data collection, the standard error (SE) that is accepted and the indicators applied.

Based on this analysis, the number of farms that have to be sampled per region in a monitoring scheme can be computed. However, the changes of farm enterprises over time in terms of existence, size, type and management pose a problem for monitoring. A fixed pool of farms could be selected in the first year of sampling, but some of the selected farms will change and this can bias the sampled farm population. Farms could also be selected each sampling year, but this introduces a lot of variation in the long term data series which will make the interpretation of trends more difficult. FADN uses a fixed pool and complements this with a flexible pool. This seems a good solution for the biodiversity monitoring scheme as well.

This same problem of flexibility can also be encountered on a farm scale. In vegetation monitoring, permanent plots have a preference because they allow the monitoring of changes in vegetation. In arable farms where there is a rotation of crops this is not feasible. Semi-natural habitats are likely to be more long-term in their location and size, but even a species rich hedge can be taken out or created by farmers. Here there are two options: 1) every time a farm is sampled, the sample locations per habitat type are randomly determined; or 2) for dynamic habitats (mainly the production areas) sample locations are randomly selected each time and for more permanent habitats (linears, semi-natural habitats) only when needed.

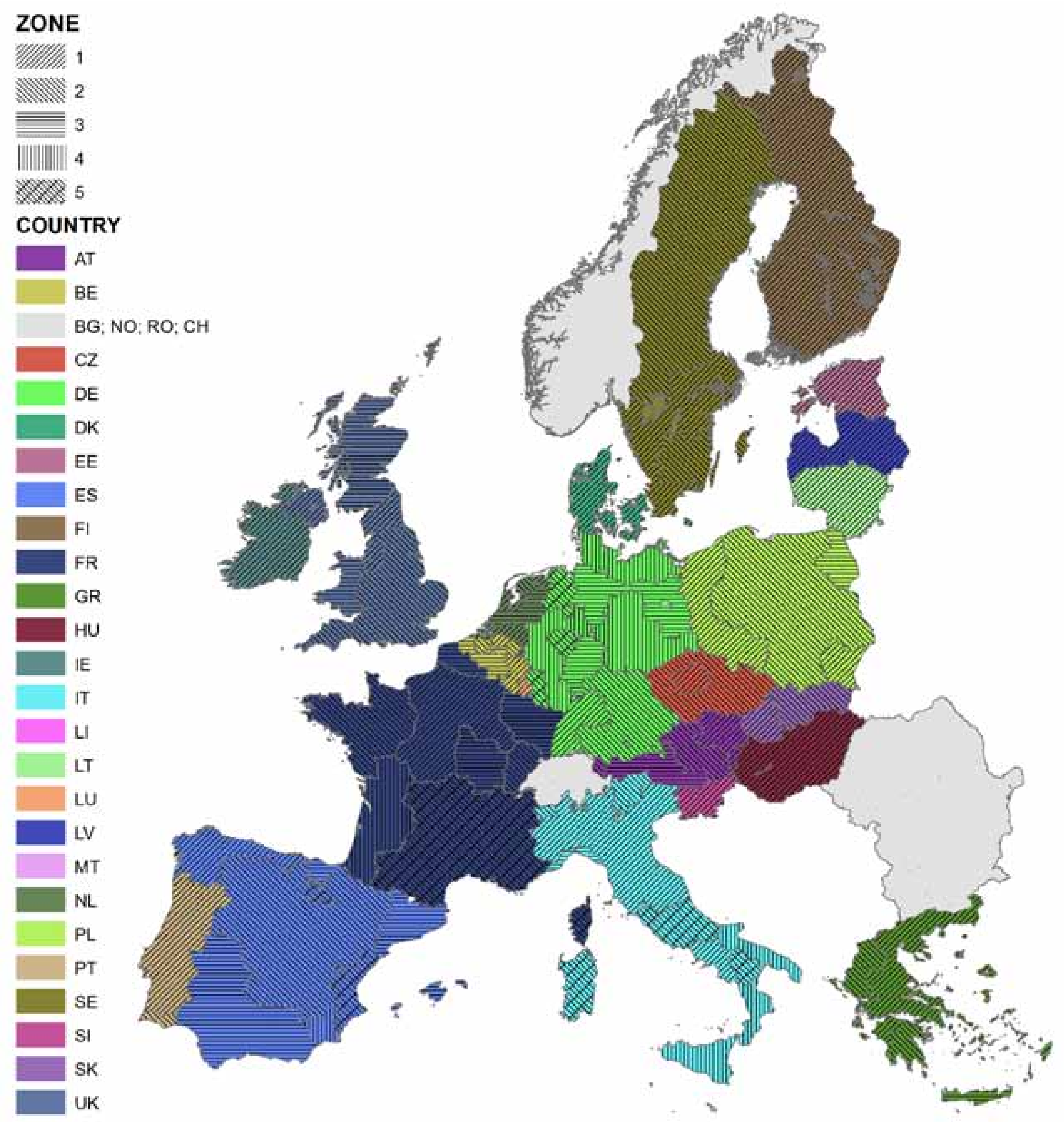

Figure 9.1. BioBio monitoring zones based on form statistics (NUTS 2) and on environmental regions. Their intersection leads to up to five zones per country. In each zone eight farm types are differentiated. Results could be reported per farm type per zone.

An analysis is yet to be performed to determine an adequate number of farms to be sampled, based on the variability of the indicators measured in the BioBio case studies, and will be reported later. For resolving specific difficulties of farm scale biodiversity monitoring, similar approaches as in economic farm monitoring could be adopted. Locating species plots on farms should be as conservative as possible (to reduce variability) but will require some adaptation to the crop rotation.

9.3 Accounting for costs and efforts of the measurement of the BioBio parameters

Margules and Austin (1991) stated that biological surveys are inherently cost-effective because they allow for a reduction of the level of uncertainty on natural systems and their complex reactions to management actions. Nevertheless, the available resources for monitoring programs are limited and will rarely reach the ideal level (Burbidge 1991). At the same time, there may be different alternative monitoring schemes, providing different information and having different costs. In this context, a reliable cost analysis is an essential component of a monitoring program (Caughlan and Oakley 2001). The importance of cost analyses is twofold: for a sound and affordable implementation of a monitoring program and for an efficient allocation of available resources during the decision-making process. Despite this, only few studies exist which propose a methodological approach or provide empirical evidence about such costs. The few cost-effectiveness studies of biodiversity measurement are based de facto on proxies and expost estimations (e.g. Qi *et al.* 2008; Schmeller and Henle 2008), or cover a limited area (e.g. Franco *et al.* 2007). The BioBio project plays an important role in the reduction of this gap because it provides a direct (empirical) assessment of the costs of the measurement of biodiversity indicators in 12 European case studies. In the following we use such information to estimate the costs of the proposed monitoring program.

9.3.1 Methods

The cost assessment followed an "input-based" approach i.e. the cost of the measurement was computed as the sum of the monetary costs of the resources required to undertake the measurements of the BioBio parameters, i.e. habitat mapping (HM), vegetation (V), bees (B), spiders (S), earthworms (EW) and questionnaires (Q). Cost data collection (about 13,000 records gathered between March 2010 and December 2011) was organised on a weekly basis during the field sampling activities in order to trace efforts and costs per indicator, farm, types of activity and resource. The data collected concern unitary cost of resources, labour time, distance and duration of travel, consumables, equipment, other costs (e.g. overnights) and the type of activity (fieldwork, deskwork, laboratory, taxonomy; Targetti *et al.* 2011).

