ENVIEVAL

Development and application of new methodological frameworks for the evaluation of environmental impacts of rural development programmes in the EU

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Report D4.2

Report on monitoring and data requirements for micro level methods

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List of Acronyms

CF	Carbon Footprint
CFP	Carbon Footprint of Products
CLC	Corine Land Cover
CMEF	Common Monitoring and Evaluation Framework
FADN	Farm Accountancy Data Network
FBI	Farmland Bird Index
FSS	Farm Structure Survey
FYROM	Former Yugoslav Republic of Macedonia
GHG	GreenHouse Gas
GIS	Geographic Information System
GLM	Generalized Linear Model
GNB	Gross Nutrient Balance
HNV	High Nature Value
IACS	Integrated Administration and Control System
IEA	International Energy Authority
ISO	International Standards Organisation
LPIS	Land Parcel Information System
LULUCF	Land Use, Land Use Change and Forestry
MS	Member State
NUTS	Nomenclature of Territorial Units for Statistics
NVZ	Nitrate Vulnerable Zone
OECD	Organisation for Economic Cooperation and Development
PCA	Principal Component Analysis
RDP	Rural Development Programme
RS	Remote Sensing
SALUS	System Approach to Land Use Sustainability

SAPM	Survey on Agricultural Production Methods
UAA	Utilized Agricultural Area
UNECE	United Nations Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change
WF	Water Footprint

Executive Summary

Based on the findings of the indicator and methodological reviews in WP2 – WP5 and the results of the first stakeholder consultations in WP9, the data requirements for a set of candidate methods and corresponding public goods and indicators have been assessed. This report aims to analyse these data requirements and to summarise the main findings to propose guidelines for the structure of the databases for the case studies from a micro-level perspective. Section 3 provides an overview of the selected method/public good/indicator combinations at micro level. Section 4 starts with a list of key questions to be answered by the assessment and then reports in detail the data requirements for the selected methods, applied to selected CMEF, direct and indirect indicators for each public good, in order to depict clearly the state-of-art of data requirements for RDP assessment at micro level. Thus, each method has been analysed in terms of types of data (primary and secondary), spatial aspects and temporal dimension, data processing, sensitivity, and consequences of data gaps. Section 5 will provide an overview of the key aspects of the data monitoring requirements of the candidate methods. Specifically, Subsection 5.1 assesses the outputs of Section 4 in tables that compare the data requirements for the selected methods for each public good, with respect to data types, level of detail, spatial and temporal dimensions, data processing, applicability in case-study areas and micro/macro linkage. Subsection 5.2 scores the data requirement of Subsection 5.1, assigning four scores that 'weight' the data requirement. A discussion of the related findings and preliminary conclusions are provided in Subsection 5.3, while Section 6 highlights key aspects for the structure of the databases for the case studies from a micro-level perspective. Generally, this report underlines the necessity to acquire more adequate data, database and data sources for the environmental evaluation of RDP at micro level. Micro-level data should be developed in a more consistent and standardised way, targeting an accurate data collection at farm level, in order to provide a detailed overview of the whole farming systems. An emerging question is related to the representativeness of the data collected at farm level. The complexity of active variables within the farming systems necessitates the establishment of a baseline common to European Member States. This complexity also restricts the possibility to assess very specific methodologies in order to reduce uncertainty. Finding methods that ensure representativeness of data is crucial for the future challenges of the ENVIEVAL project.

1 Objectives of the Tasks

Based on the results of the review of the methodologies dealing with environmental impacts at micro level, this report analyses the data requirements of the selected candidate methods which are more suitable with the combination of public goods and case-study areas. Each method has been classified in terms of level and details of data, geographical coverage and sample procedure, quality of data and potential restrictions when data availability is limited.

As partially shown in Figure 2.1, the objectives of the tasks are linked to each other in a way to:

- inform selection of case-study areas in month 11 (for Task 6.1 in WP6), in terms of what kind of data need to be available in the areas to be able to test a method;
- produce guidelines for the structure of the databases in month 12 (for Task 6.2 in WP6);
- compare and classify the data and monitoring requirements;
- inform the development of the logic models (Tasks 3.3, 4.4 and 5.4) and the handbook, and
- select method combinations across WP3 – WP5 for the public good case studies

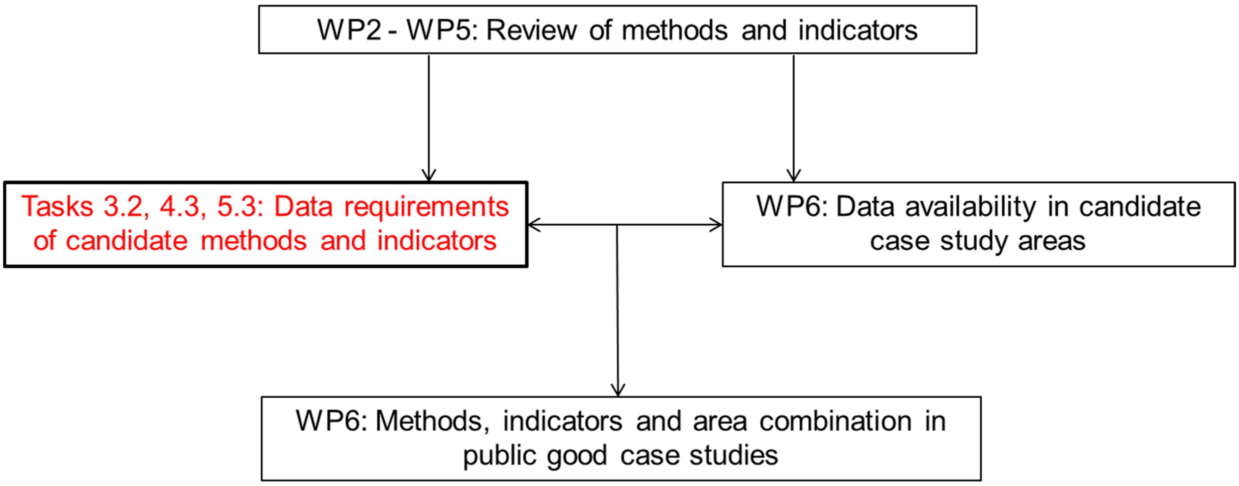

Figure 1 Overview of the different parts of the data assessment

2 Definitions and Identification of Key Dimensions for the Assessment of the Data Requirements

This section provides an overview of the key dimensions to be followed in the assessment of the data requirements of the candidate methods in Section 4 and includes a short glossary of some definitions.

