Measuring Farmland Biodiversity

by Felix Herzog et al.
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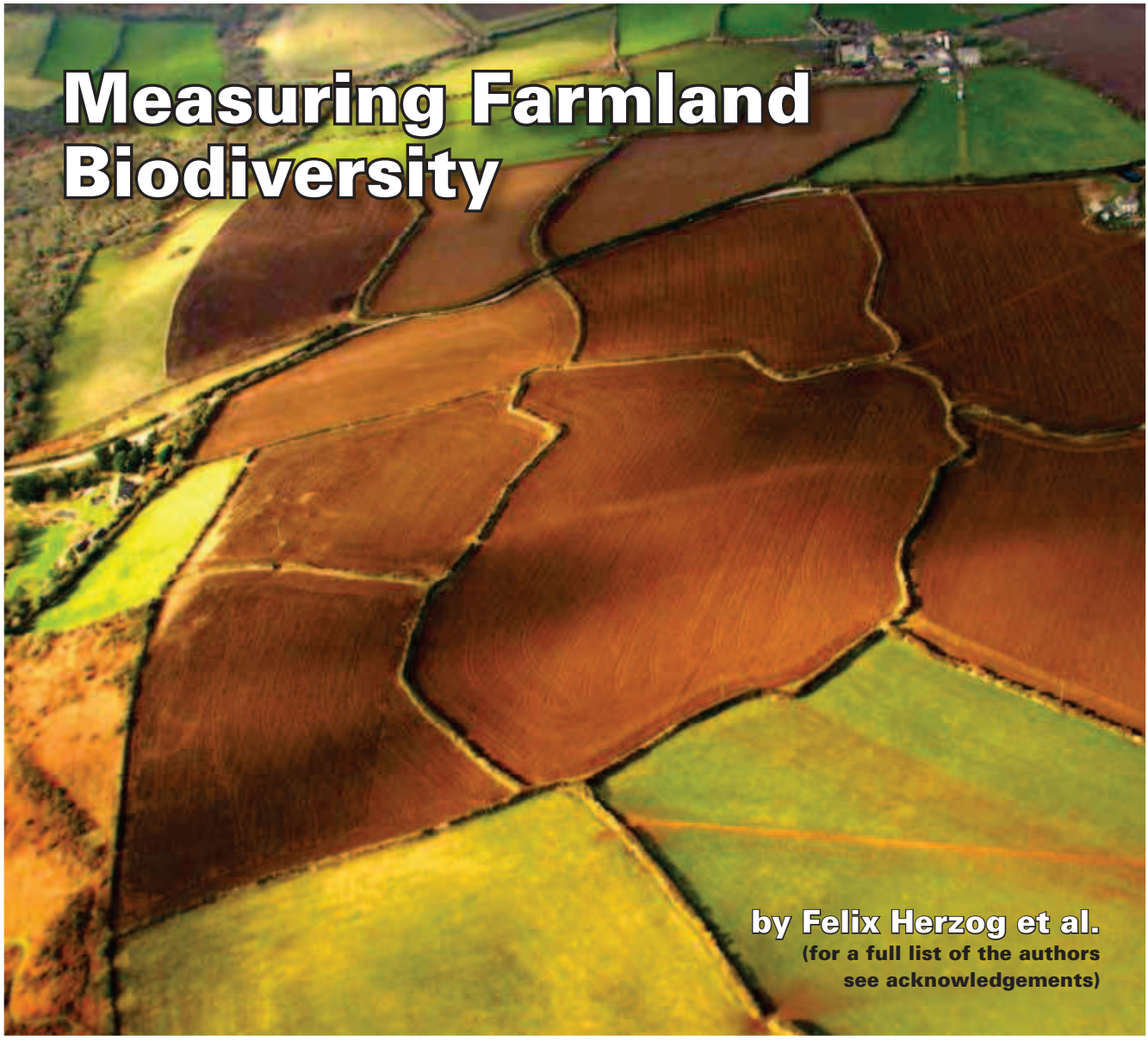

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A patchwork of agricultural land in the Tresco Isles, UK..