Box 9.1: The phases indicated by Caughlan and Oakley (2001):

1. Development phase;
   - 1.1. Objective setting;
   - 1.2. Design planning;
   - 1.3. Administrative support development;
   - 1.4. Pilot study.
2. Regular monitoring phase;
   - 2.1. Scientific oversight;
   - 2.2. Data collection;
   - 2.3. Data management, analysis and reporting;
   - 2.4. Quality assurance;
   - 2.5. Administration and other expenses (e.g. staff training).

9.3.2 From BioBio to a full monitoring program cost

Budgetary costs of monitoring programs include several items and two distinct phases (Caughlan and Oakley, 2001, see Box 9.1). The development phase of a monitoring program deserves a generous allocation of funds in order to avoid expensive corrections during the subsequent regular monitoring phase or even the failure of the entire program. Indeed, the development phase aims to define and test the methodological approach of the monitoring program in order to optimise the survey efforts (e.g. avoid under/over-samplings) and ensure a correct flow of the regular monitoring phase. Cost-data collection during the BioBio project could be referred to the point 1.4 "Pilot study". It is very likely that unitary costs and efforts will be considerably lower during the regular data collection (point 2.2) because of optimization of the sampling design, availability of trained staff and mechanisms related to the call for tenders (i.e. competition between private monitoring agencies). The cost assessment of a full monitoring program should also consider the possibility to incur in specific economies of scale (e.g. bulk purchase of consumables and equipment), the optimization of the sampling protocol (e.g. employment of high skilled staff only when required), the potential synergies between indicators (i.e. one travel serving two or more indicators or farms), fixed vs. variable costs, depreciations, etc. For these reasons, the estimation of cost of a full monitoring cycle cannot be performed by simply adding the cost of the single parameters as assessed in the BioBio project. Nevertheless, the data collection of the BioBio project is a robust and reliable base to provide estimations of the costs of the regular monitoring phase. After consultation with the BioBio case study leaders, the cost of the BioBio activities have been translated in "Data collection costs" (point 2.2) applying the following reduction rates (as compared to Targetti *et al.* 2011) and synergies between indicators (reduction rates in brackets).

- Habitat mapping (50 %). The regular monitoring phase will benefit from the availability of trained staff. The

utilization of field computer and the utilisation of open-source GIS software will contribute to cut the costs. Synergies with the vegetation data collection are possible;

- Vegetation (20 %). The reduction rate is mainly related to the possibility to employ field computers and to the synergies with the habitat mapping;
- Bees. No cost reductions are envisaged (even though it is possible to consider synergies with the spider field activities);
- Spiders (30 %). Very likely the number of sub-samples can be reduced[1]; possibilities to employ other machinery (e.g. for spider sorting) is envisaged;
- Earthworms. No cost reductions are envisaged (data analysis should give deeper insights on the methods applied and possibilities to reduce sampling effort);
- Questionnaires (30 %). The regular monitoring will benefit of standardized questionnaire in order to reduce the data input efforts. A reduction of the number of questions is also envisaged;
- Taxonomy[2] (15 %). Taxonomy costs could be reduced by optimisation of staff resources (e.g. non-skilled workers for species sorting activities); availability of reference collections and availability of electronic keys;
- Consumables and equipment (20 %). Regular monitoring should benefit from economies of scale (e.g. bulk contracts).

9.3.3 Costs of the measurement of the BioBio indicators in a regular monitoring program

The 12 BioBio case studies covered a wide range of farm types and regions. Thus, the range of differences in efforts and cost per farm in the different case studies are significant. For this reason, we referred the efforts and costs of the BioBio parameters to the most appropriate unit of measurement: hours of work per hectare for the habitat mapping, per farm for the questionnaire and per plot for the others (Figures 9.2, 9.3, 9.4).

Figures 9.2, 9.3 and 9.4 show that (see also Targetti *et al.* 2011):

- Costs and efforts are clearly different between indicator groups;
- Fieldwork is the most time-consuming activity of the farm-scale measurement of biodiversity (except for the habitat mapping);
- Species indicators are the most expensive indicator groups;
- Taxonomic identification is a considerable share of species indicators' costs (about 30 %).

9.4 Efforts and cost requirements for a possible monitoring scheme

As outlined in the previous section, a full monitoring program is composed of two distinct phases and budget requirements. Accordingly, correct cost estimation should consider and allocate resources to the different budgetary items. Besides this, accurate budget estimation should also take into account a scenario where external resources (i.e.

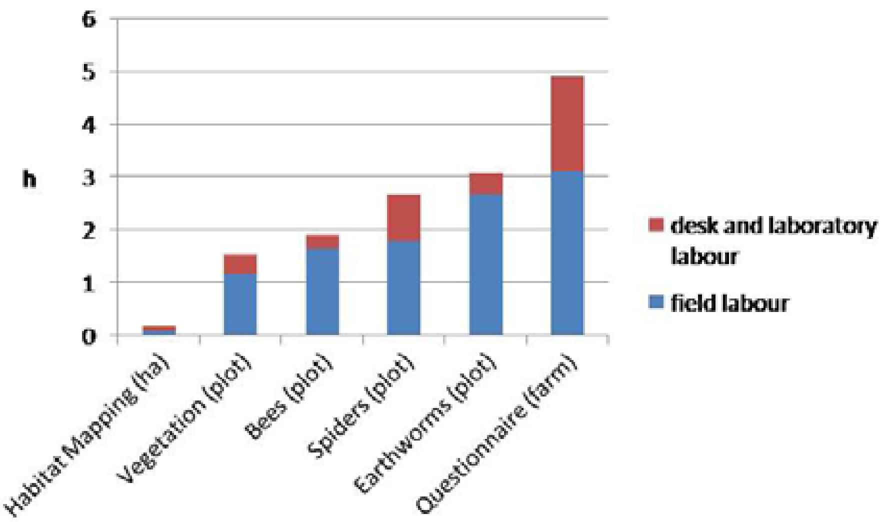

Figure 9.2: Overview of estimated labour efforts (after travel) required for the measurement of the BioBio indicators, based on data recorded in the 12 case study regions and applying assumptions for reductions of effort in a monitoring context (Section 1.3.2). In brackets the measurement unit of each single parameter.

[1] Yet not confirmed by data analysis

[2] Species identification costs were separated from the other costs for the bees, spiders and earthworms. Identification of plant species was performed by internal resources.