2.1 Definitions

Primary data - Data generated specifically for monitoring and evaluation, e.g. environmental monitoring programmes, surveys of beneficiaries and non-beneficiaries

Secondary data - Data generated and processed for other purposes but of use in the evaluation, e.g. FADN, Census data and IACS

Table 1 Key dimensions

Upper level	Lower level	Comments / explanations
Type of data	Biophysical data	Data that describe/capture the natural components in the agricultural landscape/land (soil, water, habitats, biodiversity and land cover/use)
	Economic data	Data that describe the economic activities in agriculture, including the use of inputs of labour, capital, and goods and services to produce outputs of goods or services, either at farm, regional or national level.
	Social data	Data that describe the characteristics of the land managers and other relevant actors and their decision making
	Policy data	Data that describe the policy measures and programmes (e.g. including payment level, participation / uptake, measure requirements etc.)
Primary data	Sampling strategy	
	Sampling size	
	Data format	
	Data origin	Refers to data source and who (e.g. land managers, policy administration, evaluators etc.) has or needs to collate the data
	Data access	
Secondary data	Sampling size / required data points	
	Data format	Format can refer to spatial and non-spatial databases. In relation to spatial data specifically it refers to raster, polygon, line or point data.
	Data origin	
	Data access	
Spatial dimensions	Scales	'Scale' refers to spatial, temporal, quantitative, or analytical dimensions used to measure and study any phenomenon
	Levels	'Level' refers to locations along a scale as the units of analysis that are located at different positions.
Temporal dimensions	Dates of capture	
	Frequency of observations	
Data processing		The required efforts to transform the type of data suitable for use by/in the methodology

3 Overview of Candidate Methods, Public Good and Indicator Combinations

Based on the findings of the indicator and methodological reviews in WP2 – WP5 and the results of the first stakeholder consultations in WP9, a set of candidate methods and corresponding public goods and indicators has been selected for which the data requirements will be assessed. Table 2 provides an overview of the selected method – public good – indicator combinations at micro level.

Table 2 Overview of the candidate methods and suitable public goods and indicators (WP4)

Method	Public good	CMEF impact indicator (if it exists)	Alternative direct indicator	Alternative indirect indicator
Biophysical model s	Soil functionality	Soil erosion by water (% of UAA affected by certain rate of soil erosion)		Cropping methods (soil cover and tillage methods)
Biophysical models	Soil functionality	Soil organic matter in arable land		Cropping methods (soil cover and tillage methods)
Biophysical models	Water	Water quality (Gross Nutrient Balance for N and P)		
Spatial analysis with geo-statistical approach	Biodiversity (HNV)	Percentage of Utilised Agricultural Area farmed to generate High Nature Value	Habitat connectivity Habitat patch size Vegetation quality index Spatial complexity	
Statistical sampling with Spatial analysis	Biodiversity wildlife	Farmland bird index	Flowering plants of semi-natural habitats Population trends of agriculture related butterfly species	
Statistical sampling with Spatial analysis	Water quality	Water quality (Nitrates in freshwater)		
Statistical sampling with Spatial analysis	Water quality		Pesticide in groundwater/surface water	
Hierarchical models	Biodiversity (HNV)	Percentage of Utilised Agricultural Area farmed to generate High Nature Value	High Natural Value Index (crop diversity index & stocking density index) Vegetation quality index	
Footprint (carbon-)	Climate stability	Emissions from agriculture (GHG emissions from agriculture: 1 CH4, N2O and CO2 including energy use)		Production of renewable energy from agriculture Direct use of energy in agriculture
Footprint (carbon-)	Climate stability	Emissions from agriculture (GHG removal from agriculture: 2 CO2 from LULUCF)		
Footprint (water-)	Water quality	Water quality (Gross Nutrient Balance for N and P)		Fertiliser applications to arable land Nitrogen quantity used per hectare of UAA
Landscape metrics	Landscape	-	Fragmentation of land parcels Habitat patch shape Spatial complexity	

Method	Public good	CMEF impact indicator (if it exists)	Alternative direct indicator	Alternative indirect indicator
Farm survey / Land cover_use survey	Biodiversity (HNV)			% UAA under Natura 2000 (Protected forest) Crop diversity index Conservation status of agricultural habitats (grassland) Farming intensity
Farm survey / Land cover_use survey	Biodiversity wildlife			Stock and Change of linear habitats and biotopes in agricultural landscapes
Farm survey / Land cover_use survey	Water quality	Water abstraction in agriculture		Irrigated area Irrigation technique
Farm survey / Land cover_use survey	Climate stability	Emissions from agriculture (Ammonia emissions from agriculture)		Production of renewable energy from agriculture Direct use of energy in agriculture
Farm survey / Land cover_use survey	Landscape	-		Protection of landscapes and specific natural elements
Mixed method approach (e.g. farm surveys and statistical methods combined with scaling and qualitative methods)	Animal welfare	-	Quality of livestock housing	Grazing area / outdoor access

4 Assessment of the Monitoring and Data Requirements of the Selected Methods

The assessment of monitoring and data requirements at the micro level is a challenging issue on the basis of data, datasets and data sources as provided by EU, Member States and local governments. As Deliverables 4.1 and 5.1 of the ENVIEVAL project have shown, analysis at the micro level is still in its early stages for scholars, practitioners and evaluators, and no public good can be considered at an advanced stage compared to others. In RDP assessment, micro level is mainly represented by the farm level, which is considered as the simplest management unit of agricultural systems. Therefore, the most intuitive way to distinguish between micro and macro level is to consider the individual beneficiaries of RDP from the sectoral and territorial level as a micro-unit of reference on which to apply the concept of 'micro level'. This box provides a list of questions related to the main aspects of data requirements, to identify the key data dimensions relevant for RDP environmental assessment. These questions are the basis of the detailed explanation of data requirements for the selected methods in Section 4, applied to selected CMEF, direct and indirect indicators for each public good to depict clearly the state-of-art of data quality for the RDP assessment at micro level.