In Brief

About one-third of the world's land surface is used for farming, a fact that bears important implications for biodiversity. In Europe, for instance, an estimated 50 percent of all wild species are reliant on agricultural habitats, while agricultural productivity often depends on the presence or absence of particular species. Despite this close coupling, surprisingly little is known about the status and evolution of farmland biodiversity. A team of European and African researchers, hoping to fill this gap in information, recently invented and piloted a new toolbox called the BioBio indicator set, which measures 23 different instances of biodiversity across a variety of farm types and scales in Europe. Applications were also tested in Tunisia, Ukraine, and Uganda, where they proved a feasible starting point for adaptation to the agricultural context of different countries.

In the Gascony region of Southwest France, famously home to the Bordeaux grape, farmland biodiversity may be higher than what's found in any other agricultural region of Europe—an important fact only recently brought to light.

Biodiversity—the diversity of genes, species, and habitats—is among the natural resources under threat by the growing human population.[1] In Europe, an estimated 50 percent of all wild species are reliant on agricultural habitats, leading to close interactions between farming and wildlife:[2] Wild species provide ecosystem functions essential for farming success—predation of insect pests, for instance, along with pollination of flowering crops, decomposition of organic material, and build-up of soil fertility. And composition and diversity of wild species are affected by farming practices, notably fertilization, pesticide applications, mechanical operations, animal husbandry, and conservation or removal of semi-natural habitats such as hedgerows.

About one-third of the world's land surface is used for farming, which means we have a vital interest in knowing the status of farmland biodiversity.[3] First, because we want to promote the species that contribute to agricultural yields and defend against the pests that affect it negatively. Second, because we want to preserve biodiversity for its intrinsic value. In fact, some of the most critical conservation issues today relate to farmland biodiversity, which is threatened both by agricultural intensification and abandonment.

Given those challenges, it is surprising how little we know about the status and evolution of farmland biodiversity. Current evaluations are often limited to farmland birds, which have shown declining trends over the last decades. More recently, Europe has been monitoring butterfly populations.[4] Administrators and the public are often interested in rare species with conservation status, but there is no consistent information on the status of more common species, despite the fact that these, to a great extent, are what interact with farming practices, providing services or causing damage.[5]

Farmland birds and butterflies are monitored at the landscape scale, often in plots of one square kilometer or more.[6,7] While this scale corresponds well with the comparatively high mobility of those species, it is not related to the narrower scale of action of the most important decision-maker acting on farmland biodiversity—the farmer. He or she decides on the type of farming enterprise (crops, animals); the farming system (organic, conventional); the use of the land (crop rotation, pasture management); the nature and amount of inputs used (fertilizer, pesticides, etc.); amelioration (irrigation, drainage); the farm machinery and its use, and so forth. These factors strongly affect agricultural biodiversity. Consequently, most policy measures that aim to preserve agricultural biodiversity address the farm scale and farm management practices by means of incentives, compensation measures, or cross-compliance mechanisms that tie farm subsidies to farmers' compliance with ecological standards.

A new project called BioBio, designed by 16 research institutions from 14 countries, aims to identify a generic set of farmland biodiversity indicators applicable across Europe for major farm types. The indicators capture genetic, species, and habitat diversity at the farm scale. In creating them, we paid particular attention to appeals of the stakeholder advisory board (SAB), which elaborated a list of requirements. The board consisted of representatives from international, national, and regional administrative bodies, research and education organizations, farmers' organizations, consumers' associations, and nongovernmental organizations dedicated to the conservation of nature and the environment.

Key Concepts

- **The diversity of life—genetic, species and habitat diversity—is a critical and threatened resource. In an agricultural context, the functions provided by biodiversity are particularly important, yet not much is known about farmland biodiversity and how it is sustained.**
- **We developed a toolbox consisting of 23 indicators addressing all components of farmland biodiversity as well as management practices. The indicators were tested in 15 case study regions in Europe and Africa.**
- **We propose that 0.25 percent of the budget for European agricultural subsidies be diverted to monitoring of continental farmland biodiversity and adaptation of the toolbox for application beyond Europe.**
- **Guidebooks to indicator measurement and interpretation, including an extended summary in twelve languages, are available at www.biobio-indicator.org.**