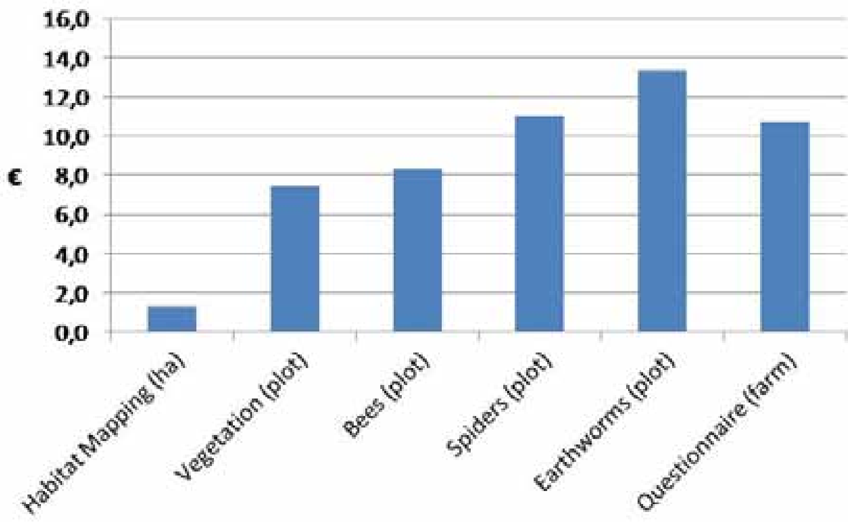

Figure 9.3: Overview of the costs of consumables, equipment and other costs for the measurements of the BioBio indicators, based on data recorded in the 12 case study regions and applying assumptions for reductions of effort in a monitoring context (Section 1.3.2). In brackets the measurement unit of each single parameter.

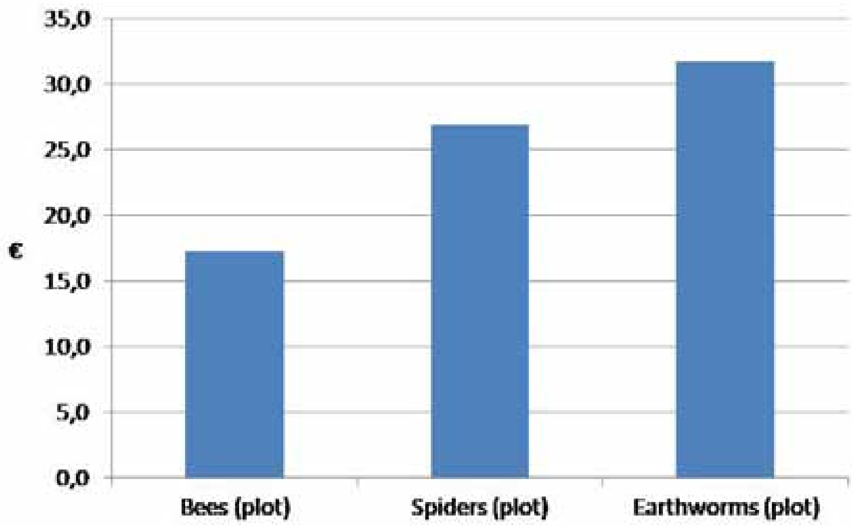

Figure 9.4: Overview of the costs per plot of the taxonomic identification for bees, spiders and earthworms, based on data recorded in the 12 case study regions and applying assumptions for reductions of effort in a monitoring context (Section 1.3.2).

resources from external agencies or institutions) are available. Here, we consider the BioBio project activities as the pilot study of a full monitoring program. BioBio tested candidate indicators for biodiversity using a standardised design in case studies covering the major farm types and biogeographical regions across Europe. The BioBio project has been funded by an external institution (EU Commission in this case) and the cost assessment of the monitoring program will include the regular monitoring phase only (point 2 in Box 9.1). Prior to a routine monitoring, however, a second pilot or transfer study may be required to test and refine the methods in additional European regions and for additional farm types.

Data collection generally represents a large portion of the overall budgetary costs of a monitoring program. The other cost items could be estimated in percentage on the total monitoring costs. Caughlan and Oakley (2001) recommended to allocate 30 % of the budget to point 2.3 "Data management, analysis and reporting" and 30–50 % to point 2.4 "Quality assurance". In the case of the monitoring based on the BioBio project, it is reasonably conservative to reduce significantly these cost items. This assumption is based mainly on: i) Caughlan and Oakley (2001) did not explicitly address large scale monitoring programs, where the centralization of point 2.3 and 2.4 activities will allow for a reduction of costs due to economies of scale; ii) as the same authors stated, the quality assessment cost is expected to decline yearly in a long term monitoring program.

Even though important, the points 2.1 and 2.5 ("scientific oversight" and "administration and other costs") are minor cost items. Therefore, these cost items will be assessed separately à forfait (see Section 1.4.4).

The costs of a possible monitoring program of the BioBio indicators have been assessed considering:

- The monitoring cost for an average farm (average N° of plots, average farmland hectares; see Figure 9.5);
- A standard composition of field-staff;
- An average time spent in travel to reach the sampling plots (1 hour of travel for the go and back journey).

