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A Rapid Method for Monitoring Landscape Structure and Ecological Value in European Farmlands: the LISA approach

Abstract

Farmland biodiversity has dramatically declined in European agricultural landscapes over the past century. The key driver of this decline is the intensification of farming practices. In response, various policies have been developed to protect and promote farmland biodiversity, including so-called greening measures under the Common Agricultural Policy (CAP). However, there is currently very little systematically collected data on the ecological quality of European farmland. Therefore, we developed a survey method to provide repeatable and comparable data. This method comprises the mapping of land use and ecological quality of parcels in sample plots of 500 m x 500 m, vegetation transects on up to four predefined parcels in each sample plot and a photo documentation of the transects and the whole plot. Using this LISA method (Landscape Infrastructure and Sustainable Agriculture), we investigated about 25 plots in each of 35 regions in 2014 and 13 regions in 2016, altogether in 10 EU countries. The methodology provides a time- and cost-efficient possibility to collect standardised data on the ecological quality of farmland habitats. We show that biodiversity in arable fields is at an extremely low level. The survey methodology proved to be applicable in all parts of Europe and thus being applied widely it could deliver a representative view on the ecological situation of all agricultural landscapes in Europe.

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1 Introduction

Farmland biodiversity in Europe has suffered a major decline since the beginning of the 20th century (Donald et al. 2001; Henle et al. 2008). The key driver of the current farmland biodiversity crisis has been linked with agricultural intensification, which reduces spatio-temporal complexity of farmed landscape and thus their capacity to support a diverse range of species with different trophic levels and dispersal abilities (Stoate et al. 2001; Tscharntke et al. 2005; Storkey et al. 2012). In addition, this process has been accompanied by an opposite trend of agricultural abandonment due to land reforms and socio-economic changes, especially in eastern European countries (Liira et al. 2008; Stoate et al. 2009; Griffith et al. 2013; Mihók et al. 2017). The negative impact of agricultural changes on farmland biodiversity is best reflected in long-term monitoring of farmland birds which have declined by 57% since 1980 (PECBMS 2019). However, similarly alarming population declines have been reported for other farmland taxa, including insects (Hallmann et al. 2017) or mammals (Pavliska et al. 2018). The continuing negative trend of farmland biodiversity has serious implications for the delivery of a wide range of ecosystem services as pollination and biological control (Tscharntke et al. 2005).

To halt ongoing dramatic loss of farmland biodiversity, different policy instruments have been created, such as the "greening" measures introduced during the last reform of the Common Agricultural Policy (CAP) (EC 2013). Since 2015, greening measures have been implemented in all EU member states and complement agri-environmental programmes, which have been available since 1992 (EC 1992b). Besides the crop diversification and maintenance of permanent grassland, farmers with arable land exceeding 15 ha must maintain Ecological Focus Areas (EFAs) equivalent to 5% of their arable land (Pe'er et al. 2014). Eligible land cover types for EFAs include nitrogen-fixing crops, fallow land and landscape features such as hedges and buffer strips. Specific landscape features are biodiversity-rich elements able to enhance otherwise intensively cultivated landscapes (Pe'er et al. 2017), serve as crucial habitat for many plant and animal species (Dover et al. 2000; Benton et al. 2003; Billeter et al. 2008; Šálek et al. 2018) and are important predictors of species persistence in agricultural landscapes (Öckinger and Smith 2007; Thomas 2000; Fahrig et al. 2011;). Despite introducing these greening measures, progress in halting biodiversity loss has so far been very limited (Pe'er et al. 2014; 2017; 2019).

To assess the effects of the CAP on farmland biodiversity, it is important to collect field data to monitor landscape structure and its changes. For example, buffer strips are one of the options of landscape elements to be implemented as greening within the CAP in the year 2015. Therefore, the extent of buffer strips could have been higher in 2016 than in 2014, a hypothesis to be proved by a monitoring of the extent and quality of buffer strips. Data from the integrated administration and control systems (IACS) can only verify the extent of registered buffer strips (e.g. after the implementation of CAP greening measures in 2015) but do not identify the not registered buffer strips nor do the data provide information on the quality of buffer strips. In this regard, it is crucial to gain an overview of the quantity and quality of potential habitats or "ecological infrastructure" such as beneficial ecological landscape elements and species-rich farmland (e.g. high nature value farmland). Whilst large-scale, systematic data is available on crop types and yields in the EU (Eurostat 2019), there is currently no standardised field monitoring method and field data against which the situation of farmland biodiversity can be measured and compared (Underwood and Grace 2017).

In this study, we developed a rapid and effective monitoring method called LISA (Landscape Infrastructure and Sustainable Agriculture) for assessing landscape structure, ecological value and biodiversity in a range of agricultural landscapes across Europe. More specifically, the main aims of this study were to i) monitor quantity and ecological quality of different land cover types and landscape elements ii) find feasible and suitable indicators of farmland ecological quality and methods to conduct a rapid inventory, iii) test the suitability of a common monitoring methodology over a wide range of biogeographic regions in the European Union, and iv) provide insights into the current ecological state of

European farmland, interpreting how this may apply to policy-induced changes. This paper provides an overview of the development of the methodology and gives some examples of results that can be produced using this approach.

2 Methods

2.1 Development of the methodology

The Pan-European Common Bird Monitoring Scheme (PECBMS) provides the oldest indicator on the ecological state of European agricultural landscapes on behalf of the indicator group of farmland birds (Gregory et al. 2005). However, as birds are highly mobile, they cannot be used to track the changes of landscape and ecological quality in detail. Therefore, a detailed ecological monitoring can provide additional information for the PECBMS and explain changes of the development of bird populations. Thus, methods should be applied which on the one hand are able to monitor the ecological quality on parcel level and on the other hand deliver information on whole regions without the effort of mapping landscape elements, vegetation, land use and the parcel specific ecological quality in the whole landscape.

A sample approach had to be developed providing ecological data from on the ground surveys with a small effort and integrating knowledge and experiences from different existing European approaches. More concretely the most important parameters of the field monitoring are:

- Extent of different landcovers and landscape elements;
- Patchiness of the land use and spatial distribution;
- Parameters of vegetation contributing to the evaluation of the intensity of land use such as type of vigour of grassland;
- Ecological quality of all land uses and landscape elements measured with indicators and proxies of the species richness and / or the structural richness;
- Pollination potential – e.g. numbers of flowering species and flowering abundance;

A good overview on the general aspects of designing and implementing monitoring programs are given by Lindenmayer and Likens (2010) and Reynolds et al. (2016).

The most crucial points for developing the methodology were the following:

- Time window: There is a short time window of about 6-8 weeks within which the survey has to be carried out as for the recording of the ecological quality of arable land and grassland the vegetation has to be assessed before the crops are harvested and the grasslands are mown or pastured. This time window extends - according to latitude and altitude situation - from April to June (southern European countries) and from May to July (northern European countries).
- Size and number of plots: larger plots require more time for the survey than smaller plots, and numerous plots deliver more representative results for a region than only a few plots. The optimal compromise between the required number of plots and size of the plots is different for different landscapes, depending on land cover heterogeneity and parcel size.
- Rapid approach: the time window is small and within this period a relatively large number of plots must be surveyed in order to be representative. Thus, the approach has to be rapid, so it cannot comprise complete floristic or faunistic records.

Given these restrictions, we reviewed the existing European approaches for a rapid ecological inventory method in order to find key indicators for the survey protocol development. The rationale behind this review was to consider existing approaches and experiences in order to integrate suitable and feasible elements in the own approach as far as possible. Table 1 shows important approaches; however, we will not give a comprehensive literature review. We will refer to some of these important approaches in the description of the method.

2.2 LISA Method

Based on the review of existing approaches and most crucial points for developing the methodology (mentioned above) we identified the following elements for a future monitoring methodology (Figure 1) which we called LISA (Landscape Infrastructure and Sustainable Agriculture):

Table 1. Survey approaches analysed to find relevant parameters and indicators for the development of a European wide standardised survey methodology.