Finding the Right Indicators

We tested BioBio biodiversity indicators on 237 farms in 15 case study regions across Europe, Northern, and sub-Saharan Africa. On each farm, teams mapped habitats, recorded wild species, and interviewed farmers about farming practices, crops, and farm animals according to a standardized protocol.[8] Case study regions covered the major European farm types and were located in major bio-geographical regions. Among the 23 biodiversity indicators, 16 indicators remain relevant for all farm types while seven apply only to specific farm types.[9]

Our biodiversity measurement toolbox has four focuses: genetic, species, and habitat diversity, as well as

Stakeholder Expectations

Thierry Fabian, an agricultural engineer, is the head of the French Institute for Designations of Origin in Caen. Obtaining the AOC label for cheeses, wine, or cider helps farmers market their products. Fabian wants to evaluate whether the traditional farming practices related to those products yield environmental benefits and promote farmland biodiversity. If so, this would constitute an additional marketing argument for those products.

Since 1991, Peter Mayrhofer has been developing the Ecopoint system in Lower Austria in which farmers are encouraged to promote biodiversity by, for example, planting and maintaining traditional fruit orchards or dry meadows. By doing this they can generate additional subsidies. Mayrhofer, who works for the regional agricultural administration, is interested in measuring the direct impact of this environmental scheme on biodiversity. Thierry Walot from the regional administration of Wallonia (Belgium) has the same interest.

Both, Patrick Ruppol from the Belgian Organic Farmers' organization and Eva Corral from the Federation of European Farmers and Cooperatives are looking for a tool to measure biodiversity on the farms of their members. They need indicators that farmers can understand and that are directly related to farm management so that, if farmers alter their practices, they can measure the effects on wildlife.

In order to protect nature, Claudio De Paola of the Ticino Italian Regional Park, Eduardo de Miguel of the Spanish Fundaçion Global Nature, and Simeon Marin of Green Balkans Bulgaria want to evaluate the status of farmland biodiversity in their parks in relation to their efforts to foster traditional, extensive farming while preventing land abandonment.

farm management practices. Because molecular genetic methods that capture diversity at the genetic level remain technologically demanding and expensive, we chose three simple indicators based on crop-cultivar and livestock-breed information. These were collected in farmer interviews to assess genetic resources of crops and livestock.

The BioBio *species* diversity indicators operate at local to intermediate scales and cover the four major ecological functions relevant for farming: Primary production (plants), pollination (wild bees and bumblebees), predation (spiders), and decomposition of organic material (earthworms). The emphasis on invertebrates, in addition to vascular plants, reflects the contribution of invertebrates to overall species diversity; arthropods alone make up about 65 percent of multicellular organisms, by number.[10] Moreover, they provide relevant information on general environmental conditions, react quickly to environmental changes, and, due to their limited mobility, allow direct assessment of farm management effects. Farmland birds were not retained as an indicator group due to their mobility.

Habitat indicators are derived from a generic mapping approach of the farm.[11] The farm area is subdivided into intensively farmed land, including all crop fields and grasslands managed for the primary purpose of agricultural production, and semi-natural habitats. Both categories can be further subdivided. These divisions are somewhat subjective and require clear rules, as transitions between habitat types are gradients. Still, many relevant policies operate on the habitat level, so this has proven a useful tool.

In addition to the three levels of biodiversity—genetic, species, and habitat—we monitored eight farm management indicators that reflect the pressure of farm management on species and habitats. These indicators are based on interviews with farmer about use of and expenditure on inputs like energy, fertilizer, and pesticides, on the frequency of field operations, and on the density of livestock on the farm.

The weighting of different indicators according to ecological importance was a challenging and live question throughout the project's development. Ultimately, because it is quite difficult to come up with scientifically sound distinctions—is an earthworm more valuable than a bee?—and because the stakeholders preferred "raw" indicators, we did not create a weighted index.