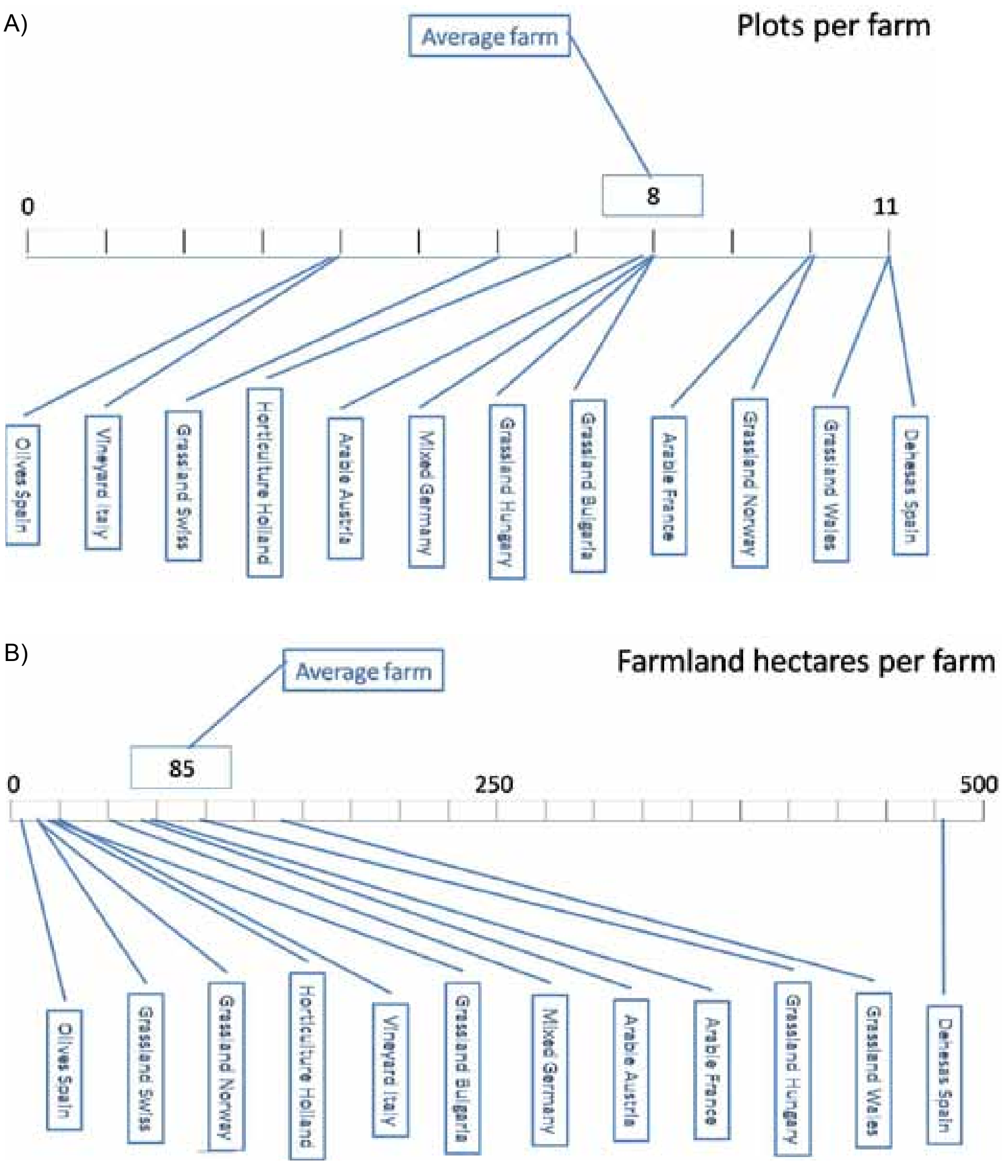

Figure 9.5: Average number of plots per farm (A) and average hectares per farm (B) in the 12 BioBio case studies.

As stated in the previous section, the wide range of farm types covered by the BioBio project entails significant differences in effort and cost between case studies: It is very important to notice that a reliable estimation of the monitoring costs should consider the specificities of the agricultural systems to be surveyed (e.g. hectares of farmland, distance and accessibility of plots, expected number of plots, etc.). Nevertheless, in a first approach, we base our estimation on the efforts and costs assessed for the "average BioBio farm" (Table 9.1).

Based on the experience of the BioBio field activities, the field staff composition has been standardised in order to optimise the costs (salary bands) with the skills required (high skilled, low skilled). Field staff calculation will consider the following standardised field staff composition:

- Habitat mapping + Vegetation: 2 persons;
- Bees: 1 person;
- Spiders: 2 persons;
- Earthworms: 2 persons;
- Questionnaire: 1 person.

Because of clear differences of labour costs across the European countries, the assessment of costs of the monitoring program strictly depends on the country to be surveyed. Given the fact that the cost for the other resources (consumables etc.) were assessed as an average from 12 European countries and that these represent a relative minor cost, the costs outlined in the Table 9.1 can be employed as a reference.

9.4.1 Assumptions for the cost estimation and results

The following points refer to Box 9.1:

Point 2.1 Scientific oversight. Even though the pilot phase provides design and general setting, the monitoring activities need to be supervised constantly

Table 9.1. Labour efforts and costs for consumables, equipment, taxonomy and others for the average BioBio farm. Person days are assessed assuming 7 hours of work per day.

	Skilled labour (person days)	Not skilled labour (person days)	Total labour (person days)	Consumables, equipment, taxonomy, others (€)
Habitat mapping	1.7	0.6	2.3	111
Vegetation	1.1	0.7	1.8	60
Bees	2.6	0.0	2.6	204
Spiders	1.0	2.5	3.5	303
Earthworms	0.5	3.7	4.2	360
Questionnaire	0.8	0.0	0.8	11
Total	7.6	7.5	15.1	1048

by qualified scientists in order to: verify that the program is meeting the targets, provide corrections to the sampling design when necessary. We propose to allocate 1 % of data collection costs to this task.

Point 2.2 Data collection. Three scenarios are possible: A) an equal cost per farm is granted across the EU without considering the different cost levels between countries; B) the cost per farm is adjusted according to the differences of cost labour across EU; C) data collection is performed directly by local administrations. Scenario A considers an average cost per farm across EU (e.g. considering Belgium as reference). This option would advantage monitoring in lower cost countries (and disadvantage monitoring in high cost countries). Scenario B allows for the correction of the cost of labour by means of correction coefficients (e.g. according to Council Regulation –EC- No 1239/2010). This option could create distortions between the different call for tenders across EU, i.e. higher competition (and very presumably higher quality of monitoring agencies) in high cost countries and vice versa in low cost countries. The third scenario considers the opportunity for local administrations to hire ad-hoc personnel. This option could be supported by the long duration of the monitoring program and the significant money savings allowed by the employment of internal resources.

Point 2.3 Data management, analysis and reporting. This task includes data analysis and reporting results to different audiences (scientists, land managers, policy-makers, the wider society). Divulgation of results is important to ensure support to the program and facilitate the flow of information between the monitoring program and the decision makers. We assume that 4 person days per farm of skilled labour should be adequate for this task.

Point 2.4 Quality assurance. As for point 2.3, we assume that 4 skilled person days per surveyed farm will be required for Quality assurance in the first year of the monitoring program. This effort could be reasonably reduced by a rate of 5 % per year in the subsequent years of the program (data quality increases yearly).

Point 2.5 Administration and other expenses (e.g. staff training). As for point 2.1, we propose to allocate 1 % of data collection costs to this task.

In Jongman *et al.* (2012) the results are presented for the scenario B of point 2.2 – where costs are adjusted to the different cost levels across EU countries. We consider the scenario where the labour cost of quality assessment and data analysis (points 2.3 and 2.4) is not adjusted to the different cost levels (taking Belgium costs as reference). This should allow for a homogenisation of data quality assessment across EU and help to counterbalance the effect of the higher competition in the call for tenders in the high cost countries. Labour costs (in person days) for skilled and not-skilled workers are presented in Table 9.2 for France, Italy (actual data) and Belgium (estimation based on correction coefficients)

Table 9.2 Labour cost for skilled and not skilled workers for biodiversity monitoring in EU countries (example).

	Skilled labour (€ per person day)	Not skilled labour (€ per person day)
France[a]	750	500
Italy[b]	410	250
Belgium[c]	515	333

[a] average salary band of one public organization, one naturalist NGO and one private firm based on 2010 labour cost (source: Levrel et al. 2010)

[b] average salary band of three private agencies based on 2012 labour cost (source: Targetti and Viaggi survey, 2012)

[c] average salary band of data for France and Italy adjusted for Belgium by means of the Council Regulation (EC) No 1239/2010 correction factor.

Swiss Case Study: Mountain Grassland with Cattle

The case study area is situated in Obwalden, central Switzerland, in the village of Stalden which lies on the southeast-facing hillside above Lake Sarnen. The agricultural landscape is characterised by steep, intensively managed grasslands and orchards, and in the higher regions by communally owned summer pastures. The strong topography limits mechanisation. The farms surveyed are grassland-based ruminant producers with cattle for milk production or breeding. About 25 % of the farms in the region are organically managed. Part-time farming is common.