Survey approach	Description	References
AGRIT (agri-environment statistics) in Italy	Sample approach on the extent and quality of landscape elements in three regions based on plots of 6.25 ha each. Field samples are supported by spatial information from integrated administration and control systems	Tropea et al. 2012
European Bio-Bio-study	Set of biodiversity indicators associated with organic and low-input farming systems. The data is collected on samples of individual farms. These indicators shall be used to monitor the contribution of farming to the maintenance of biodiversity in different areas across Europe	Herzog et al. 2012
European Biodiversity Observation Network (EBONE)	Development of a basis for the collection of biodiversity data at regional to European scale, based on a set of biodiversity indicators	Bunce et al. 2008
French flower meadows approach	For the purpose of creating a comparable base for a national competition on flower meadows a list of indicator species has been identified which covers the overall diversity of grasslands from the North Sea to the Mediterranean Sea and from the Alps in the East to the Atlantic Ocean in the West	Mestelan et al. 2010
High Nature Value (HNV) farmland monitoring in Germany	Monitoring of species richness and habitats in agricultural landscapes: the German HNV farmland indicator is the only approach within the multitude of HNV farmland indicator approaches across Europe which is based on concrete field data collected on plots of 100 ha each	PAN et al. 2011, Benzler 2012, Pepiette et al. 2012
LUCAS - Land Use/ Cover Area frame Survey	A European-wide area frame survey for the provision of coherent and harmonised statistics on land use and land cover in the EU Member States. On a register of points, specific surveys on soil and vegetation are carried out.	European Commission 2013, Paracchini 2013
Quantification of Ecological Services for Sustainable Agriculture (QuESSA) project	The project aims to quantify the crucial semi-natural habitats providing essential ecosystem services across economically important cropping systems, farming intensities and four European agro-climatic zones	Holland et al. 2014
Study on floral diversity of arable land across Europe	Vegetation comparisons of arable fields in different regions from South Italy to Norway	Hoffmann 2012

- Mapping of area plots of 500 m x 500 m (25 ha) each, where the single plots represent the optimum ratio between the time required for visiting and recording the plots and the covered area and number of plots. The mapping comprises all agriculturally used habitats and fallow land as well as all kinds of landscape elements; thus, the type, extent and quality of land use and landscape elements were recorded. The AGRIT approach in Italy (Tropea et al. 2012) and the HNV farmland monitoring approach in Germany (Benzler 2012) use such a kind of sample plot mapping.
- Recording of detailed vegetation parameters at up to four predefined points within each plot using a transect method; thus, detailed biodiversity parameters are recorded with a standardised methodology. This transect method for assessing the ecological quality (by the means of recording key species and other parameters, e.g. vigour of vegetation has been applied e.g. in France (Mestelan et al. 2010), in Switzerland (Oppermann and Gujer 2003) and in Germany (Benzler 2012).
- In addition, photo documentation is carried out in order to be able to verify the records and to compare the pictures in later surveys (monitoring). The photo documentation comprises photos of each transect in both directions (thus up to 4 transects in each plot with at least 2 photos per transect) and 1-2 overall photos from the whole plot. Initially also further photos of landscape elements and different land use situations were taken; however, this resulted in enormous photo collections (data space) with unclear further application.

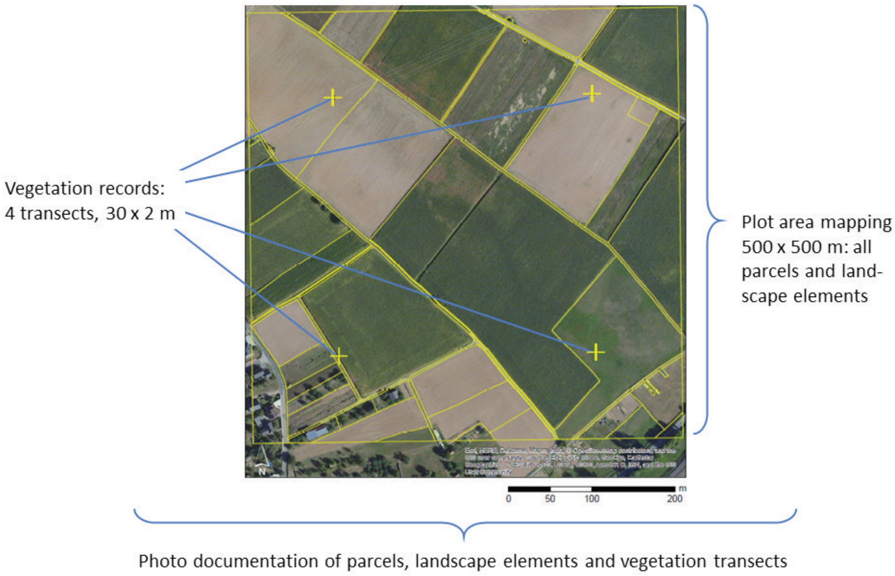

Figure 1. The three elements of the monitoring design: plot area mapping on a square of 500 m x 500 m, 4 vegetation transects and photo documentation. The identification points for the vegetation transects are situated at 100 m distance from the nearest edge lines of the plot. The photo documentation comprised photos of the transects and at least one overall plot photo as well as further photos of parcels and landscape elements (see text).

The monitoring methodology consists of these three elements (Figure 1). A corresponding survey manual was developed (link to the LISA study and survey methodology (April 2016): http://www.ifab-mannheim.de/links_download.html). The pilot investigations comprised 25 plots in each survey region and up to 4 vegetation transects of 30 m length and 2 m width in each plot (thus up to 100 vegetation transects per survey region). In the following, the elements of the survey are described in detail.

2.3 Area Mapping

In each participating country, study regions of about 500-1000 km² were selected. The regions were not selected to be representative for the countries but were intended to cover intensive as well as extensive areas both in arable and grassland regions for testing the methodology under different conditions. To identify intensive and extensive land use existing pre-information on average yields in cereals and milk as well as personal judgements of the partners in the participating countries were used (Table S3). For a roll-out of the methodology, of course, a stratified sampling design is necessary (see chapter 4).

In each of the selected regions, study plots were selected by placing a regular 5 km grid on the region. From the plots on the grid, all 25 neighbouring plots were selected in each region using the minimum criterium “at least 10% of open land/agricultural land” (thus only the plots were excluded that showed more than 90% forests, settlements or another non-agricultural land. The study plots have a size of 25 ha (500 m × 500 m). Within each study plot, all land cover types and landscape elements were mapped in the field and subsequently digitalised using GIS (for the full list of mapped land cover elements see Table S1). The mapping of parcels and landscape elements was done on printed satellite maps and data were recorded in the “main sheet” of the survey protocol (Table 2a). A specific recording of vegetation was done in four transects in each plot – see the following chapter 2.4 and Table 3.

The mapping also included a qualitative assessment of nature value and land use intensity of each parcel (Table 2b and 2c) and each landscape element based on a scale from 1 to 5 (Table 2d) and a specific guidance document (see link to the manual: http://www.ifab-mannheim.de/links_download.html). Forests, urban areas, large water bodies or wetlands were recorded as non-farmland elements. Coverage of land cover types, the extent of areas of different ecological value and landscape elements were calculated using ArcGIS software (ESRI 2011). Table 2 shows an overview of the collected information on the main

Table 2a. Overview of parameters collected in the main sheet.

Parameter	Description
Main sheet	
Land cover	Coding of land cover according to the classification in a code list (Table S1). The following main categories were used, which were divided in several subcategories • Arable • Fallow land/set-aside • Grassland • Shrubland • Landscape elements • Non-agricultural elements
Land use intensity	Coding of the land use intensity for arable land, grassland, and buffer strips. Land use intensity was estimated in 5 classes, based on structure and density of the stand from very extensive land use to very intensive land use; further description see Table 2b
Nature value	Coding of the nature value of each mapped element (both – parcels and landscape elements). The nature value was estimated in 5 classes based on biodiversity and structural parameters from very low nature value to very high nature value. Descriptions for different land cover types and landscape elements and their nature value were provided in the manual. For examples see Table 2c and 2d
Width	The width of linear and punctual elements with a width of ≥ 1 m and < 10 m was recorded in the field. For elements with heterogeneous widths, the average width was estimated. Elements with a width < 1 m were added to the neighbouring element
Length	The length of linear elements was recorded only for elements shorter than 10 m. For longer elements length was calculated using ArcGIS
Ecological impact / sensitivity	Coding of ecological impact of a certain land-use on an area / on an element: soil erosion, danger of water pollution, flooding, arable use of bog soils or herbicide (dead plants, chlorosis) and fertilizer drift (occurrence of nitrophytic plants); in the manual three impact levels are described for each impact type
Habitat type	Coding of the habitat type in case an element could be attributed to a habitat type according to the Habitats Directive (European Council 1992a)
Plot nature value	The estimation of nature value of the whole 25 ha plot was recorded as a summarising view of the surveyor based on different criteria regarding the composition and extent of units with different nature values. Thus, a plot comprising mainly parcels and elements with high nature value received a high plot nature value
General judgement	A personal judgement of the surveyor on the overall land use intensity and biodiversity of the investigation plot was given with verbal comments

Table 2b. Description of the land use intensity for arable land, grassland and buffer strips.

Land use intensity	Coding of the land use intensity for arable land, grassland, and buffer strips. Land use intensity was estimated in 5 classes, based on structure and density of the stand from very extensive land use to very intensive land use.		
class	arable land	grassland	buffer strips
1: very extensive	very light/ sparse growth	Irregularly cut/grazed	mulched/mown irregularly
2: rather extensive	light growth	0-1 cut per year/grazed 1(-2) times per year	mulched/mown 0-1 times a year
3: medium	medium light/ dense growth	2 cuts per year/permanent pasture	mulched/mown ≥ 1 time a year
4: rather intensive	dense growth	(2 -) 3 cuts per year/pastured often	mulched/mown ≥ 2 times a year
5: very intensive	very dense, mass growth	4 – 7 cuts per year/pastured very often	mulched/mown ≥ 3 times a year

Table 2c. Description of the nature value for arable land and grassland.