1. What types of data are needed (specify what kind of biophysical, economic, social and policy data are needed)?
2. Which of those data types are required as primary data? Specify the type of data and outline required sampling strategy and size, data format and origin and issues in relation to data access.
3. Which of those data types are required as secondary data? Explain the required sampling size or number of data points, data format and origin and issues in relation to data access for each type of data.
4. How does the method incorporate spatial dimensions? At what scales and levels do the data need to be available?
5. How does the method consider temporal dimensions? What are the dates of capture and the frequency of the required data? Does this fit with the temporal dimensions of the evaluation framework?
6. Explain the type and extent of data processing work required to apply the method.
7. Assess the sensitivity of the methods to data quality.
8. Assess the constraints or consequences for the application of the methods if appropriate data are not (fully) available.
9. Other?

4.1 Biophysical Models

Soil Functionality

4.1.1 Soil erosion by water (% of UAA affected by certain rate of soil erosion)

1) Types of data:
    - Area of farmland participating in RDP
    - Area of farmland eligible for RDP measure
    - Land cover (CLC)
    - Land Parcel Information System (LPIS - GIS data)
    - Land use at cadastral level
    - Soils data: Regional Soil Maps
    - Historical raining data
    - Slope (%)
    - Type of farm labour - machinery techniques (extensive or intensive agriculture)
2) Primary data: No primary data are needed
3) Secondary data: The required secondary data are FADN, Census, LIPS data, which require adequate detail to be able to distinguish differences in land use and land cover with the participating and non-participating areas.
4) Spatial aspects: Biophysical models allow for non-spatial and spatial analysis of RDP impacts on soil erosion. The method can be used for the assessment at different spatial levels. It is possible to have information at different levels of detail and using aggregation between the results of detailed assessment. The minimum mappable areas of the data should be at parcel level to have a micro evolution of the phenomena.
5) Temporal dimension: The temporal dimension strictly depends on the frequency of the land cover data. GIS-based data can help to partially overcome the temporal gaps among data.
6) Data processing: Data in raster format can be calculated using ArcGIS or R.
7) Sensitivity to data quality: It may impair the ability to measure the impact of RDP on this public good.
8) Consequences of data gaps: Both the resolution and the extent of the analysis determine the extent of error in the impact assessment.
9) Other:

- Soil Service (if existing) is a very powerful instrument with soil cartography, very important in order to distinguish the soils and uses, knowledge of the soils of the territories, organic matter and erosion (quality indicators) and water.

4.1.2 Cropping methods (soil cover and tillage methods)

1) Types of data:
    - Area of farmland participating in RDP
    - Area of farmland eligible for RDP measure
    - Land cover (CLC)
    - Land Parcel Information System (LPIS - GIS data)
    - Farm data on land use
    - Farm Accountancy Data Network (FADN)
    - Farm Structural Survey (FSS)
2) Primary data: No need for primary data, if a detailed ‘Survey on Agricultural Production Methods’ (SAPM), as part of FSS, is already available.
3) Secondary data: Secondary data are required. They need to be of adequate detail to distinguish land use/cover in participating and non-participating areas. Existing land use/cover data can be used; however the level of detail in the classification will significantly determine the effectiveness of measurement.
4) Spatial aspects: Biophysical methods can be used for the assessment at different spatial levels, either by using different type of resolution (however, due to the data dependency, caution needs to be taken in comparing results of different levels) or by aggregating the results of detailed assessment. The minimum mappable areas of the data should be at least 1 ha raster: this would be suitable for measuring diversity in cropping systems.
5) Temporal dimension: The temporal dimension strictly depends on the frequency of the land-cover data. Remote sensing (RS), aerial photography, and GIS-based data may help to partially overcome the temporal gaps among data.
6) Data processing: Data in raster format can be calculated using ArcGIS.
7) Sensitivity to data quality: It may impair the ability to measure the impact of RDP on this public good.
8) Consequence of data gaps: The resolution and extent of the analysis determine the extent of error in the impact assessment.
9) Other: A significant aspect to be underlined is the data level information. A key issue, that may be common to many MS, is the availability of data at cadastral level. These data are used predominantly to evaluate the farm payment, but have become fundamental for

future and statistical elaboration, and not just for the payment. Furthermore, in many databases, there is a lack of ‘parcel level’ (less than 5-10 ha) data, and this leads to difficulty with the precision of the data.

4.1.3 Soil organic matter in arable land

1) Types of data:
    - Area of farmland participating in RDP
    - Area of farmland eligible for RDP measure
    - Land cover (CLC)
    - Land Parcel Information System (LPIS - GIS data)
    - Land use data: SALUS (System Approach to Land Use Sustainability) program is designed to model soil erosion by water, and the data required are: various crop rotations, planting dates, plant populations, irrigation and fertiliser applications, tillage regimes and climatic data.
2) Primary data: No need for primary data
3) Secondary data: Secondary data are required. They need to be of an adequate detail to distinguish land use/cover in participating and non-participating areas. Existing land use/cover data can be used; however the level of detail in the classification will significantly determine the effectiveness in measuring is present or absent.
4) Spatial aspects: This indicator requires using different data sources. The level of detail is determined by the data with the coarsest resolution. If possible, scaling can be used to bring the data resolution closer together.
5) Temporal dimensions: Land cover, population and infrastructure data are updated on a regular basis; however they may not be updated in line with the timing of the RDP. A possibility is to update the published data with RS data for the RPD period.
6) Data processing: The data in raster format will be used.
7) Sensitivity to data quality: It may impair the ability to measure the impact of RDP on this public good.
8) Consequences of data gaps: This method has previously been used for prediction rather than measurement of change. The consequences of the data constraints are that it reduces the effectiveness of the method to measure change, and hence the impact of RDP
9) Other: Additional indicators covering the territorial/environmental conditions of the programming area (e.g. specific species, soil conditions, etc.) can be helpful. The availability of data (or rather the lack of it) will call for the use of the data which is ready.