Number of farms surveyed: 10 organic, 9 non-organic
Average farm size: 10 ha
Average N-Input: 83 kg/ha
Average energy input: 194 kg fuel equivalents
Total number of habitat types: 19
Total number of plant species: 269
Total number of bee species: 64
Total number of spider species: 125
Total number of earthworm species: 17
Total number of crop species: 9
Total number of crop varieties: 134
Total number of livestock species: 2
Total number of breeds: 12

9.5 A reasonable budget for monitoring

From a theoretical point of view it is also interesting whether the policy framework that needs monitoring of its impact and efficiency would be able to provide the necessary budget. The decision to allocate a budget for monitoring and evaluation should not be based on cost alone, but on the benefit derived from the monitoring activity. In other words, the right question is not "How much does it cost?" but "Which is the benefit that can be gained from a better informed decision?". Unfortunately monetary estimates of the benefits arising from biodiversity monitoring are not available[1]. Recommendations for effort to be invested in evaluating the effectiveness of programs or projects range between 0.5 and 10 % of their total budget (Rieder 2011) depending on the complexity and novelty of the program and on whether only the implementation of the program is to be assessed or whether its effects should be monitored, as would be the case here. Recommendations of the European Commission are at the lower end of this range (0.5 %, EC 2004). Given the importance of the Common Agricultural Policy (CAP) for social, environmental and economic development of rural Europe, we argue that it would be reasonable to allocate a significant share (say 3 %) of the CAP budget to the evaluation of its effects, including landscape and biodiversity for which 0.5 % would be reserved. Given that we will need two approaches to complement each other when it comes to determining the trends and causes in changes in the farmland biodiversity, let us further assume that 0.25 % should be allocated towards a farm based monitoring scheme such as proposed by BioBio and 0.25 % of the budget should be allocated to a landscape oriented approach. This would mean that 625 € million would be available in five years (given the permanence of the current average CAP budget) for the farm based monitoring scheme, which amounts to approximately just over 50.000 farms, 1.7 % of the total number of farms in Europe. These farms would be distributed proportionally across the sampling regions (Figure 9.1) and farm types within regions. See Jongman *et al.* (2011) for detailed tables. If the monitoring scheme would be applied by sampling 20 % of the farms in a rolling five years survey, this implies that the first comparable results would be available in year 6.

We consider the rough percentage of 0.25 % of the total CAP budget a good starting point for a monitoring scheme. If placed according to the suggested spatial design, the number of sampled farms should allow for representative biodiversity indicators for the whole of Europe and for major farm types. Adding to that, the benefits of the monitoring program are not limited to the evidence on biodiversity trends. In comparison to existing schemes, this monitoring scheme will also provide data on causal relationship between changes in farm practices (in specific farming systems) and the status of farm biodiversity.

[1] Estimation of benefits arising from biodiversity monitoring was not an objective of the BioBio project

References

Andersen E. Verhoog A.D., Elbersen B.S., Godeschalk F.E.& Koole B., 2006 A multidimensional farming system typology. Seamless Report 12, Ref PD4.4.2

Andersen E., Elbersen B., Hazeu G., van Diepen C., Baruth B., Verhoog A.D., Terluin I., Borkowski N., & Janssen S., 2010. The environmental component, the farming systems component and the socio-economic component of the final version of the SEAMLESS database, SEAMLESS Report No.52, SEAMLESS integrated project, EU 6th FrameworkProgramme, contract no. 010036-2, www.SEAMLESS-IP.org, 401 pp, ISBN no. 978-90-8585-595-8.

Brus D.J., Knotters M., Metzger M.J. & Walvoort D.J.J., 2011. Towards a European-wide sampling design for statistical monitoring of common habitats in Europe. Alterra Report 2213, 66pp

Burbidge A.A., 1991. Cost consideration on surveys for nature conservation. In Margules, C.R.,&Austin (eds.) Nature Conservation: cost effective biological surveys and data analysis. CSIRO, Australia.

Caughlan L. & Oakley K.L., 2001. Cost considerations for long-term ecological monitoring. Ecological Indicators 1, 123–134.

De Gruijter J. J., 2000. Sampling for spatial inventory and monitoring of natural resources – Alterra-rapport 070, Alterra, Green World Research, Wageningen, The Netherlands.

EBONE (no date) http://www.ebone.wur.nl. [Accessed 22/07/12]

Franco A.M.A., Palmeirim J.M. & Sutherland W.J., 2007. A method for comparing effectiveness of research techniques in conservation and applied ecology. Biological Conservation. 134, 96–105.

Jongman R.H.G., Bunce R.G.H., Metzger M.J., Mücher C.A., Howard D.C & Mateus V.L., 2006. A statistical Environmental Stratification of Europe: objectives and applications. Landscape Ecology 21, 409–419.

Jongman R.H.G., Staritsky I., Geijzendorffer I., Herzog F. Viaggi D. & Targetti S., 2012. Report on the suitability of continental scale indicators for reflecting biodiversity of organic/low input farming systems, proposition of a monitoring system at the continental scale. Deliverable 4.2 of the EU FP7 Project BioBio. http://www.biobio-indicator.org/deliverables.php

Levrel H., Fontaine B., Henry P.Y., Jiguet F., Julliard R., Kerbiriou C. & Couvet, D., 2010. Balancing state and volunteer investment in biodiversity monitoring for the implementation of CBD indicators: a French example. Ecological Economics 69, 1580–1586.

Margules C.R., & Austin M.P., 1991. Preface. In: Margules, C.R.,& Austin M.P., (Eds.) Nature Conservation: cost effective biological surveys and data analysis. CSIRO, Australia.

Mateus V.L., 2004. Countryside Land Cover Strategic Sample Survey. Thesis Universidade de Évora, Portugal/Alterra-Wageningen UR, The Netherlands, pp 63.

Metzger M., Bunce R.G.H., Jongman R.H.G., Mücher C.A., Watkins J.W., 2005. A climatic stratification of the environment of Europe. Global Ecol. Biogeogr 1 – 15.

Qi A., Perry, J.N, Pidgeon J.D., Haylock L.A. & Brooks D.R., 2008. Cost-efficacy in measuring farmland biodiversity – lessons from the Farm Scale Evaluations of genetically modified herbicide-tolerant crops. Annals of Applied Biology 152, 93–101.

Rieder S., 2011. Kosten von Evaluationen. Leges 1, 73 – 88.

Schmeller D.S., Henle K., 2008. Cultivation of genetically modified organisms: resource needs for monitoring adverse effects on biodiversity. Biodiversity and Conservation 17, 3551–3558

Targetti S., Viaggi D. & Cuming D., 2011. Analysis of Costs and Efforts of BioBio Indicators of Biodiversity. Deliverable 3.3 of the EU FP7 Project BioBio. http://www.biobio-indicator.org/deliverables.php

10 Application beyond Europe

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The applicability of the BioBio indicators beyond Europe was tested in Tunisia, Ukraine and Uganda. While the approach generally seems to be applicable, specific adaptations are still required. In Tunisia and Uganda, the farm-management questionnaire needs to be adapted to local conditions. Owing to different farming structures and farm size, the sampling design must be adapted, particularly in the Ukraine. It was not possible to sample all species groups in all regions. The habitat-mapping key and earthworm sampling require adaptation to tropical conditions.

10.1 Introduction

As an outreach activity, the wider applicability of the BioBio biodiversity indicators, which were developed for Europe, was tested in other agro-ecological zones and in a different policy context. The aim of this part of the project was to identify:

- which indicators are generally applicable for low-input and organic farming systems beyond Europe;
- would the methods need to be adapted, and how;
- which indicators would need to be developed in order to comply with the conditions of low-input and organic farming in other agro-ecological zones and institutional settings.