Nature value	Coding of the nature value of each mapped element (both – parcels and landscape elements). The nature value was estimated in 5 classes based on biodiversity and structural parameters from very low nature value to very high nature value (see following example). Example nature value of arable land/grassland: The classification also allows intermediate steps, thus the values of 1.5, 2.5, 3.5 and 4.5.	
Class	Arable land	Grassland
1	hardly any segetal plant species	mostly fertilised, intensively managed meadow or pasture without or with hardly any species which characterise species rich plant communities that are typical for this site
2	few segetal plants occur with a very low coverage	few characteristic flower species occur but the meadow / pasture is dominated by only a few grass species
3	some segetal plants are present	meadow or pasture is characterised by some typical species of extensive land use, but other typical species are missing. Moreover, the structure of the vegetation is either too dense (due to fertiliser input) or too sparse (due to overuse e.g. by cattle or goats)
4	a considerable number of segetal plants species are present in at least some larger parts of the field	many characteristic flower species occur and the vegetation is typical for an extensive land use on this site, but there are considerable parts of the parcel which are characterised by less species richness or by other signs of over- or under-use
5	many segetal plant species occur in more or less the whole field without considerably dominating and affecting the crop and the structure of the field	The grassland is rich in species and the plant composition of the vegetation of the whole parcel is typical for extensive land use

Table 2d. Description of the nature value for one type of landscape elements (field roads and tracks).

Nature value	Coding of the nature value of each landscape element. Example nature value for field roads and tracks; The classification also allows intermediate steps, thus the values of 1.5, 2.5, 3.5 and 4.5.
Class	Characterisation
1	asphalt tracks
2	pure gravel-tracks/paved asphalt tracks with a grass strip in the middle
3	dirt or gravel tracks with a simple grass or grass/herb strip in the middle or species-poor grass tracks (very obvious track function)
4	dirt tracks with a species rich grass/herb strip or medium species-rich grass tracks, sometimes small structures or wet patches occur
5	very valuable track structures, very species rich and at least 5 m in width, sunken roads or also pure dirt and grass tracks with a width of at least 10 m; small structures such as earth embankments or wet patches are present

sheet of the protocol. In 2016, digitized field maps were provided with the mapped parcels within the plots from 2014 and with the parcel IDs. On these maps, only the changes were recorded in 2016.

2.4 Vegetation records in transects

For recording detailed biodiversity indicators, we used the method of vegetation transects (e.g. Oppermann and Briemle 2002, Russi et al. 2016). In each 25 ha plot, four points were pre-selected in the four corners of the plot at 100 m distance from the next two edge lines of the plot (Figure 1). These pre-selected points determined the parcels and starting points for the vegetation transects. In order not to damage the crop and to advance more rapidly, transects were done from a starting point at 10 m distance to the closest parcel edge from the pre-selected point.

In total, up to 100 vegetation transects were done in each region (25 plots with each 4 transects), low-

Figure 2a)-c). Three examples of cereal fields with different types of vigour and different numbers of flowering plants: a) Spain – characteristic are indicator species (e.g. Poppy - *Papaver spec.*) and a medium- sparse type of vigour (light – sparse growth), b) same region in Spain – fewer indicator species, medium type of vigour and c) Poland – no indicator species, dense type of vigour; these parameters are very important for recording the vegetation in arable fields (and in grasslands) (Photos: IFAB).

er numbers of vegetation transects were performed when one or more points in the plots fell in forests, in human settlements or when the pre-selected points fell in the same parcel (large-scale landscapes).

Vegetation transects had a length of 30 m and a width of 2 m each (60 m^2). Surveyors had to head north to walk the transect (if this direction was not possible there are rules how to shift the transect or its direction). Data were collected in a "vegetation sheet", with a defined set of parameters for both arable land and grassland transects (see Table 3 and vegetation sheets in the manual). The parameters recorded referred to the structure of the crop or grassland (e.g. type and height of the crop, growth stage, coverage in arable land, vigour, height of vegetation strata, shrub cover in grassland) and to the vegetation biodiversity (indicator species and flowering plants, coverage of crops and wild plants) (Table 3, Figure 2a)-c)).

The list of indicator species comprise characteristic and easily identifiable native arable and grassland plants species or species groups indicating ecological conditions (see Table S2). The lists of indicator species were based on findings that certain indicator plant species are reliably correlated with total number of plant species or certain habitat types (Duelli and Obrist 2003; Matzdorf et al. 2008). The lists were compiled from different approaches e.g. from species-rich grassland agri-environmental schemes (AES in France, Germany and Switzerland) since the year 2001 (Oppermann and Gujer 2003; Mestelan et al 2010) and from vegetation analysis of forb species in arable land (Hoffmann 2012a; 2012b). Moreover, all the involved experts from different European countries with their specific geographical and botanical background were asked to complete the list before the start of the surveys in 2014 and 2016. The species/species groups should be easily recognisable, quite abundant and have an indicator value for extensive land use (Keenleyside et al. 2014). As there doesn't exist systematic research on the indicator value of plant species across Europe the work started based on the mentioned grassland lists from AES and experience knowledge of the involved persons as an explorative approach. Thus in 2014, two lists of 97 species/species groups each for arable land and grassland were developed and tested. In 2016, the comprehensive lists were reduced by deleting those species that had not been recorded in 2014 or which occurred only once. The arable indicator species list in 2016 comprised 40 species/species groups, the grassland indicator species list comprised 61 species/species groups (for full list of indicator species see Table S2). This is the first application of the same indicator species method in many European countries.

The purpose of developing and applying a unique European list of indicator species for arable land and for grassland was to make sure that in all countries and regions the same species and species groups were recorded. An evaluation of which indicator species are really suitable in which region as "key species" and how many indicator species are necessary as threshold for defining species-rich habitats should be worked out separately.

Table 3. Overview of parameters collected in the vegetation sheets.

Vegetation sheets: general parameters for arable land and grassland	
Exposition / inclination of slope	Exposition is noted as direction of the slope; inclination is classified from 1 (0-2°, flat) to 5 (≥35°, steep slope)
From main sheet	Different parameter: land use intensity, nature value, habitat type, ecological impact / sensitivity
Number of actually flowering plants	Total number of flowering insect-pollinated non-crop plant species (excluding grasses and sedges)
Actual flower density	Visual impression of the density of flowering insect-pollinated non-crop plant species on a scale from 1 (no or only few flowers) to 5 (dense flower carpet/high density)
Number of indicator species	Number of present indicator species/species groups from the list for arable land and grassland (see Table S2)
Dominant species	Dominant species with ≥ 25% coverage are noted
Vegetation sheet: arable land	
Specified crop type, e.g. rye, wheat etc. according to the list with land cover codes	
Height measured in [cm] and crop stage from 0 to 9 according to principal growth stages of the BBCH scale	
Coverage of vegetation (%), coverage of crop (%) / type of vigour, coverage of wild plants (%)	
Vegetation sheet: grassland	
Actual use of the grassland parcel is noted: pasture, meadow, abandoned; further, type of shrub coverage from 0 (no shrubs) to 4 (shrubs and bushes on > 60% of the parcel)	
Height measured in [cm] beginning from highest down to lowest strata	
Type of vigour: Vigour is measured from 1 (very meagre, sparse growth) to 5 (very dense, mass growth), including intermediary steps	

2.5 Photo documentation

For documentation and monitoring purposes digital photos were taken from the plot (overview photos), from the vegetation transects and from each landscape element. The photos were recorded with GPS coordinates in order to be able to check the situation in later monitoring years. The photos not only provide valuable monitoring information, they also provide informative landscape pictures of each survey region and help in the interpretation of landscape and vegetation changes. Examples of the photo documentation are shown in Figure 2.

2.6 Guidance and performance of the survey

All surveyors received a detailed guidance booklet with the description of the parameters and the methodology. In 2014, a supervisor did a field training of 1-2 days with the surveyors providing an introduction, a common understanding of the manual, exercising mapping and recording and to clarifying questions.

On average, at least ½-1 hour in the field was necessary for the mapping of one plot by an experienced surveyor, depending on the complexity or heterogeneity of the landscape. The transect walks needed 5-15 minutes for each transect depending on the species-richness of the vegetation and all four transect records took on average ½-1 hour per study plot. Hence, the time needed for one plot in total was at least 1-2 hours. Thus, up to 5 plots could be completed per surveyor in one day in dominantly homogeneous agricultural landscapes. However, small-scale, complex landscapes needed more time, because large numbers of parcels and / or landscape elements had to be recorded and mapped. For the access to the survey plot about 10-30 minutes for each plot have to be added to the survey time.

3 Results

Using the methodology, we monitored a total of 805 plots of 25 ha in 35 regions in 10 EU countries in 2014. In 2016, 13 regions in 6 countries out of the 35 regions from 2014 were re-assessed to test for an adapted survey methodology and to obtain comparable monitoring data (Figure 3).