Water Quality

4.1.4 Water quality (Gross Nutrient Balance for N and P)

1) Type of data:
    - IACS or/and aggregated payment data for CAP and RDP measures
    - Input data (consumption of fertilisers, gross input of manure and other inputs)
    - Potential surplus of nitrogen (GNS) on agricultural land and potential surplus of phosphorus on agricultural land (kg/ha/year)
    - Removal of nutrients with the harvest of crops
    - Removal of nutrients through the harvest and grazing of fodder
    - Crop residues removed of the field.
2) Primary data: Water use and fertilisation input use are collected by monitoring data at farm level
3) Secondary data: Nitrate fertilisers, FADN data, national and regional database on the nitrogen (Census data, Nitrates Directive), expert interviews.
4) Spatial aspects: Most of the analysis is carried out at farm level (micro level).
5) Temporal dimensions: Gross Nutrient Balance (GNB) (4 year average)
6) Data processing: GNB represents the total potential threat by nitrogen and phosphorus surplus or deficits in agricultural soils, including nitrogenous emissions from livestock production and the application of manure and fertilisers (Ammonia and Nitrous oxide). GNB is calculated as the balance between inputs and outputs of nutrients to the agricultural soil.
7) Sensitivity to data quality: High
8) Consequences of data gaps: GNB does not inform on the form (organic, ammonia, nitrate) in which nitrogen is in the soil. If nitrate is the much more prone to leaching form, organic N is rather stable and it is a function of the carbon concentration in the soil.
9) Other: GNB represents the theoretical nitrogen surplus in the soil, calculated as the difference between the total quantity of nitrogen inputs in the soil and the quantity of nitrogen outputs annually leaving the soil. GNB is suitable as an indicator of the potential N loss to aquatic system, even though it does not provide information about the forms (organic, ammonia, nitrate) of nitrogen is in the soil. If nitrate is the much more prone to leaching form, organic N is rather stable and depends on the carbon concentration in the soil. A better assessment of N risk for water quality would require estimation/measurement of gas emission (Net Nitrogen Balance). Ideally, water quality

monitoring (nitrogen fluxes measurements at the outlet of agricultural catchments) would be the best method.

4.2 Spatial Analysis with Geo-statistical Approach

Biodiversity HNV

4.2.1 Percentage of Utilised Agricultural Area farmed to generate High Nature Value

1) Type of data:
    - UAA area (Agricultural Census; IACS; FADN, FSS; LPIS)
    - Farm data (Agricultural Census, FADN - Area of farmland eligible for RDP measure)
    - Land cover (CLC) (i.e. semi-natural pastures and meadows; traditional orchards; mosaics of low-intensity crop types; fallow land in low intensity farming systems)
    - Land use at cadastral level
    - HNV created on farm under RDP
    - Landscape, Phytosociological and Vegetation maps (e.g., 1:5000)
    - Habitat survey data (e.g., species richness, abundance, FBI)
    - Remote Sensing (RS), aerial photography and GIS
2) Primary data: Habitat survey data of RDP/non RDP areas; hierarchical sampled survey
3) Secondary data: IACS; CLC; FADN; LPIS; FSS; landscape, phytosociological and vegetation maps; habitat survey; Natura 2000 Network, RS and aerial photography data. They require an adequate detail level for distinguishing among RDP participant/non-participant areas.
4) Spatial aspects: The availability of data covering the extent of the analysed region (e.g. biodiversity data, livestock density, etc.) at the farm level would allow for aggregation at the macro scale.
5) Temporal dimension: The temporal dimension strictly depends on the frequency of land cover data. RS, aerial photography and GIS-based data can help to partially overcome the temporal gaps among data. HNV farmland refers to farmland characterised by the presence of particular land-cover types and patterns (especially semi-natural vegetation and low-intensity crop mosaics) which indicate that this farmland is valuable for nature conservation. The presence of populations of particular wildlife species may also indicate this. HNV farmland may exist at different scales, from the individual parcel to an entire landscape.
6) Data processing: Fragstats, ArcGIS Patch Analyst or R.

7) Sensitivity to data quality: It is related to the availability of data regularly updated both temporally and spatially.

8) Consequences of data gaps:

   - Ideally, to identify the location and extent of HNV at a micro level, data sources would be used to identify land where given land-cover types coincide to given management practices. The more the analytical level is close to the parcel level, the higher the accuracy in evaluation. In this way, crossing data on land cover types and on farming practices would allow to identify a chosen set of HNV characteristics within the region. However, there are currently severe data limitations, due to the unavailability of the required data to distinguish the full range of HNV characteristics at the level of a land parcel or farm holding, or to accurately map their distribution across a region;
   - CLC data represent land cover and not land use, and thus do not contain information on the intensity of management (e.g. input use, grazing pressure). CLC data have minimum size of 25 ha per mapping unit, and only provide for a proxy distribution of HNV farmland. Thus below this size objects are not mappable. This severely affects the representativeness of the evaluation of actual aspects at the micro level, and thus its effectiveness. This also implies difficulties in identifying patches of HNV farmland within mixed classes, or when the dominant class is mapped.
   - Photo-interpretation techniques show limits in detecting structurally complex classes.
   - FADN sample in total represents only 52% of the farms and 86% of the Utilised Agricultural Area in the EU-15 (and potentially less in the new Member States). This leads to the underrepresentation of small farms (defined in economic terms), that can include a high concentration of a region's HNV farming.
   - Referring to Utilised Agricultural Area (UAA), it partially excludes from the data set the area actually occupied by the agricultural business, for example without considering seasonal lets or wintering/summering arrangements, as well as the use of common land and fallow grazing.

9) Other: HNV farming system refers to both the land cover (farmland) and the way it is managed for production by a particular farming system and practices. The data process implies that the system as a whole (e.g. at farm or even landscape level) is limited to only one parcel. The most substantial data processing tasks are in relation to the aggregation of the single parcels. In terms of micro/macro linkage, some European experiences exist. In France, following a JRC methodology, data collected at farm level have been generalised

to represent the average situation at municipality level. However, caution is needed if municipalities are large and heterogeneous. The methodology is flexible and could be adapted to different characteristics of farming in different parts of Europe.

4.2.2 Habitat connectivity

1) Types of data:
   - Farm data (Agricultural Census, FADN - Area of farmland eligible for RDP measure)
   - Land cover (CLC) (i.e. semi-natural pastures and meadows; traditional orchards; mosaics of low-intensity crop types; fallow land in low intensity farming systems)
   - Land use at cadastral level
   - HNV created on farm under RDP
   - Landscape, Phytosociological and Vegetation maps (e.g. 1:5000)
   - Habitat survey data (species richness, abundance, FBI)
   - Remote Sensing (RS), aerial photography and GIS
2) Primary data: Habitat survey data of RDP/non RDP areas
3) Secondary data: IACS; CLC; FADN; LPIS; FSS; landscape, phytosociological and vegetation maps; habitat survey; Natura 2000 Network, RS and aerial photography data. They require an adequate detail level for distinguishing among RDP participants/non participants areas.
4) Spatial aspects: Farm level data (RDP) will be assessed in the context of neighbouring areas to assess connectivity and diversity/spatial complexity.
5) Temporal dimension: The temporal dimension strictly depends on the frequency of land cover data. RS, aerial photography and GIS-based data can help to partially overcome the temporal gaps among data.
6) Data processing: Fragstats, ArcGIS Patch Analyst or R.
7) Sensitivity to data quality: It is related to the availability of data regularly updated both temporally and spatially.
8) Consequences of data gaps:
   - CLC land cover data have minimum size of 25 ha per mapping unit. They provide a proxy distribution of the variable under examination, and thus, below this size, objects are not mappable. This severely affects the representativeness of the evaluation of actual aspects at the micro level, and thus its effectiveness. Also photo-interpretation techniques show limits in identifying structurally complex classes.