Applications Beyond Europe

We tested wider applicability of the BioBio indicators in three countries representing different ecological zones and policy contexts: Tunisia, Ukraine, and Uganda. While generally applicable, the BioBio approach needed some adaptation. Tunisia lacks taxonomic expertise for arthropods and the specimens had to be sent to Europe. Due to prolonged drought, earthworms were hardly present and could not be evaluated; in Ukraine, we adapted the sampling design to the large scale of farms and landscapes; and in Uganda, we adjusted the habitat key to accommodate the diversity of smallholder polyculture; also, spider taxonomy is not well known, which impairs the usefulness of this group as a biodiversity indicator.

Nonetheless, the BioBio indicators proved a valuable starting point in each of these countries. For practical implementation, the indicator set would require adaptation to lower levels of available resources (funding, knowledge, infrastructure, and institutions). Adopting other taxa could be considered for the tropics, and morphospecies might be used if the taxonomy is unstable. This means that a catch of spiders, for example, would be sorted according to features like size, color, and so forth, without actually identifying individual species. One then obtains a morphospecies count without knowing which species are present.

Highest Diversity in Gascony, France

In the valleys and hills of Gascony in Southwestern France we surveyed 16 arable farms. The BioBio indicators revealed that, with 440 plant species, 171 bee species, 261 spider species, and 16 earthworm species, overall species richness was highest here among the 15 case study regions. This is partly because the region is under the influence of both sub-Atlantic and sub-Mediterranean climates, and because the number of habitat types (52) was among the highest. (Only the Hungarian case study had more habitat types, with 58; others ranged between 10 and 30.) The average farm size in Gascony was 79 hectares with an average nitrogen input of 41 kilograms per hectare. Only Hungary, Spain, and Italy had lower nitrogen input levels. The energy input was also among the lowest. These factors (climatic condition, habitat richness, low level of inputs) help to explain the comparatively high number of species recorded on these farms.

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Despite close interaction between agriculture and biodiversity—farms cover one-third of the world's land surface—little is empirically known about the ecological effects of different farming practices.

Research and Development to Monitoring Application

Developing indicators and monitoring would be an easy task if there were no financial constraints. But, of course, the cost of these biodiversity indicators restricts implementation. Therefore, the design of a monitoring program comes down to an optimization exercise: maximize information gained within a given budget.

Although monetary estimates of the values of biodiversity are coarse, they show that biodiversity is important for the long-term viability of agriculture and provides many undervalued or invisible functions and benefits.[11,12] Focus group discussions with farmers in the case study regions revealed that the ethos and emotional response of farmers are important drivers of biodiversity-friendly farming.[13] Providing clear information on the biodiversity status of farms and how this biodiversity interacts with management practices can encourage improvement in private and public analyses of the costs and benefits related to farming activity—and not only in monetary terms. If a farmer is well informed about the consequences of his or her management on biodiversity, this could reduce the risk of opportunistic implementation of farming practices because of subsidies instead of genuine effectiveness.

Still, monetary incentives are important, and they can be linked to programs or product labels that highlight biodiversity-friendly farming. This means that taxpayers and consumers would pay a premium to promote farmland biodiversity. Policymakers and sales organizations need to justify this spending by demonstrating tangible results; at some point, taxpayers and consumers will want to know if their spending yields the intended biodiversity benefits. Such demands often come up at short notice, triggered by, for example, a scandal revealed by the press. At that point it will be too late to react. If policymakers and sales organizations want to make sure that their programs work, they have to continuously evaluate them through monitoring.

How Much Does It Cost?

Naturally, cost depends largely on the size of the farms. Recording the indicators on an average farm of 85 hectares, consisting of eight different habitat types, requires 15 labor days (half for skilled labor, half for unskilled) plus €1,000 (about US$1,350) for material and taxonomic expertise. While the actual fieldwork is by far the largest portion of the budget, funds must also be available for scientific oversight and administration, data management, analysis and reporting, and quality assurance.