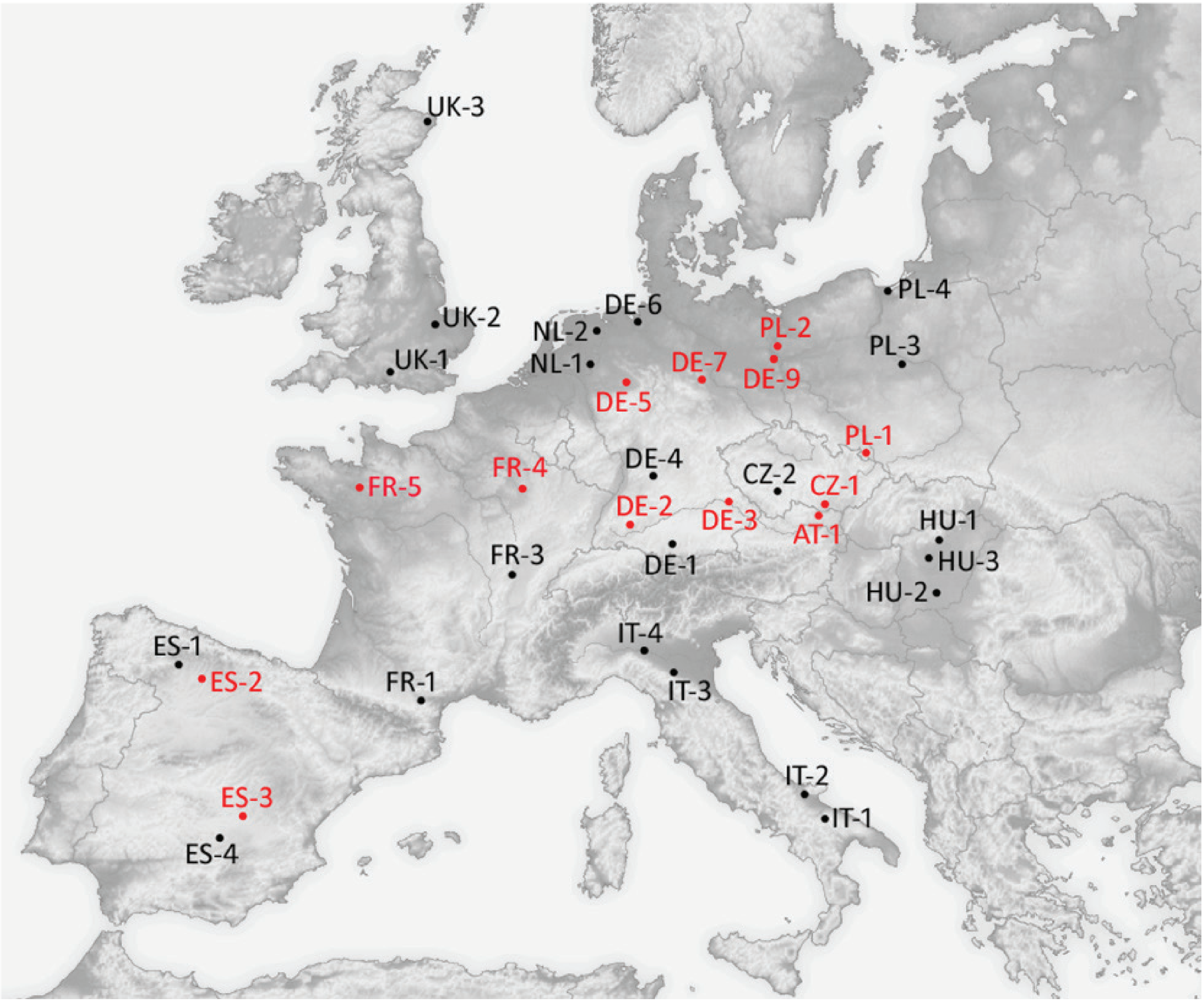

Figure 3. Map showing the study regions in 2014 and 2016 (regions re-assessed in 2016 in red). Own map based on the „Europe topography map“ by San Jose - License under CC BY-SA 3.0 Wikimedia Commons. The points locate the pilot regions (e.g. four regions in Spain ES-1, ES-2,.., ES-4; all points (red and black) indicate the 35 pilot regions assessed in 2014; the regions indicated with red points and red letters were re-assessed in 2016 while the black regions were only assessed in 2014)

In the following, we present some data from 2014 with the wide range of covered regions and some data from 2016 for parameters for which we improved the methodology.

3.1 Land use and landscape structure

The majority of the 35 regions were dominated by arable habitats (24 regions); three regions were dominated by grasslands and eight regions had a mixed land use structure (Figure 4). There was considerable variation in coverage and structure of landscape elements between the regions. The average coverage of landscape elements across all regions was 4.8%, ranging between 1.5 and 15% per study region (Figure 5). The most common landscape elements were complex elements (e.g. hedges, grassy buffer strips and/or ditches; covering 1.6% of farmed landscape). The coverage of buffer strips was very low in most study regions and did not exceed 1% in any of the regions.

3.2 Biodiversity indicators

As biodiversity indicators for the species richness, the number of indicator species and the number of

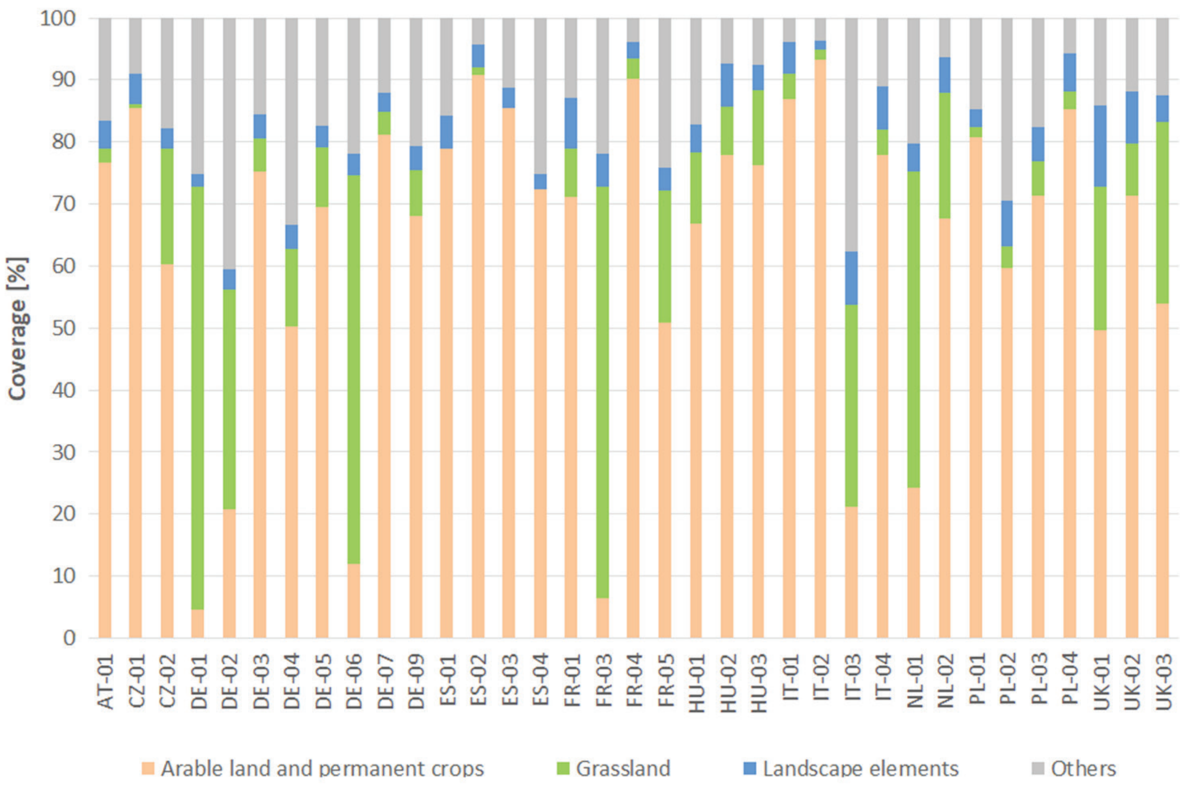

Figure 4. The coverage of main land cover types (%) in 35 studied EU farmland regions in 2014.