- FADN sample totally represents only 52% of the farms and 86% of the Utilised Agricultural Area in the EU-15 (and potentially less in the new Member States). This leads to the under-representation of small farms (defined in economic terms), that can include a high concentration of a region's HNV farming.
- Utilised Agricultural Area (UAA) partially excludes from the data set the area actually occupied by the agricultural business, for example without considering seasonal lets or wintering/summering arrangements, as well as the use of common land and fallow grazing.
- Data volatility can potentially limit the temporal and spatial effectiveness of comparison. The nature of habitat patch-size is in fact very species-specific, and this can have implications for the generalisation of research outputs, that could vary by species and/or type of landscape.
- Habitat patch size and their connectivity are strictly related in impacting on different species at different times. Habitat connectivity could be integrated with specific indices able to measure characteristics of landscape fragmentation, including landscape division, adjacency-based metrics, cohesion, the splitting index, Shannon's Diversity Index, proximity, distance to a similar patch class and connectivity measures.

4.2.3 Habitat patch size

1) Type of data:
    - Farm data (Agricultural Census, FADN - Area of farmland eligible for RDP measure)
    - Land cover (CLC) (i.e. semi-natural pastures and meadows; traditional orchards; mosaics of low-intensity crop types; fallow land in low intensity farming systems)
    - Land use at cadastral level
    - HNV created on farm under RDP
    - Landscape, Phytosociological and Vegetation maps (e.g., 1:5000)
    - Habitat survey data (species richness, abundance, FBI)
    - Remote Sensing (RS), aerial photography and GIS
2) Primary data: Not required
3) Secondary data: IACS; CLC; FADN; LPIS; FSS; landscape, phytosociological and vegetation maps; habitat survey; Natura 2000 Network, RS and aerial photography data.

They require an adequate detail level for distinguishing among RDP participants/non participants areas.

4) Spatial aspects: Farm level data (RDP) will be assessed in the context of neighbouring areas to assess connectivity and diversity/spatial complexity.
5) Temporal dimension: The temporal dimension strictly depends on the frequency of land cover and land use data. RS, aerial photography, maps and GIS-based data can help to partially overcome the temporal gaps among data.
6) Data processing: Fragstats, ArcGIS Patch Analyst or R.
7) Sensitivity to data quality: It is related to the availability of data regularly updated both temporally and spatially.
8) Consequences of data gaps:
   - CLC land cover data have minimum size of 25 ha per mapping unit. They just proxy provide for a proxy distribution of examined variable and thus below this size objects are not mappable. This severely affects the representativeness of the evaluation of actual aspects at the micro level, and thus its effectiveness. Also photo-interpretation techniques show limits in identifying structurally complex classes.
   - FADN sample totally represents only 52% of the farms and 86% of the Utilised Agricultural Area in the EU-15 (and potentially less in the new Member States). Small farms (defined in economic terms) are thus not sufficiently represented. In this way, the reference to UAA excludes partially from the data set the area actually occupied by the agricultural business, for example without considering seasonal lets or wintering/summering arrangements, as well as the use of common land and the grazing of fallows.
   - Data volatility can potentially limit the temporal and spatial effectiveness of comparison. The nature of habitat patch-size is in fact very species-specific, and this can have implications for the generalisation of research outputs, that could vary by species and/or type of landscape.
   - Habitat patch size and their connectivity are strictly related in impacting on different species at different times. Habitat patch size could be integrated with specific indices able to measure characteristics of landscape fragmentation, including landscape division, adjacency-based metrics, cohesion, the splitting index, Shannon’s diversity, proximity, distance to a similar patch class and connectivity measures.

4.2.4 Vegetation quality index

1) Type of data:

- Farm data (Agricultural Census, FADN - Area of farmland eligible for RDP measure)
- Land cover (CLC) (i.e. semi-natural pastures and meadows; traditional orchards; mosaics of low-intensity crop types; fallow land in low intensity farming systems)
- Land use at cadastral level
- HNV created on farm under RDP
- Landscape, Phytosociological and Vegetation maps (e.g., 1:5000)
- Habitat survey data (species richness, abundance, FBI)
- Remote Sensing (RS), aerial photography and GIS

2) Primary data: Not required
3) Secondary data: IACS; CLC; FADN; LPIS; FSS; landscape, phytosociological and vegetation maps; habitat survey; Natura 2000 Network, RS and aerial photography data. They require an adequate detail level for distinguishing among RDP participants/non participants areas.
4) Spatial aspects: Farm-level data (RDP) will be assessed in the context of neighbouring areas to assess connectivity and diversity/spatial complexity.
5) Temporal dimension: The temporal dimension strictly depends on the frequency of land cover and land use data. RS, aerial photography, maps and GIS-based data can help to partially overcome the temporal gaps among data.
6) Data processing: The data in raster format will be used to calculate the indicator in Fragstats, ArcGIS Patch Analyst or R.
7) Sensitivity to data quality: It is related to the availability of data regularly updated both temporally and spatially.
8) Consequences of data gaps:

- CLC land cover data have minimum size of 25 ha per mapping unit. They just proxy provide for a proxy distribution of examined variable and thus below this size objects are not mappable. This severely affects the representativeness of the evaluation of actual aspects at the micro level, and thus its effectiveness. Also photo-interpretation techniques show limits in identifying structurally complex classes;
- FADN sample totally represents only 52% of the farms and 86% of the Utilised Agricultural Area in the EU-15 (and potentially less in the new Member States). Small farms (defined in economic terms) are thus not sufficiently represented. In this way, the reference to UAA excludes partially from the data set the area actually occupied by the agricultural business, for example without considering seasonal lets or

wintering/summering arrangements, as well as the use of common land and the grazing of fallows;

- Data volatility can potentially limit the temporal and spatial effectiveness of comparison. The nature of habitat patch-size is in fact very species-specific, and this can have implications for the generalization of research outputs, that could vary by species and/or type of landscape;
- Habitat patch size and their connectivity are strictly related in impacting on different species at different times. The vegetation quality index could be integrated with specific indices able to measure characteristics of landscape fragmentation, including landscape division, adjacency-based metrics, cohesion, the splitting index, Shannon's diversity, proximity, distance to a similar patch class and connectivity measures.