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Genetic Diversity Indicators	
Number and amount of different breeds (2,3)	Simple count of breeds/varieties, based on farm interviews
Number and amount of different varieties	
Origin of crops (1,3)	Share of races maintained on farm
Species Diversity Indicators	
Number and amount of vascular plant species	Primary producers (plants), herbivores (bees), predators (spiders) and detrivores (earthworms)—all with low to medium mobility and therefore related to the plot/farm scale.
Number and amount of wild bee and bumblebee species	
Number and amount of spider species	
Number and amount of earthworm species	
Habitat Diversity Indicators	
Habitat richness	The four indicators describe the composition of the farm in terms of plot/patch type and geometry.
Habitat diversity	
Average size of habitat patches	
Length of linear elements	
Crop richness (1,3)	Indicators for specific habitats. Interpretation is contextual: higher percentage of shrubs implies more biodiversity on intensive farms, but abandonment on extensive farms.
Percentage of farmland with shrubs	
Percentage of farmland with trees (1,2,3)	
Percentage of semi-natural habitats (SNH)	Requires expert judgment; relatively low scientific validity, but high stakeholder interest.
Farm Management Indicators	
Total direct and indirect energy input	Negatively correlated with most species counts; a good proxy for intensity of farm management.
Intensification/Extensification (expenditures on inputs)	This monetary indicator correlated well with the number of wild species in most case study regions.
Area with use of mineral nitrogen fertilizer	The increased use of nitrogen affects the composition of plants, and thus indirectly acts on fauna.
Total nitrogen input	
Frequency of field operations	Each mechanical field operation disturbs the ecosystem.
Pesticide use (1,3,4)	Pesticides directly eliminate specific species.
Average stocking rate (2,3,4)	Farm animals interact with biodiversity both directly (grazing) and indirectly (nutrient input from organic fertilizer).
Grazing intensity (2,3,4)	

Farm-scale biodiversity indicators. Those restricted to specific farm types are indicated: (1) Field crops and horticulture, (2) Specialist grazing livestock, (3) Mixed crops—livestock, (4) Permanent crops.

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There is a rule of thumb that between 0.5 and 10 percent of the budget spent for policy measures should be allocated to evaluating their effectiveness.[14] With only 0.25 percent of its budget, the European Common Agricultural Policy could implement the BioBio indicators on 50.000 farms (1.7 percent of all farms in Europe), assuming a rolling survey with five-year intervals—10,000 farms visited each year.

From Proof of Concept to Implementation

The BioBio indicators are ready to move from the research phase to implementation. First, however, there needs to be a pilot phase that, among other things:

- tests the indicators on farm types and in regions not yet investigated
- optimizes the sampling design (the proposal here can be refined and likely made less costly)
- builds the necessary know-how in field staff and, in particular, fauna taxonomists (in fact, a large biodiversity monitoring project could contribute to safeguarding the taxonomic expertise now threatened in several countries)
- and organizes the logistics of such an endeavor (data flows, database management, ownership of data, concept for publication).

The proof of concept has been conducted in our first test. As in industrial development, the prototype ought to be turned into a routine product.

We now know some of the many uses of the BioBio indicator toolbox. It can be applied on individual farms, particularly large farms that want to—but currently cannot—accurately advertise the status of biodiversity on their land. Label organizations and administrators, too, can benefit from BioBio: the former as they claim to promote biodiversity-friendly practices, such as organic farming or integrated farming. Monitoring the biodiversity status on labeled farms would allow these groups to improve their guidelines and to demonstrate that higher prices are justified by evidence of biodiversity benefits. The latter, as they work on issues and policies to support farmland biodiversity. Results would help to improve the efficiency of these programs and target them to the specific conditions of individual regions. Finally, BioBio provides a starting point for farmland biodiversity research in less developed countries. This research is urgently needed in countries where yields need to be increased, but where farmers don't have access to modern technologies and inputs. The interactions between crops and wild species must be better understood in order to investigate agricultural intensification that harms wild species as little as possible.

Kat Grigg

A new toolbox of 23 indicators offers a system for quickly assessing genetic, species, and habitat diversity on farms. One of the indicators is the number and species count of bees.

The BioBio indicators allow for a comprehensive assessment of farmland biodiversity at a reasonable cost. Indicators relate to the farm scale, which has the advantage of directly linking driving forces (farm management) to the status of biodiversity. This kind of information is required by both farmers and policymakers to steer their decisions towards more biodiversity-friendly practices, particularly given the growing concern about the connection between biodiversity, agriculture, and landscape services. Today's agricultural policymaking generally rests on economic indicators of production and profit. A broader view is urgently needed. S

Acknowledgements

We are grateful to the BioBio stakeholders for their time, effort, and support. Part of this project was funded under the 7th framework program of the

Though tested mainly in Europe, pilots were also conducted on Tunisian and Ugandan farms, like this one. Once adapted to the environment, the toolbox could help promote localized best practices for agriculture around the world.