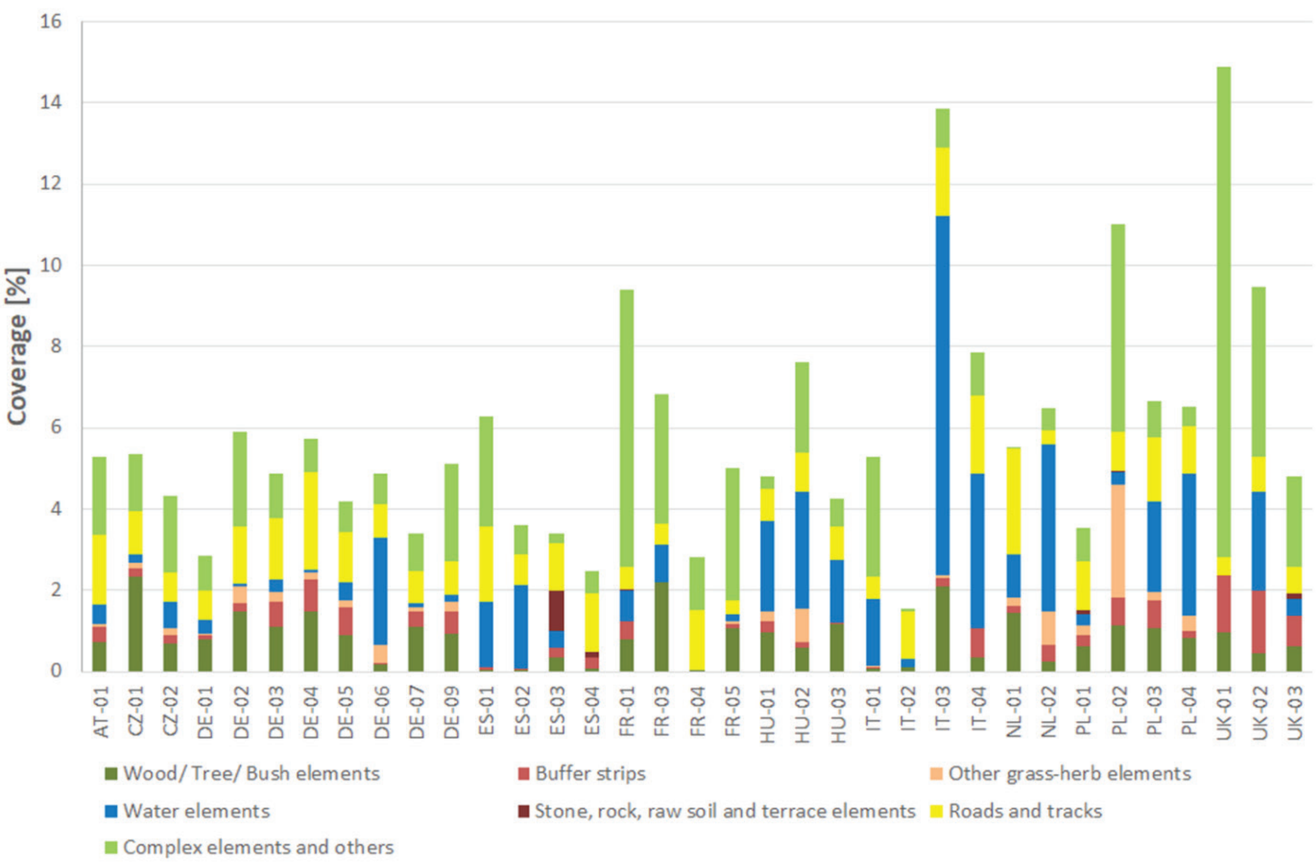

Figure 5. The coverage of different landscape elements (%) in 35 studied EU farmland regions in 2014. The figure shows both the extent and the composition of landscape element types which vary considerably across the investigated regions; thus the typical composition of landscape structure is detectable.

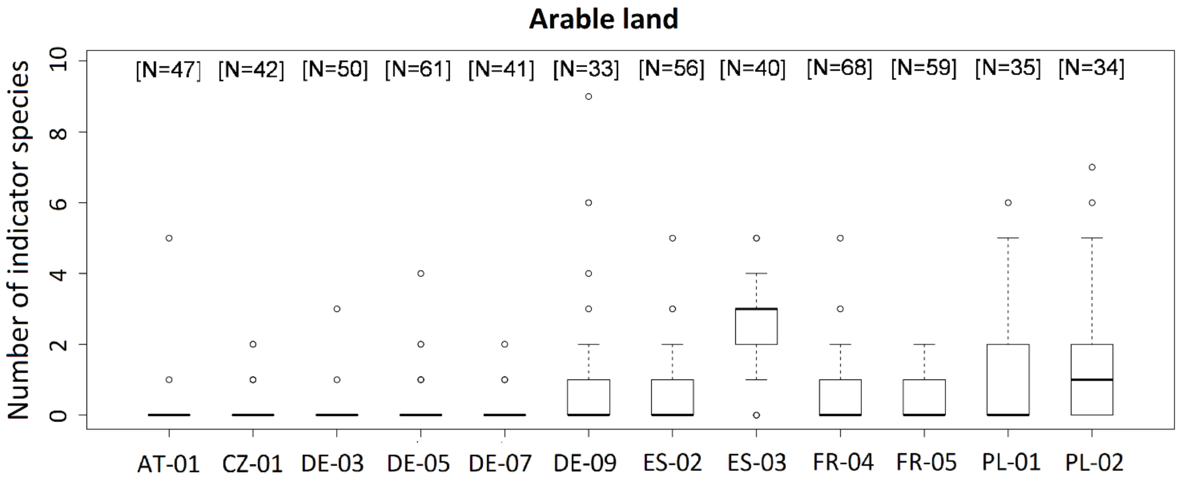

Figure 6. Number of indicator species in arable habitats in the 12 dominantly arable regions in 2016. Graph shows box whisker plots with medians, 25% quantiles, 75% quantiles, the lowest and highest data points still within 1.5 interquartile range and the extremes.

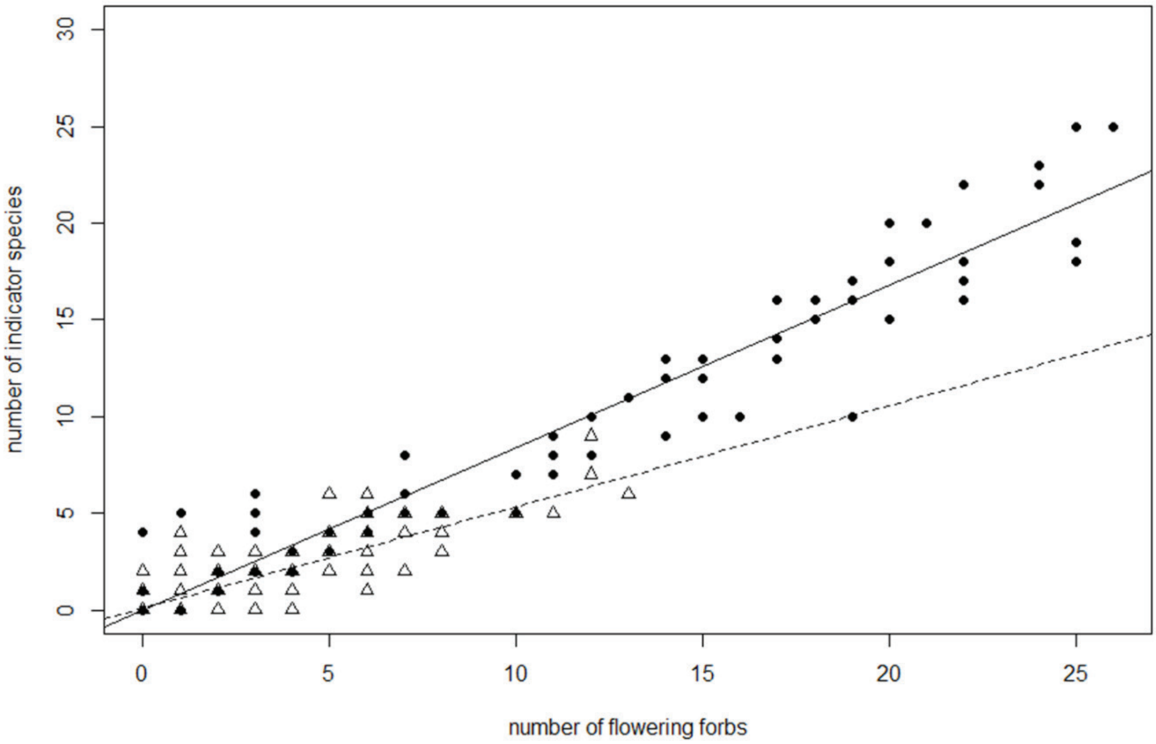

Figure 7. Relationship between the number of flowering forbs and the number of indicator species in arable land (triangles, dashed line) and grassland (filled circles, solid line) – data from 2016 (N = 615 arable and N = 67 grassland transects).

flowering forb species were recorded. The number of indicator species in most arable fields was very low (in average near to zero) in almost all surveyed regions. The lowest numbers were found in central and western European arable regions (AT, CZ, DE, FR) but also in the eastern and southern European regions (PL, IT, ES) the numbers were low (Figure 6). The only exception was region ES-03 (Spain) where the average and the median number of indicator species were higher than two species.

An additional biodiversity parameter was the number of currently flowering forb species (e.g. flowering plant species excluding ferns, graminoids and sedges) without identifying the species. The number of flowering forb species reached up to 9 species in arable transects and up to 25 species in grassland transects.

The indicator species numbers were highly correlated with the number of flowering forbs values both for arable land and for grassland (Figure 7).

3.3 Extent of farmland with high ecological value

One parameter for the ecological value of farmland is the number of indicator species and the percentage of transects rich in indicator species (Figure 8). Additionally, landscape elements also form an important part of the ecological value of the agricultural landscape. Based on the mapping of landscape elements and the recording of indicator species in transects, a synthesis of the extent of farmland with high ecological value can be done. Figure 9 shows this synthesis for the arable regions investigated in 2016 by summing up the percentage of landscape elements with a medium to very high nature value (nature values 3-5 on a scale from 1 to 5) and the percentage of arable land with at least 4 indicator species. The graph shows an extremely low extent of farmland with high ecological value of mostly less than 5% of the farmland, and only 4 regions (of 13 arable regions with sufficient data) showed an extent of more than 10% farmland with high ecological value.