4.2.5 Spatial complexity

Required data are the same for habitat patch size. Additional data about habitats (heterogeneity, edge per patch, and so on) may provide for the analysis of species if these are targeted in the measure.

4.3 Statistical Sampling with Spatial Analysis

Biodiversity Wildlife

4.3.1 Farmland Bird Index (FBI)

1) Type of data:
   - Area of farmland participating in RDP (IACS)
   - Area of farmland eligible for RDP measure
   - Land cover (CLC)
   - Land use at cadastral level
   - Soil: Integrate production, biological production, sod seeding and extensive meadows; conservation of natural and semi-natural areas and of agrarian landscape; environmental set aside; Productive; Not productive
   - Habitat data (Managing Authority RDP 2007/2013)
   - Biodiversity data: Richness; Abundance of agricultural birds species (FBI) (European Rural Network)
   - RS and aerial photography data
2) Primary data: Not required
3) Secondary data: IACS; CLC; FADN; LPIS; FSS; landscape, phytosociological and vegetation maps; habitat survey; Natura 2000 Network, RS and aerial photography data. They require an adequate detail level for distinguishing between RDP participants/non participants areas.
4) Spatial aspects: Evaluations should take place at the field/plot scale (to assess the benefits of individual measures) and/or at landscape scale (to assess wider-scale populations benefits), as appropriate for the species being studied. For species that disperse widely (for example most birds and bats), both scales may be of interest. For species that are less dispersive and slow to reproduce, it is essential that they are studied at the field scale or patch scale, as populations will respond directly to localised land management.
5) Temporal dimensions: Each Member State collected FBI data yearly during the period 2000 – 2012. However some regions have a more frequent data collection.
6) Data processing: PCA; GLM; Software R. FBI is a multi-species index obtained by the aggregation of a set of individual species indices using a geometric mean. Individual indices are calculated for each species independently. By using the geometric mean, the species are weighted equally in the indicators. Where the species indices are provided for a time period of different lengths, the chain method is used in the indicator computation.

7) Sensitivity to data quality: It is related to the availability of data regularly updated both temporally and spatially.
8) Consequences of data gaps:

- Data mainly exist at national and EU-level aggregation. FBI should be calculated at a lower level, by bio-geographical areas (different agricultural habitats) on the basis of geo-referenced data. Moreover, data strictly depend by the species movements and inclinations. For example, some birds are less specialised in micro-habitat use than many other taxa;
- Species distribution at a given scale may not match the patterns of other taxa, population trends may not always correlate with those of other taxa, and environmental degradation can also result in positive population trends in some situations. Moreover, over time, specialised species of farmland birds represent the biodiversity state well as their sensitivity is high. On the other hand, common species do often even benefit from habitat perturbations. Many species can change annually in abundance and this may reflect a variety of environmental factors, such as extreme weather conditions in the breeding season, poor winter conditions, changes in predation pressure, or sampling error and statistical noise. Long-term monitoring and the use of a wider range of species helps to detect the underlying trends.
- Landscapes are dynamic and are not static systems. Their management depends upon a range of socio-economic, policy and environmental controls. In most cases, however, the FBI does not have such a good coverage or the data do not coincide with areas under specific measures. Therefore, the index should be integrated with other previous or ongoing bird monitoring data, if they exist, or combined with data of existing common bird monitoring and special measure-specific studies. In most cases, the evaluation of individual measures or schemes requires ad hoc and highly replicated field studies;
- The elaboration of monitoring sample strategies is often a challenging task, due to the fact that farms are no identical, the landscape is different, the share of semi-natural habitats is different, farm sizes are different etc. All these differences could severely affect the bird impact indicator results and should be taken into account while monitoring sample strategies are developed. Samples have to be representative in terms of habitat and geographical location. Therefore, the best way to gather representative sample is to use large numbers of random plots. However, financial constraints can undermine the sampling process at smaller scales.

4.3.2 Flowering plants of semi-natural habitats

1) Type of data:
   - Area of farmland participating in RDP (IACS)
   - Area of farmland eligible for RDP measure
   - Land cover (CLC)
   - Land use at cadastral level
   - Soil: Integrate production, biological production, seeding and extensive meadows; conservation of natural and semi-natural areas and of agrarian landscape; environmental set aside; productive; non-productive
   - Habitat (Managing Authority RDP 2007/2013)
   - Biodiversity: Richness; species abundance
2) Primary data: Monitoring data are needed through experimental plots in different sites where participating and non-participating farms have to be selected.
3) Secondary data: IACS; CLC; FADN; LPIS; FSS; landscape, phytosociological and vegetation maps; habitat survey; Natura 2000 Network, RS and aerial photography data. They require an adequate level of detail for distinguishing among RDP participant/non participant areas.
4) Spatial aspects: Evaluations should take place at the field/plot scale (to assess the benefit of individual measures) and/or at landscape scale (to assess wider-scale population benefits), as appropriate for the species being studied. For species that disperse widely both scales may be of interest. For species that are less dispersive and slow to reproduce, it is essential that they are studied at the field scale or patch scale, as populations will respond directly to localised land management.
5) Temporal dimensions: The availability of monitoring data at the beginning and end of the RDP programme should be preferred, although the high monitoring costs may lead to a more simple participant/non-participant survey.
6) Data processing: PCA; GLM; Software R. Flowering plant abundance scores are expressed as the interval median value for each range, to give an estimate of the number of flowering units on each sampling area. Individual indices are calculated for each species independently. Species richness is tested by analysis of variance. Where the species indices are provided for time periods of different lengths, repeated measures are performed to test for average treatment effects across all years.
7) Sensitivity to data quality: It is related to the availability of data regularly updated both temporally and spatially.