European Union (Grant KBBE 227161) and by the Austrian Ministry for Science and Research. We thank the farmers for access to their land and for the information obtained through interviews.

Full list of authors includes: Felix Herzog, Philippe Jeanneret, Youssef Ammari, Siyka Angelova, Michaela Arndorfer, Debray Bailey, Katalin Balázs, András Báldi, Marion Bogers, Robert Bunce, Jean-Philippe Choisis, David Cuming, Peter Dennis, Tetyana Dyman, Sebastian Eiter, Zoltán Elek, Eszter Falusi, Wendy Fjellstad, Thomas Frank, Jürgen, Friedel, Salah Garchi, Ilse Geijzendorffer, Tiziano Gomiero, Gergely Jerkovich, Rob Jongman, Max Kainz, Esezah Kakudidi, Eszter Kelemen, Roland Kölliker, Norman Kwikiriza, Anikó Kovács-Hostyánszki, Luisa Last, Gisela Lüscher, Gerardo Moreno, Charles Nkwiine, John Opio, Marie-Louise Oschatz, Maurizio Guido Paoletti, Károly Penksza, Philippe Pointereau, Susanne Riedel, Jean-Pierre Sarthou, Manuel Schneider, Norman Siebrecht, Daniele Sommaggio, Siyka Stoyanova, Erich Szerencsits, O. Szalkovski, Stella Targetti, Davide Viaggi, Jerylee Wilkes-Allemann, Sebastian Wolfrum, Sergiy Yashchenko, and Tommaso Zanetti.

References

1. Millennium Ecosystem Assessment. Ecosystems and Human Well-being: Biodiversity Synthesis. *World Resources Institute* [online] (2005) www.millenniumassessment.org/en/ (Synthesis.html.
2. Technical Report: EEA core set of indicators: revised version April 2003 (Kristensen P., EEA, Copenhagen, 2003).
3. World agriculture: towards 2015/2030. *Food and Agriculture Organisation* [online] (2003) www.fao.org/docrep/005/y4252e/y4252e00.htm#TopOfPage.
4. Assessing biodiversity in Europe—the 2010 report. *European Environment Agency* [online] (2010) www.eea.europa.eu/publications/assessing-biodiversity-in-europe-84.
5. Gaston K. J. Valuing Common Species. *Science* 327,154–155 (2010).
6. BTO Common Birds Census Instructions BTO (Thetford Marchant, JH,1983).
7. BDM Anleitung für die Feldarbeit zum Indikator «Z7-Tagfalter». *Bern, Koordinationsstelle Biodiversitäts-Monitoring Schweiz, Bundesamt für Umwelt* [online] (Bern, 2012) www.biodiversitymonitoring.ch/fileadmin/user_upload/documents/ daten/anleitungen/1010_Anleitung_Z7-Tagf_v15.pdf.
8. Dennis P, Bogers M.M.., Bunce R.G. Herzog F & Jeanneret P. *Biodiversity in organic and low-input farming systems. Handbook for recording key Indicators* 92 [online] (Wageningen, Alterra, Alterra-Report 2308, 2012) www.biobio-indicator.org.
9. Herzog, F et al. *Biodiversity indicators for European farming systems. A guidebook* 17, 1– 99 [online] (ART-Schriftenreihe, 2012) www.biobio-indicator.org.
10. Hammond P.M. 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. (1994). EBONE [online]. www.ebone.wur.nl.
12. The economics of ecosystems and biodiversity. *TEEB* [online] (no date) (www.teebweb.org).
13. Kelemen, E et al. Farmers' perceptions of biodiversity: lessons from a discourse-based deliberative valuation study. *Land Use Policy* [online] (doi: 10.1016/j.landusepol.2013. 06.00510.1016).
14. Rieder S. Kosten von Evaluationen. *LEGES* 2011(1), 73–88 (2011).