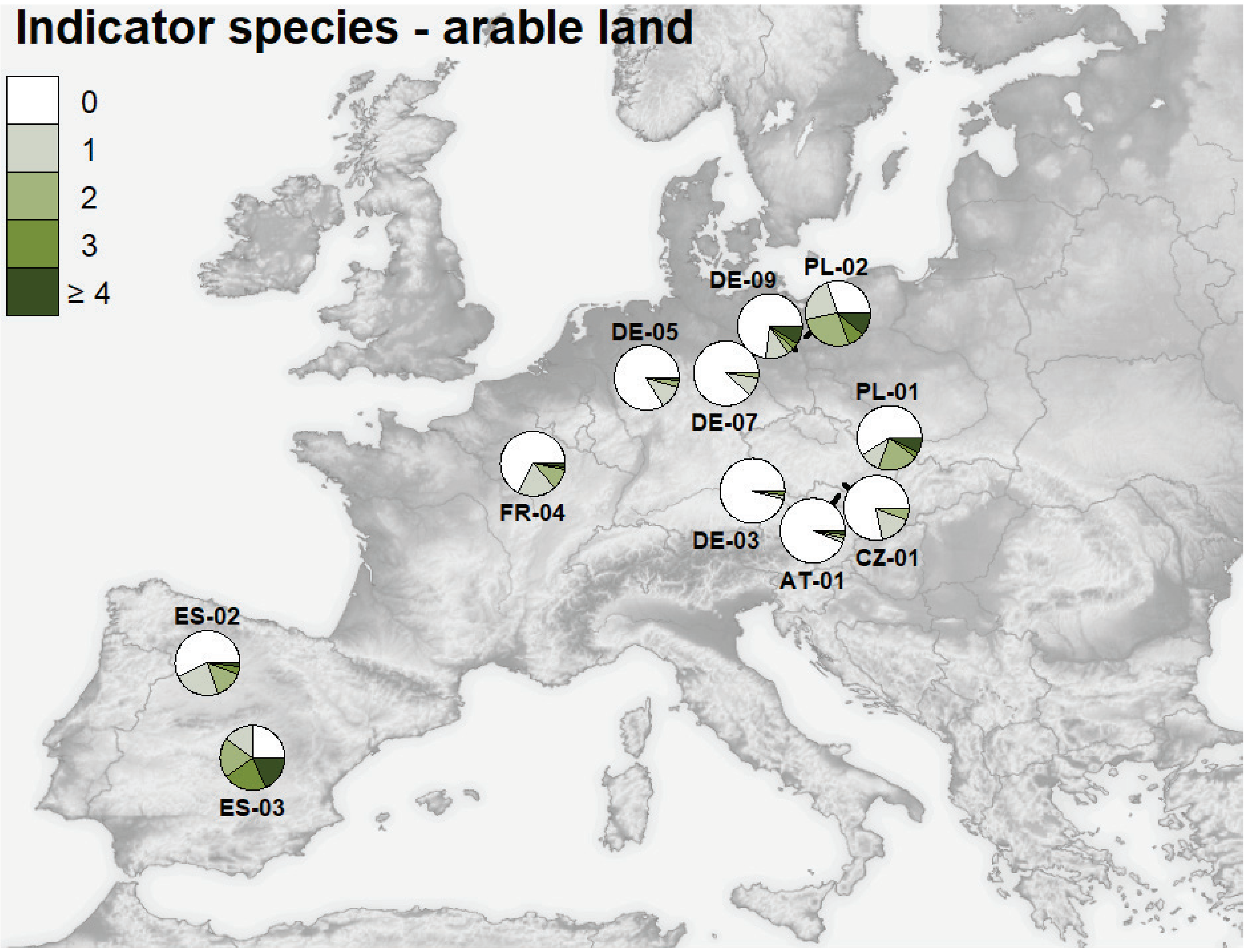

Figure 8. Percentage of transects with different numbers of arable indicator species in dominantly arable regions in 2016. The map shows the percentage of transects with 0, 1, 2, 3 and ≥ 4 indicator species.

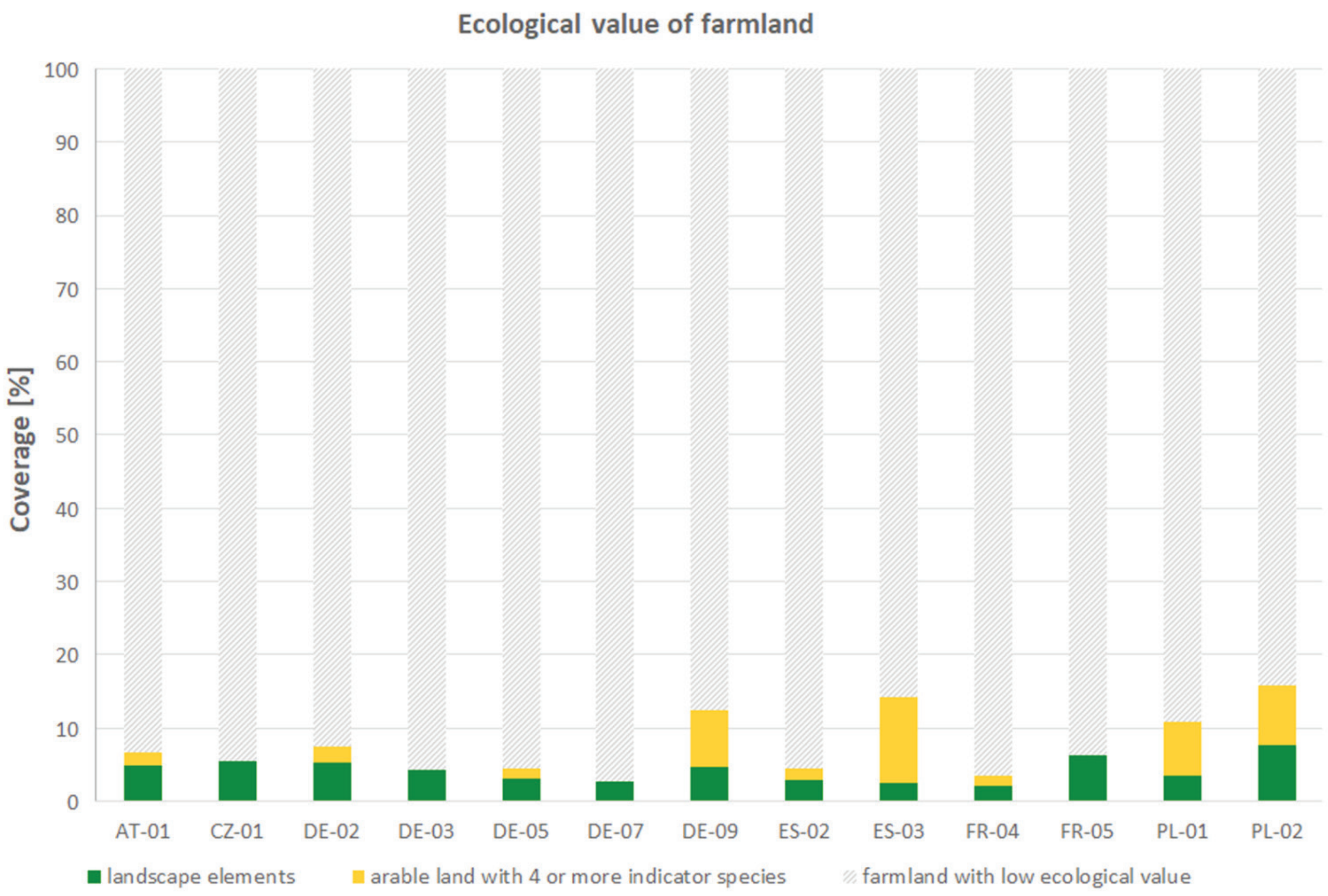

Figure 9. Extent of farmland with high ecological value in some arable regions in 2016: landscape elements including buffer strips and arable land with four indicator species.

4 Discussion

4.1 Methodological approach and indicator species

There are a number of challenges when setting up a biodiversity monitoring at the European scale, of which some have already been addressed in previous research (e.g. Lomba et al. 2014; Herzog and Franklin 2016): i) the choice of the adequate spatial and temporal resolution scale, ii) the training and coordination of field surveyors and iii) the need for a thorough quality control of recorded data.

Regarding the applicability of the methodology, the trials in 2014 and 2016 showed that in general, our rapid survey approach was successfully applied in a wide range of European farmlands. An important issue for the application of the method (and similar approaches) is the training of the field surveyors in the field. We experienced that the trainings that we gave in the field at the beginning of the surveys were very important: i) for the common understanding of the methodology, ii) for practical issues of the mapping (e.g. how to proceed with landscape elements of irregular shape, how to deal with very small parcels), iii) to gain insights into different conditions in different natural regions and iv) for establishing good personal contact with the surveyors for more effective communication. Regarding the surveyors' skills, fundamental botanical knowledge is required to carry out the surveys and receive reliable results. Furthermore, it turned out that the surveyor trainings in the field are crucial to achieve a common understanding of the methodology.