The implementation of this work package was based on partnerships with the National Institute for Research in Rural Engineering, Water and Forest (INRGREF) in Tunisia, Bila Tserkva National Agrarian University in Ukraine, and Makerere University in Uganda. These institutes contributed three case-study areas spanning a gradient of increasing difference from the European case studies:

- Low-input organic and non-organic olive groves in Tunisia, quite similar to the olive groves in Extremadura, Spain;
- Mixed, low-input and intensive arable farming in Ukraine, somewhat comparable to the mixed farming system in Germany, but with much larger fields and farms;
- Organic and non-organic subsistence farming in Uganda, utterly different from the European case studies.

Table 10.1 outlines the farming systems investigated and the number of farms assessed.

In order to test whether the European candidate indicators defined in BioBio are applicable in the three case studies, partners took part in the process of devising the criteria for indicator selection and in the development of assessment methods. The requirements for the applicability of indicators in the three case studies did not override the selection of indicators for the European case studies because the overall objective of BioBio was to propose an indicator set for Europe. Consequently, the three teams assessed the same indicators tested in the European case studies.

10.2 Tunisia

Tunisia is the northernmost country of the African continent, midway between the Atlantic Ocean and the Nile Valley. Occupying a territory of 162,155 km^2, the country has an estimated population of just over 10.3 million. Tunisia enjoys a Mediterranean climate with mild, rainy winters and hot, dry summers in the north and along its coast. November ushers in the rainy season, with heavy showers. On average, precipitation ranges between 1000 mm and 1500 mm in the north, and between just 100 mm and 200 mm in the south. Agriculture accounted for 14 % of GDP in 2005. Olives and olive oil, citrus fruits, cereals and dates are the main farm produce. Tunisia is the primary olive-growing country of the southern Mediterranean, with over 30 % of its arable land devoted to oleiculture. Organic agriculture is relatively new to Tunisia, starting in the 1980s with private initiatives and growing significantly

Table 10.1. Number and type of farms investigated in Tunisia, Ukraine and Uganda.

Country	Farming System	No. of Farms	Average Farm Size
Tunisia	Olive groves	10 organic and 10 non-organic	74 ha (most farms less than 30 ha)
Ukraine	Mixed arable and livestock	3 low-input and 3 high-input	2626 ha
Uganda	Small-scale arable farming	8 organic and 8 non-organic	0.42 ha

Figure 10.2. Flowering plants on a Tunisian olive farm (photo: R. Kölliker).

Figure 10.3. Vegetable crop between olive trees (photo: S. Garchi).

over the last few years. Tunisia currently has around 285,000 ha of organically certified land.

The farms investigated are situated near the country's eastern coast (Figure 10.1), in the districts of Monastir and Mahida, between Sousse and Sfax. The average temperature of this area is around 22 °C, and annual rainfall lies between 200 and 400 mm. Soils are mainly Calcisols, Luvisols and Fluvisols.

Agriculture is an important economic activity occupying more than 80 % of the land. The area's main crops are olives, pistachios, barley, almonds, pomegranates, prickly pears, and several fodder crops. About 60 % of the agricultural land is planted with olive trees. Organic farming accounts for a sizeable proportion of olive oil production, with over 40 % of organic land being planted with olive trees and around 115,000 ha of olive plantations no longer being treated with chemical fertilisers and pesticides in 2008 (Figures 10.2 & 10.3). The surveyed farms specialise in olive growing, and both organic and non-organic farms can be classified as low-input farms.

When testing the BioBio indicator set, we were faced with two fundamental difficulties:

1) The farm management questionnaire was not adapted to some of the farms. Many farmers are not accustomed to keeping records, and a number of the indicators – e.g. energy consumption – could not be evaluated because records were not available.

2) Earthworms were so rare that earthworm sampling was abandoned after fifty plots, since almost no specimens were detected.

Otherwise, the sampling procedure was implemented in a similar manner to that used at the olive farms in Spain, and indicators were recorded. Spiders and bees had to be sent to specialist taxonomists in Europe for identification, as this expertise was not available in Tunisia.

10.3 Ukraine

With an area of 600,000 km^2, Ukraine is the second-largest country in Eastern Europe. The landscape consists mostly of fertile plains (steppes) and plateaus, criss-crossed by rivers such as the Dnieper, Seversky Donets, Dniester and Southern Buh. The country's only mountains are the Carpathians in the west. Ukraine has a mostly temperate continental climate, with an average annual precipitation of approximately 600 mm. The country's humus-rich black soils have created one of the most fertile regions in the world, and hold great potential for agricultural production. Nevertheless, these soils are threatened by rapid erosion and loss of fertility if not managed properly. Ukraine typically produced over half of the sugar-beet crop and one-fifth of all grain grown in the former USSR. In 2007 there were about 90 organic farms in Ukraine with a total area of 255,000 ha, which is 0.7 % of the total agricultural land.

Figure 10.1. Location of Tunisian case study.

Figure 10.5. No-till cultivation on a Ukrainian farm (photo: S. Yashchenko).

Figure 10.6. Catching bees on a plot in a cereal field (photo: S. Yashchenko).

The farms surveyed are located in southern Kiev province in central Ukraine, near the city of Bila Tserkva (Figure 10.4). The case-study region lies in the Forest-Steppe Zone. The climate is temperate-continental, with an annual precipitation of 550–580 mm and an average temperature of 7.7 °C. Eight-four per cent of agricultural lands in the case-study region have a chernozem soil with a humus content of 2.7–4.2 %. Large parts of ecosystems in the case-study region are maintained predominantly by extensive agriculture (Figure 10.5). Agriculture occupies around 64 % of the land, with the main crops being cereals (wheat, barley, maize), sunflowers and sugar beet. Most of the farms combine arable agriculture with livestock husbandry (cattle, pigs). Woodland accounts for about 20 % and nature-protection areas about 3 % of the country's total area. Ukrainian case study farms are large-scale agricultural systems which were formerly cooperatives, a situation common to many countries in Eastern Europe.

All BioBio indicators were successfully measured, as with the European case-study regions (Figure 10.6). Taxonomic expertise in arthropods and earthworms was available in Ukraine, allowing identification of the specimens. Despite this, the sampling design required major adaptation. Not only were Ukrainian farms significantly larger than in Europe, but individual fields were also much bigger (15 to 697 ha). Consequently, the size of the individual habitats required at least three sampling points to be located in different parts of each habitat to compensate for the difference in environmental conditions owing to the large area covered. Fields were therefore divided into three sections, with one sampling taking place in each of these sections in order to acquire data from different locations in the fields.

Figure 10.4. Location of Ukrainian case-study regions.

10.4 Uganda

Uganda is a landlocked East African country covering a total area of 236,040 km² and with a population of 27 million. Situated on the East African plateau, the country has an average elevation of approx. 1100 metres above sea level. The climate is modified by altitude, and is therefore generally but not uniformly equatorial. Southern Uganda is wetter, with rainfall generally spread throughout the year. Further to the north, a dry season gradually emerges. The north-eastern Karamoja Region has the driest climate, and is prone to droughts in some years. Rwenzori in the southwest receives heavy rainfall all year round. Lake Victoria – one of the world's biggest lakes – heavily influences weather and climate in the south of the country, preventing temperatures from varying significantly and increasing cloudiness and rainfall. Around 50,000 certified smallholders farm organically in Uganda. Organic export companies increased from five in 2001 to 22 by the end of 2005.

The case-study region is located in the Kayunga District, which lies approximately 74 km northeast of Kampala (Fig-

Figure 10.8. Pineapple plantation intercropped with bananas (photo: C. Nkwiine).

Figure 10.9. Banana, coffee and shade trees (photo: F. Herzog).

Figure 10.7. Location of the Ugandan case-study region.

ure 10.7). This region has a modified equatorial climate, which means humid-to-sub-humid conditions. Average annual rainfall is 1228 mm, falling mostly between March-June and September–November. The average temperature ranges between 22 and 25 °C. Kayunga District is characterised by gently rolling hills with wide valleys and an elevation of between 1300 m in the north and 950 m in the south. Soils are sandy clay loams of Luvisols and some silty loams of Fluvisols. Agriculture is the main economic activity in Kayunga District, representing 90 % of total employment. Many farmers produce organic products. Two types of agriculture are practiced in Kayunga: animal husbandry in the north, and subsistence crop farming in the south, where the BioBio Project site is located. Some of the crops raised in the district include vanilla, cassava, bananas, coffee, maize, millet, watermelon, pineapples and passion fruit (Figures 10.8 and 10.9). Kayunga District is the leading producer of pineapples in Uganda, and the local organic farms export the fresh fruit.

Temperate farming in Europe is characterised by distinct seasonality, with a growing season in spring and summer, interrupted by a cold season in winter. With tropical farming in Uganda, however, there is no interruption of the growing season. What's more, Ugandan farming is characterised by spatial and temporal intercropping. Monoculture is the exception: several crops are grown simultaneously in a given field, with one of them possibly being gradually replaced by another. For example, while pineapples are planted as a monocrop for the first 1–2 years, they may be gradually intercropped with e.g. banana and/or coffee in subsequent years. When after 5–6 years the pineapple plants are removed, the bananas will be intercropped with coffee and/or trees.
The application of the BioBio indicators led to the following difficulties:

1) The EBONE habitat-mapping key was not adapted to tropical habitats. An ad hoc adaptation was proposed, but requires further testing and improvement.

2) The farm management questionnaire was not adapted to the farming system, and could therefore only survey part of the management operations.

3) Spider sampling was not done because spider taxonomy is not sufficiently stable in East Africa.

4) Whilst the sampling method for bees was successfully adopted, earthworm sampling proved difficult due to the different structure of tropical soils, which more or less stops the chemical AITC (allyl isothiocyanate) from penetrating more than 10 cm deep.

5) Specimens had to be sent to Kenya for identification because taxonomic expertise in bees and earthworms was not available in Uganda.

Table 10.2. Applicability and results of BioBio indicator assessment in Tunisia, Ukraine and Uganda ('not applicable' = indicator was not applicable in case study; 'not yet available' = indicator was applicable in case study but results have not yet been analysed completely).

		Ukraine	Tunisia	Uganda
General Description				
Habitat	Habitat types (total)	11	26	37
	Habitat types (per farm)	10	7	6
Plants	Species (total)	91	145	249
	Species (per farm)	46	26.3	73.5
Earthworms	Individuals (total)	2018	not applicable	260
	Species (total)	10	not applicable	8 morphospecies
	Individuals (per farm)	336	not applicable	16.3
	Species (per farm)	8	not applicable	4 morphospecies
Spiders	Individuals	1508	248	not applicable
	Species	124	47	not applicable
	Individuals (per farm)	251	12.4	not applicable
	Species (per farm)	55	6.2	not applicable
Bees (*Apis mellifera* excluded in Ukraine and Tunisia)	Individuals	365	60	5629
	Species	59	9	133 morphospecies
	Individuals (per farm)	61	3	351.8
	Species (per farm)	21	1	29.2 morphospecies
Crop species/varieties		6 / 30	not yet available	17 / 92
Animal species/breeds		not yet available	not yet available	not applicable
Farm Management		not yet available	not yet available	not yet available
Indicator Assesment Costs		not applicable	not applicable	not applicable

10.5 Results and recommendations

The case study in Tunisia was similar to that of the olive groves in Spain, with all indicators except earthworms being applicable. In Ukraine, aside from the necessity of adapting the farms' sampling design to the larger farm- and plot size, there were no major problems in implementing the indicators developed for Europe. The Ugandan system differed the most from the European systems, making implementation of the BioBio indicators more difficult. The results show the general applicability of the BioBio approach beyond Europe and for different environmental conditions. For tropical farming in particular, however, the approach requires adaptation.

The major problem faced is the shortage of adequate resources for establishing e.g. a monitoring scheme based on the selected indicators. For practical implementation it would be necessary to adapt the indicator set to lower levels of available resources (funding, knowledge, infrastructure and institutions). One solution might be to place greater importance on simple methods or low-cost approaches when it comes to implementing indicators and sampling schemes (see e.g. Coddington J. A. *et al.* 1991, Danielsen *et al.* 2000). Another way to cope with a shortfall of human resources and institutions could be participatory monitoring methods (see Danielsen *et al.* 2005, Danielsen *et al.* 2006). The discussions of Yoccoz *et al.* (2001, 2003), Rodríguez (2003) and Danielsen *et al.* (2003a, 2003b) on the correlation between the scientific back-

ground of biodiversity indicators for monitoring and the potential of participatory approaches for developing countries provide a good starting point for developing adapted indicators based on the BioBio findings.

References

Coddington J. A., Griswold C. E., Davila D. S., Penaranda E. & Larcher S. F., 1991. Designing and testing sampling protocols to estimate biodiversity in tropical ecosystems. The unity of evolutionary biology. Fourth international congress of systematic and evolutionary biology. Volume I (ed. Dudley, E. C.), pp. 44–60. Dioscorides Press, Portland.

Danielsen F., Balete D.S., Poulsen M.K., Enghoff M., Nozawa C.M. & Jensen A.E., 2000. A simple system for monitoring biodiversity in protected areas of a developing country. Biodiversity and Conservation 9, 1671–1705.

Danielsen F., Burgess N.D. & Balmford A., 2005. Monitoring matters: examining the potential of locally-based approaches. Biodiversity and Conservation 14, 2507–2542.

Danielsen F., Burgess N.D., Balmford A., *et al.* 2006. Monitoring matters: evaluating locally-based biodiversity monitoring in developing countries. Oryx 40, 14–15.

Danielsen F., Mendoza M.M., Alviola P. *et al.* 2003a. Biodiversity monitoring in developing countries: what are we trying to achieve? Oryx 37, 407–409.

Danielsen F., Mendoza M.M., Tagtag A. *et al.* 2003b. On participatory biodiversity monitoring and its applicability – a reply to Yoccoz *et al.* and Rodriguez. Oryx 37, 412–412.

Rodriguez J.P., 2003. Challenges and opportunities for surveying and monitoring tropical biodiversity – a response to Danielsen *et al.* Oryx 37, 411–411.

Yoccoz N.G., Nichols J.D. & Boulinie, T., 2001. Monitoring of biological diversity in space and time. Trends in Ecology and Evolution 16, 446–453.