In order to obtain robust data, a sufficient number of sample plots and vegetation transects as well as a yearly monitoring are essential to level out short-term effects such as crop rotation or weather, and monitor long-term trends and changes, being sensitive enough to pick up meaningful differences in habitat quality and extent. However, the number of plots and the number of vegetation transects can be varied according to the desired accuracy for a monitoring.

Another interesting outcome of the project is the list of indicator species. As mentioned before, there are several agri-environmental schemes and grassland evaluations already operating quite successfully with indicator species (Oppermann and Gujer 2003; Matzdorf et al. 2008; Mestelan et al. 2010; Keenleyside et al. 2014). In this approach, we applied a European list of species for the first time for both grassland and for arable land. However, we did not define a threshold for species-rich grasslands and arable land, nor did we apply different regional species lists, although the species composition of e.g. dry boreal grasslands is quite different from that of Mediterranean grasslands (Vrahnakis et al. 2013). In general, the lists of indicator species need further development and a larger number of records in order to improve the representativeness. While for grasslands such an investigation has been undertaken in the last years (Sutcliffe et al. 2019) for arable land such an extended pilot investigation across arable land in many European countries should be encouraged. Working with lists of indicator species always have the weakness that indicator species only reflect a limited number of the whole species composition and thus are incomplete and reduce the accuracy compared to complete vegetation records. However, the trade-off is the short time required for recording the indicator species versus doing full vegetation records. A possibility to compensate between both approaches is to do full vegetation records on a limited number of transects in addition to the transect records with indicator species (e.g., on 5, 10 or 20 % of the transects).

Other limitations of the approach are missing faunistic data, unknown data on fertiliser input and plant protection product application and some rough estimation methods, especially regarding the land use intensity and the nature value. Regarding the missing data it must be stated that the LISA approach is an approach which provides basic ecological data and can be "upgraded" with further data, however, with an extra effort. Regarding the estimation methods it is planned to develop further systematic approaches for some of the parameters such as in the European EMBAL approach (IFAB 2018).

The survey data shows a comprehensive and comparable view of the ecological situation of 35 regions in 10 countries. When starting the survey in 2014, we expected farmland biodiversity in Central Europe to be low and in Eastern and Southern countries to be substantially higher. These expectations were confirmed, however, showing a weak trend: in most of the eastern and southern European study regions the arable biodiversity was also very low. The low species numbers reflect the intensive agricultural management of almost all arable land with use of pesticides and fertilisers resulting in dramatic loss of arable plants across Europe (Meyer et al. 2013). With the methods applied – recording landscape elements as well as indicator plant species – we could draw a differentiated picture of the extent of HNV farmland in different study regions. Such an approach would enable a comparable view on HNV farmland in contrast to the different individual approaches applied in the European Union in the last few years (Pepiette et al. 2012).

4.2 Evaluation of the Common Agricultural Policy

The changes in agricultural management, land use and policy measures lead to reactions of e.g. farmland birds and need dedicated evaluation (e.g. Gamero et al. 2017, Oppermann et al. 2020). There are different instruments of the CAP such as agri-environmental measures, greening (e.g. requirement of implementing EFAs as explicitly directed 'to safeguard and improve biodiversity on farms'), or CAP instruments in general that need to be monitored in order to gain clear evidence on the effectiveness of the policy – by measuring the quality and the extent of the effects induced through the political instruments and the financial budget behind these instruments.

Evidence resulting from this kind of monitoring helps policy development if there are clear results from an annual monitoring of at least four years before the next policy cycle will be started. Substantial and noticeable changes in the CAP are urgently needed to halt the loss and to improve the situation of biodiversity (Pe'er et al. 2014; 2017; 2019). This ecological monitoring is not only important for the Common

Agricultural Policy on European level but also important to better inform other biodiversity related-policies on regional, national and EU-level.

4.3 Further development and implementation

As stated earlier, there is an urgent need for a regular monitoring of ecological data across Europe. On the one hand, there is a European HNV (High Nature Value) farmland-indicator (Paracchini and Capitani 2012) which in practice is mainly based on nearly unvarying information (e.g. borders of nature reserves) in many countries (Peppiette et al. 2012), and on the other hand, there is a European LUCAS approach, which is based on point related statistical information (Eurostat 2018). Between these two approaches, there is a gap for an annual in-field survey, which combines area mapping and detailed information - the LISA-approach could fill the gap with an area mapping and a recording of the ecological quality of agricultural landscapes. Thus, also the extent of farmland with high ecological value (the major part of HNV farmland) can be recorded and monitored as the sum of arable land and grassland with a high number of indicator species (i.e. species-rich farmland) and landscape elements of high nature value (Peppiette et al. 2012; Benzler et al. 2015).

To develop such a European monitoring approach, the European Commission launched the project EMBAL ("European Monitoring of Biodiversity in Agricultural Landscapes") in 2017 (IFAB 2018). Elements of the High Nature Value (HNV) farmland indicator (Peppiette et al. 2012), the LISA approach (IFAB 2015/2017) and other approaches in Europe (Herzog et al. 2012) were included in the new EMBAL approach and a manual was drafted and agreed on European level. However, there is the need to proceed with the next steps for the concrete European-wide implementation. For example, a stratified sampling design is a critical prerequisite for analysing the status and trends in ecological indicators across large and environmentally heterogeneous regions (Jongman et al. 2006; Metzger et al. 2013). For a long-term monitoring of the extent and ecological quality of European farmland, also a good statistical design of the monitoring program is a critical component (Lindenmayer and Likens 2010). Some further information for designing the monitoring scheme is given by Herzog and Franklin (2016).

Further issues that need improvement are the estimation methods and scales for some of the parameters (e.g., clearly scaled singular parameters instead of composed parameters for the parameter "nature value", and a 9-part scale instead of a 5-part scale for parameters such as vigour and flower density), a practical field app for entering the data directly in the field (thus avoiding transcription mistakes) and an improved classification of the habitat type record (suitable to record the habitat type on a comparable level throughout Europe). Thus, the LISA approach presented in this paper already provides much ecological information and is suitable to do a landscape monitoring from local and regional level up to the European level, however, there are still issues to be improved. Most of them have been and will be picked up during further work on EMBAL (IFAB 2018, EFTAS et al. 2021).

5 Conclusions

The approach has proved its suitability as a rapid inventory method for recording the extent and quality of the ecological infrastructure and biodiversity indicators across different types of European farmland. In the context of the dramatic decline of farmland biodiversity in recent decades, this information is useful to provide an example of an approach that can give an overview of the current ecological state of European farmland. The three-fold approach with i) an area survey (mapping of land use and ecological parameters related to the land use on parcel level), ii) a vegetation survey based on transect records of indicator species and other vegetation parameters and iii) a photo documentation delivers a multitude of results that can be used for agricultural and environmental policy and related policy instruments, for monitoring, for statistics and for information for the public on the ecological state of the farmed landscape.

Regarding some specific results the survey data demonstrated the low biodiversity of European arable farmlands in terms of the extent of landscape elements and the number of indicator species in almost all surveyed regions. As dominant parts of the arable agricultural landscapes have this low biodiversity we suggest that biodiversity, as well as the ecosystem services (e.g. pollination) of the arable fields themselves need to be considered in future agri-environment related policy not only measures in a few strips beside the fields.

For the future it is important to set-up a European monitoring system of biodiversity in agricultural landscapes. The presented approach and some further development can help to develop such a European monitoring system. The combination of area-related mapping data and point-related accurate biodiversity data, all recorded on an annual basis, would help to better inform the biodiversity-related policies, e.g. measures discussed for the future CAP reform or the Biodiversity Strategy in 2020.

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Annex – supplementary material

Table S1. Land cover code list 2016

Landcover-code	Landcover	Category	Code	Specification		
A	Arable land	Non permanent crops	A11	Wheat	A51	Dry pulses
			A13	Barley	A52	Tomatoes
			A14	Rye	A53	Strawberries
			A15	Oats	A54	Other fresh vegetables
			A16	Maize	A61	Clovers
			A17	Rice	A62	Lucerne
			A19	Other cereals	A63	Mixed cereals for fodder
			A21	Potatoes	A64	Sown grass on arable land
			A22	Sugar beet	A65	Grass-Clover-Mixture
			A23	Other root crops	A66	Other Legumes and mixtures for fodder
			A31	Sunflower	A71	Floriculture and ornamental plants
			A32	Rape and turnip seeds	A72	Other non permanent crops
			A33	Soya	A73	arable land without plants (e.g. recently sown)
			A34	Cotton	A74	flower areas and strips
			A35	Other fibre and oleaginous crops		
			A41	Tobacco		
			A42	Other non permanent industrial crops		
		Permanent crops	A81	Apple fruit	A91	Olive groves
			A82	Pear fruit	A92	Vineyards
			A83	Cherry fruit	A93	Nurseries
			A84	Nuts trees	A94	Other permanent crops (including permanent energy crops)
			A85	Oranges		
			A86	Lemons		
			A87	Other fruit trees and berries		
B	Set-aside	Fallow land or set-aside	B11	Managed set-aside		
			B12	Unmanaged set-aside		
			(A74)	Flower areas / strips = A74	1	scattered trees/bushes (coverage < 5%)
C	Grassland	Grassland with sparse tree/shrub cover	C11-	Meadow / hay field	2	open stand of trees/bushes (cov. 5-25%)
			C12-	Grazing land	3	half-open stand of trees/bushes (cov.25-50%)
			C13-	Mowed and grazed grassland / unclear use	4	stand with greater gaps (cov. 50-75%)
		Grassland without tree/shrub cover	C21	Meadow / hay field	5	closed stand of trees/bushes (cov. ≥ 75%)
			C22	Grazing land		
			C23	Mowed and grazed grassland / unclear use	1	scattered trees (coverage < 5%)
		Orchard on grassland/arable land	C31-	Meadow orchard	2	open stand of trees (cov. 5-25%)
			C32-	Pasture orchard	3	half-open stand of trees (cov.25-50%)
			C33-	Arable land with trees	4	stand with greater gaps (cov. 50-75%)
D	Shrubland	Shrubland with sparse tree cover	D11		5	closed stand of trees (cov. ≥ 75%)
		Shrubland without tree cover	D12			
E	Landscape elements	Wood/ Tree/ Bush elements	E11	Solitary trees and small groups of trees/bushes		
			E12	Tree lines and avenues		
			E13	Hedges and bushes (in wet, dry or other locations)		
			E14	Isolated field coppices		
			E15	Wood areas along watercourses		
		Grass-herb elements and reed-sedge beds	E21	Buffer strips (no flower strips, see A74)		
			E22	Ruderal, grass and herbal fields of the open countryside		
			E23	Large and small reed beds		
			E24	Large and small sedge beds		
		Water elements	E31	Springs and spring swamps		
			E32	Small and medium-sized flowing waters (streams, rivers)		
			E33	Ditches (flowing and standing water)		
			E34	Small water bodies (Ponds, ponded depressions, and pools)		
			E35	Oxbow lakes in alluvial plains		
		Stone, rock, raw soil and terrace elements	E41	Cairns, dry stone and natural stone walls		
			E42	Field stone heaps		
			E43	Sand, clay and loess escarpments		
			E44	Isolated rock outcrops		
			E45	Raw soil sites (stone, sand and dirt surfaces with little or no vegetation)		
			E46	Terraces		
		Roads and Tracks	E51	Dirt/gravel track		
			E52	Grass track		
			E53	Paved farm tracks (also asphalt with grass strip)		
			E54	Sunken roads		
		Complex elements and other elements (do not include E21)	E61	Complex elements (> 30m², heterogeneous, including woody and non-woody structures)		
			E62	Man-made structures and artefacts (field barns, machinery sheds, woodpiles, ...)		
			E63	Other landscape elements (please describe)		
		Ditches	E71	Ditches		
N	Non-agricultural elements	Forest	N11	Forest		
			N12	Reforestation area		
		Wetland	N21	Inland marshes		
			N22	Peat bogs		
			N23	Salt marshes		
			N24	Salines		
			N25	Intertidal flats		
		Open water	N31	Large inland water bodies and their banks		
			N32	Large inland running waters and their banks		
			N33	Coastal water bodies and their shores		
		Settlement area and asphalt roads and railways	N41	Buildings / villages and garden areas, official roads and railways inclusive adjacent landscape elements		
		(Former) mining area	N61	mining area or renaturated fomer mining area		
X	Unknown	Not visible	X	not visible		

Table S2. Indicator species in grassland habitats and in arable habitats

Indicator species arable land	**Indicator species grassland**	
Adonis spec.	Families:	
Anagallis spec.	*Apiaceae spec.*	
Anthemis spec.	*Asteraceae* yellow flowers *(Tragopogon spec.* is a separate indicator genera*)*	
Aphanes spec.	*Cyperaceae spec.*	
Calendula arvensis		
Carduus pycnocephalus	Genera / Species:	
Centaurea spec.	*Achillea spec.*	*Mentha spec.*
Chrysanthemum spec.	*Agrimonia eupatoria*	*Myosotis spec.*
Consolida spec.	*Ajuga reptans*	*Onobrychis spec.*
Epilobium spec.	*Alchemilla spec.*	*Orchidaceae spec.*
Erodium cicutarium	*Anthyllis vulneraria*	*Origanum vulgare*
Eryngium campestre	*Caltha palustris*	*Ornithogalum spec.*
Euphorbia spec.	*Campanula spec.*	*Phyteuma spec.*
Filago spec.	*Centaurea spec.*	*Polygala spec.*
Fumaria spec.	*Centaurium spec.*	*Polygonum bistorta*
Galeopsis spec.	*Cerastium arvense*	*Potentilla spec.*
Geranium spec.	*Cirsium spec.*	*Primula spec.*
Lamium spec.	*Coronilla spec.*	*Prunella spec.*
Lapsana communis	*Euphorbia spec.*	*Ranunculus spec.*
Lathyrus spec.	*Euphrasia spec.*	*Rhinanthus spec.*
Legousia spec.	*Filipendula spec.*	*Rumex spec.*
Linaria spec.	*Galium spec.* white flowers	*Salvia spec.*
Lithospermum arvense	*Galium verum*	*Sanguisorba spec.*
Lythrum spec.	*Geranium spec.*	*Scabiosa spec.*
Matricaria spec.	*Geum rivale*	*Silene spec.*
Medicago spec.	*Hypericum spec.*	*Stellaria spec.*
Mentha arvensis	*Juncus spec.*	*Thymus spec.*
Myosotis spec.	*Knautia spec.*	*Tragopogon spec.*
Ornithogalum spec.	*Lathyrus spec.*	*Trifolium spec.* red flowers
Papaver spec.	*Leucanthemum spec.*	*Trifolium spec.* yellow flowers
Ranunculus spec.	*Linum spec.*	*Trifolium spec.* white flowers
Rumex spec.	*Lotus spec.*	*Verbascum spec.*
Silene spec.	*Luzula spec.*	*Vicia spec.*
Spergula arvensis	*Lychnis spec.*	*Viola spec.*
Stachys spec.	*Medicago spec.* blue flowers	
Thlaspi arvense	*Medicago spec.* yellow flowers	
Torilis arvensis		
Trifolium spec.		
Valerianella spec.		
Vicia spec.		

Table S3. Overview of regions surveyed in study (regions re-assessed in 2016 are highlighted in bold). The number of plots in each region is mostly 25, however not in all regions the number of 25 plots could be achieved.

Region (with country code)	**Plots**	**Altitude Ø**	**Biogeographic region**	**Predomi-nant land use**
AT-01-Hollabrunn	**25**	**310**	**continental**	**arable**
CZ-01-Znojemsko	**25**	**324**	**pannonian**	**arable**
CZ-02-Sedlec Pistin	25	566	continental	mixed
DE-01-Kempten	25	677	continental	grassland
DE-02-Albstadt	**25**	**617**	**continental**	**mixed**
DE-03-Straubing	**25**	**457**	**continental**	**arable**
DE-04-Tauberbischofsheim	25	348	continental	arable
DE-05-Soest	25	203	continental	arable
DE-06-Jade	25	9	atlantic	grassland
DE-07-Magdeburg	**25**	**100**	**continental**	**arable**
DE-09-Fuerstenwalde	**25**	**45**	**continental**	**arable**
ES-01-Leon	25	864	mediterranean	arable
ES-02-Palencia	**25**	**799**	**mediterranean**	**arable**
ES-03-Castilia-North	**25**	**749**	**mediterranean**	**arable**
ES-04-Ciudad Real	25	700	mediterranean	arable
FR-01-Carcassone	25	317	mediterranean	arable
FR-03-Bourgogne	24	328	continental	grassland
FR-04-Reims	**25**	**146**	**continental**	**arable**
FR-05-Rennes	**25**	**78**	**atlantic**	**mixed**
HU-01-Heves	25	113	pannonian	arable
HU-02-Abony	25	101	pannonian	arable
HU-03-Békés-Csanád	25	85	pannonian	arable
IT-01-Basilicata	19	468	mediterranean	arable
IT-02-Puglia	19	205	mediterranean	arable
IT-03-Modena	25	507	continental	mixed
IT-04-Parma	24	143	continental	arable
NL-01-Winterswijk	21	37	atlantic	mixed
NL-02-Veendam	21	6	atlantic	mixed
PL-01-Glubczyce	**14**	**294**	**continental**	**arable**
PL-02-Chojna	**25**	**48**	**continental**	**arable**
PL-03-Kutno	12	108	continental	arable
PL-04-Gdansk	13	29	continental	arable
UK-01-Hampshire	25	102	atlantic	mixed
UK-02-Cambridgeshire	26	31	atlantic	arable
UK-03-Aberdeen	12	111	atlantic	mixed
Sum of plots	**805**			