Yoccoz N.G., Nichols J.D. & Boulinier T., 2003. Monitoring of biological diversity – a response to Danielsen *et al.* Oryx 37, 410–410.

11 Conclusions and recommendations

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The BioBio research project yielded an operational set of 23 farm-scale biodiversity indicators which emphasise state indicators of habitat, species and genetic diversity. The project therefore complements existing indicator systems such as IRENA and SEBI as well as national monitoring systems. These indicators are the minimum set necessary to represent the types, functions and scale of activity of different organisms and a further reduction in the number of indicators would lead to a substantial loss of information. The BioBio consortium suggests further testing and establishment of the indicators during a pilot phase, followed by implementation of European-scale monitoring in order to provide information on the status, direction and rate of change of European farmland biodiversity.

11.1 Indicator set

In the FP7 research project "BioBio - Biodiversity indicators for organic and low-input farming systems", a core set of 23 indicators was identified: eight habitat and four species indicators, three indicators for the genetic diversity of crops and livestock, and eight farm-management indicators. The indicator set is a result of thorough scientific screening and testing in 12 case-study regions with various farm types and farming systems across Europe, as well as regular stakeholder consultation.

The BioBio indicator set possesses the following features:

- It relates to the scale of individual farms;
- It focuses on "state indicators" which report on the actual status of biodiversity;
- Habitat diversity indicators cover the different habitat types, their geometry, and their nature;
- Species diversity indicators cover the different trophic levels and major ecological functions of biodiversity;
- Genetic diversity indicators address the diversity of both crop species and livestock;
- Farm-management indicators relate to external inputs (energy, nutrients, pesticides), disturbances (field operations used in the cultivation of horticultural, arable and forage crops) and livestock husbandry.

Indicators were tested in 12 case-study regions, revealing a huge variability of indicator values within regions (i.e. variability between farms) and between regions (owing to differences in geography and farm types). The relationships between indicators of the remaining indicator set (correlations) also differ significantly between case studies. Further reduction of the number of indicators would therefore lead to a substantial loss of information that cannot be substituted by the other indicators. An aggregation of the indicators into a single index is not recommended owing to the different correlations between the indicators (which vary across case-study regions), and was explicitly rejected by the stakeholders because of difficulties in interpreting such an index. Instead, some of the management indicators should be further specified by sub-indicators (e.g. Herbicide / Fungicide / Insecticide Use in the case of Pesticide Use).

11.2 Applicability of the indicator set

The 12 case-study regions cover the major geographical gradients in Europe (from Mediterranean to Boreal, Atlantic to Continental). Sixteen indicators can be applied to all farm types, whilst others are restricted to farms with (i) field crops and horticulture, (ii) specialist grazing livestock, (iii) mixed crops/ livestock, and (iv) permanent crops. Farming intensity in case-study regions was low-to-medium (for both organic and non-organic farms). The indicators were not tested on highly- intensive or industrial crop or permanently housed, animal production farms.

A tentative application of the indicators in Tunisia, Ukraine and Uganda showed that whilst the BioBio approach is generally applicable, it would require specific adaptations to the scale of the farms in question (large-scale in Ukraine, smallholder farms in Uganda), the farm-management and socio-economic context (Tunisia and Uganda), and habitat classification (Uganda). The poor taxonomic knowledge and limited availability of expertise of arthropods further restricted the practical application of the full indicator set (Tunisia, Uganda).

11.3 Practicalities

A consistent methodology was developed to collect data for each indicator which proved feasible in all European case-study regions, and can therefore be recommended for further application. Indicator measurement could be

Welsh Case Study: Mountain Grassland with Sheep or Cattle, or Mixed Upland Farming

Wales is located in the west of mainland UK, with its highest mountains lying within the Snowdonia range in the north. Further south the topography becomes less rugged, although hills remain a key landscape feature, with the Cambrian Mountains dominating much of mid Wales, and the Brecon Beacons further south. Lowland areas are confined mainly to the relatively narrow coastal belts and the valley floors. Altitude, steep slopes, high rainfall and poor soils have led to slightly under 80 % of the agricultural land being classified as Less Favoured Area. As a result, much of the land is devoted to grassland farming systems with hefted sheep flocks and beef suckler systems.

Number of farms surveyed: 9 organic, 10 non-organic
Average farm size: 143 ha
Average N-Input: 152 kg/ha
Average energy input: 148 kg fuel equivalents
Total number of habitat types: 45
Total number of plant species: 321
Total number of bee species: 13
Total number of spider species: 159
Total number of earthworm species: 18
Total number of crop species: 12
Total number of crop varieties: 37
Total number of animal species: 2
Total number of breeds: 26

spread over two years in order to avoid peaks of labour demand and to facilitate the optimal timing of indicator measurement in relation to the phenological development of flora and fauna.

The effort required to evaluate the indicators for an average farm is about 15 person-days, with equal proportions of skilled and unskilled labour. Labour accounts for approximately 75 % of the total cost, while the remainder relates to consumables (equipment, vehicles, etc.) and the taxonomic cost of identifying the captured invertebrates.

11.4 Outlook

We recommend using a certain percentage of the European Common Agricultural Policy budget to evaluate the effects of the policy. The BioBio indicator set is appropriate to evaluate the effects on farmland biodiversity. This aspect may gain in importance, since farmland biodiversity and ecological focus areas may become part of cross-compliance requirements. More specifically, the indicators can be used to evaluate the effects of agri-environmental schemes. Based on a regional classification of European farms, a European monitoring programme has been designed to apply the biodiversity indicator set and 0.25 % of the CAP budget would allow a sufficient number of farms to be sampled to represent biodiversity change in those regions and for individual farm types.

BioBio was primarily a research project with stakeholder consultation and feedback. Based on its findings, the pilot phase (consisting in the testing of the BioBio approach in a selected number of the aforementioned regions) is ready to begin. In particular, farm types which have not been tested in BioBio, as well as intensive, non-organic farming, will require further examination. The results would allow us to further adapt the indicator set and to refine and establish the methodology. Subsequently, a routine monitoring programme could be implemented and we recommend a rolling survey of five year frequency composed of two years data collection). The precise sampling design of farms within regions and types of farm included for monitoring would need to be carefully considered and defined.

The BioBio indicators relate to the farm scale, which has the advantage of directly linking driving forces (farm management) to the status of biodiversity. Also, farmers are major decision makers and e.g. policies are addressed to them. However, there are also disadvantages to this approach, including the fact that most farms are not consolidated (scattered land holdings) and that farm ownership boundaries are dynamic over time. We therefore recommend supplementing BioBio farm-scale monitoring with landscape-scale monitoring in order to obtain comprehensive and consistent information about the status of European farmland biodiversity.

12 The BioBio Project Consortium

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Biodiversity Indicators for European Farming Systems

The report that lies before you summarises the lessons learnt from the EU FP7 Research Project BioBio (Biodiversity indicators for organic and low-input farming systems, KBBE-227161) conducted between 2009 and 2012. The report is aimed at stakeholders and potential users of the indicator set resulting from this research, and is structured as follows:

In addition, supporting information and all other BioBio Project public reports are available at www.biobio-indicator.org.

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