8) Consequences of data gaps:

  - Flowering index is calculated at micro level, by bio-geographical areas (different agricultural habitats) on the basis of geo-referenced data. Main challenge comes from the assessment of the effect of land use at multiple spatial scales (from location-within-field to regions) on farmland biodiversity;

- Species distribution at a given scale may not match the patterns of other taxa, population trends may not always correlate with those of other taxa, and environmental degradation can also result in positive population trends in some situations. Many species may present annual changes in abundance that may reflect a variety of environmental factors. Long-term monitoring and use of a wider range of species helps detecting the underlying trends.
- Landscapes are dynamic and not static systems. Their management depends upon a range of socio-economic, policy and environmental controls. In most cases, the risk is that flowering indices do not have a good coverage or the data do not coincide with areas under specific measures. In these cases the index should be integrated. In most cases, the evaluation of individual measures or schemes requires ad hoc and highly replicated field studies.
- The elaboration of monitoring sample strategies is often a challenging task, due to that farms are no identical – the landscape is different – the share of semi-natural habitats is different – farm sizes are different – etc. All these differences could severely affect the flowering index assessment and should be taken into account while monitoring sample strategies are decided. Samples have in fact to be representative in terms of habitat and geographical location. Therefore the best way to gather representative sample is to use large number of random plots, however financial constraints can undermine the sampling process at smaller scales.

9) Other: This approach results as useful in analysing species diversity as well as to habitat and landscape diversity. However, the enlargement of sampling sites and the increase in numbers of samples can be considered as added values of field surveys.

4.3.3 Population trends of agriculture related butterfly species

Required data are the same. Additional data about population trends of agriculture specific for butterfly species may provide for the analysis of species if these are targeted in the measure.

Water Quality

4.3.4 Water quality (Nitrates in freshwater)

1) Type of data:
   - IACS or/and aggregated payment data for CAP and RDP measures
   - Data on intervention logics of the different measures
   - Land use: Map of irrigated areas
   - Input data
   - Water quality: Surplus of nitrogen in kg/ha (available at NUTS 1 level) (Gross Nutrient Balance- GNB)
   - Soil: Regional Soil Maps and Nitrate Vulnerable Zone (NVZ) (retrieved by cadastral maps)
2) Primary data: Water use and fertilisation input use are collected by monitoring data at farm level (micro-level analysis).
3) Secondary data: Nitrate fertilisers, FADN data, national and regional database on the nitrogen (Census data, Nitrates Directive), interviews.
4) Spatial aspects: Most of the analysis are carried out at farm level (micro level).
5) Temporal dimensions: Annual values on Nitrates used in agriculture.
6) Data processing: Simplified balance of nitrogen at farm scale to estimate the surplus on the basis of natural flows, chemical and organic fertilisation and removal from estimated production (N), and simplified balance of phosphorus (P_2O_5) at farm scale to estimate the surplus on the basis of chemical and organic fertilisation and removal from estimated production (P).
7) Sensitivity to data quality: High
8) Consequences of data gaps: GNB does not inform on the form (organic, ammonia, nitrate) in which nitrogen is in the soil, for example, nitrate is much more prone to leaching, while organic N is rather stable and is function of the carbon concentration in the soil.
9) Other: GNB represents the theoretical nitrogen surplus in the soil calculated by the difference between the total quantity of nitrogen inputs entering the soil and the quantity of nitrogen outputs leaving the soil annually. The use of GNB as an indicator of the potential N loss to aquatic system is significant; however it does not inform on the form (organic, ammonia, nitrate) in which nitrogen is in the soil. A better evaluation of N risk to water quality would require estimation/measurement of gas emission (Net Nitrogen Balance). Ideally, water quality monitoring (nitrogen fluxes measurements at the outlet of agricultural catchments) would be the best method.

4.3.5 Pesticide in Groundwater/surface water

1) Type of data:
   - IACS or/and aggregated payment data for CAP and RDP measures
   - Data on intervention logics of the different measures
   - Land use: Maps of irrigated areas
   - Input data
   - Water quality: Presence of pesticide in groundwater in kg/ha
   - Soils: Regional soil maps;
   - Farm surveys and Census data
   - FADN data
2) Primary data: water use and fertilisation input use are collected by monitoring data at farm level (micro-level analysis)
3) Secondary data: Farm level detailed
4) Spatial aspects: Regional scales - most of the analyses are carried out at farm level (micro level).
5) Temporal dimensions: National and regional database on pesticide used.
6) Data processing: Simplified balance of pesticide at farm scale to estimate the surplus on the basis of natural flows.
7) Sensitivity to data quality: High
8) Consequences of data gaps: In the case of poor data the quality of the analysis can be compromised.
9) Other: Micro/macro linkages should be reached through aggregating farming region pesticide at the local scale. However, this can show limits in presenting information because it masks the heterogeneity of responses which are expected from different regions due to inherent intrinsic differences such as geology, soil, climate and socio-economic context. Aggregating scores by region, if necessary, should be conversely a function of the rate of change of local agricultural areas.

4.4 Hierarchical Models

4.4.1 Percentage of Utilised Agricultural Area farmed to generate High Nature Value

1) Type of data:
   - UAA area (Agricultural Census: IACS; FADN, FSS; LPIS)
   - Land cover (CLC) (i.e. semi-natural pastures and meadows;

- Traditional orchards; mosaics of low-intensity crop types; fallow land in low-intensity farming systems
- Natural and semi-natural forests
- Land use at cadastral level
- Species and habitat databases
- Landscape data (natural and structural elements) (landscape maps)
- Agricultural inputs data
- Farming systems
- Habitat data (habitat survey, Natura 2000 Network)
- Remote Sensing (RS), aerial photography and GIS

2) Primary data: Habitat survey data of RDP/non RDP areas; hierarchical sampled survey
3) Secondary data: IACS; CLC; FADN; LPIS; FSS; landscape, phytosociological and vegetation maps; habitat survey; Natura 2000 Network, RS and aerial photography data. They require an adequate detail level for distinguishing among RDP participants/non participants areas.
4) Spatial aspects: The availability of data covering the extent of the analysed region (e.g. biodiversity data, livestock density etc.) at the appropriate scale (farm) allows for aggregation at the macro scale.
5) Temporal dimension: The temporal dimension strictly depends on the frequency of land-cover data. RS, aerial photography and GIS-based data can help to partially overcome the temporal gaps among data. HNV farmland refers to farmland characterised by the presence of particular land-cover types and patterns (especially semi-natural vegetation and low-intensity crop mosaics) which indicate that this farmland is valuable for nature conservation. The presence of populations of particular wildlife species may also show this. HNV farmland may exist at different scales, from the individual parcel to an entire landscape.
6) Data processing: HNV farming system refers to both the land cover (farmland) and the way it is managed for production by a particular farming system and practices. The data process implies that the system as a whole (e.g. at farm or even landscape level) is limited to only one parcel. The most substantial data-processing task is in relation to the aggregation of the single parcels.
7) Sensitivity to data quality: It is related to the availability of data regularly updated both temporally and spatially.
8) Consequences of data gaps:

- Ideally, to identify the location and extent of HNV at a micro level, data sources would be used to identify land where given land cover types coincide with given management practices. The more the analytical level is close to the parcel level, the higher the accuracy in evaluation. In this way, combining data on land-cover types and farming practices would allow us to identify a chosen set of HNV characteristics within the region. However, there are currently severe data limitations, due to the required data not being available to distinguish the full range of HNV characteristics at the level of a land parcel or farm holding, or to accurately map their distribution across a region;
- CLC data represent land cover and not land use, and thus do not contain information on the intensity of management (e.g. input use, grazing pressure). CLC data have a minimum size of 25 ha per mapping unit and only provide for a proxy distribution of HNV farmland, and thus below this size objects are not mappable. This severely affects the representativeness of the evaluation of actual aspects at the micro level, and thus its effectiveness. This also implies that there will be difficulties in identifying patches of HNV farmland within mixed classes, or when the dominant class is mapped.
- Photo-interpretation techniques show limits in detecting structurally complex classes.
- The strength of the farming systems approach by using FADN is that it relates to the management practices of the farms. This means that FADN can provide data for the management needs of HNV farmland and support the identification of further potential HNV areas. In monitoring terms, this means that the FADN can be used to indicate the pressure from farming in relation to nature values. However, the main weakness of FADN is that it represents only 52% of the farms and 86% of the Utilised Agricultural Area in the EU-15 (and potentially less in the new Member States). This ranges from Ireland, where only 12% of the farms and 4% of the Utilised Agricultural Area are not included, to Austria, where 58% of the farms and 38% of the Utilised Agricultural Area are not represented. It is important to stress that economically small and 'non-professional' farms may in fact be physically large and provide a full-time activity, particularly in marginal areas where the land has low productivity but alternative employment is scarce. This leads to the under-representation of small farms (defined in economic terms) that can include a high concentration of a region’s HNV farming.
- Referring to UAA partially excludes from the data set the area actually occupied by the agricultural business, for example without considering seasonal lets or wintering/summering arrangements, as well as the use of common land and fallow grazing.

9) Other: In terms of micro/macro linkage, some European experiences exist. In France, following a JRC methodology, data collected at farm level have been converted to be generalised and to represent the average situation at municipality level. However, caution is needed if municipalities are large and heterogeneous. The methodology is flexible and could be adapted to different characteristics of farming in different parts of Europe.

4.4.2 High natural value index (crop diversity index and stocking density index)

1) Types of data:
    - Area of farmland participating in RDP (IACS)
    - Area of farmland eligible for RDP measure
    - UAA area (Agricultural Census: IACS; FADN, FSS; LPIS)
    - Land cover (CLC)
    - Land use (cadastral level)
    - Farm Structure Survey (FSS) High Nature Value data
    - Remote Sensing (RS) and aerial photography
2) Primary data: No need for primary data
3) Secondary data: IACS; CLC; FADN; LPIS; FSS; landscape, phytosociological and vegetation maps; habitat survey; Natura 2000 Network, RS and aerial photography data. They require an adequate level of detail to distinguish between RDP participant/non participant areas.
4) Spatial aspects: The availability of data covering the extent of the analysed region (e.g. biodiversity data, livestock density etc.) at the appropriate scale (farm) allows for aggregation at the macro scale.
5) Temporal dimension: The temporal dimension strictly depends on the frequency of the land cover data. RS, aerial photography, GIS-based data can help to partially overcome the temporal gaps among data.
6) Data processing: Fragstats, ArcGIS Patch Analyst or R.
7) Sensitivity to data quality: Both the resolution and the extent of the analysis determine the extent of error in the impact assessment.
8) Consequences of data gaps:

- Ideally, to identify the location and extent of HNV at a micro level, data sources would be used to identify land where given land-cover types coincide with given management practices. The more the analytical level is close to the parcel level, the higher the accuracy in evaluation. In this way, crossing data on land-cover types and on farming practices would allow the identification of a chosen set of HNV characteristics within the region. However, there are currently severe data limitations, due to the fact that the required data are not available to distinguish the full range of HNV characteristics at the level of a land parcel or farm holding, or to accurately map their distribution across a region.

- CLC data represent land cover and not land use, and thus do not contain information on the intensity of management (e.g. input use, grazing pressure). CLC data have minimum size of 25 ha per mapping unit, and only provide for a proxy distribution of HNV farmland; thus below this size objects are not mappable. This severely affects the representativeness of the evaluation of actual aspects at the micro level, and thus its effectiveness. This also implies difficulties in identifying patches of HNV farmland within mixed classes, or when the dominant class is mapped.
- Photo-interpretation techniques show limits in detecting structurally complex classes.
- The strength of the farming systems approach by using FADN is that it relates to the management practices of the farms. This means that FADN can provide data for the management needs of HNV farmland and support the identification of further potential HNV areas. In monitoring terms this means that the FADN can be used to indicate the pressure from farming in relation to nature values. However, the main weakness of FADN is that its sample totally represents only 52% of the farms and 86% of the Utilised Agricultural Area in the EU-15 (and potentially less in the new Member States). This ranges from Ireland, where only 12% of the farms and 4% of the Utilised Agricultural Area are not included, to Austria, where 58% of the farms and 38% of the Utilised Agricultural Area are not represented. It is important to stress that economically small and 'non-professional' farms may in fact be physically large and provide a full-time activity, particularly in marginal areas where the land has low productivity but alternative employment is scarce. This leads to the underrepresentation of small farms (defined in economic terms), that can include a high concentration of a region's HNV farming.
- Referring to UAA partially excludes from the data set the area actually occupied by the agricultural business, for example without considering seasonal lets or wintering/summering arrangements, as well as the use of common land and the grazing of fallows.

4.4.3 Vegetation quality index

1) Type of data:
    - Area of farmland participating in RDP (IACS)
    - Area of farmland eligible for RDP measure

- Topographic parameters (LANDMAP)
- Land cover (CLC)
- Land use at cadastral level
- Landscape, Phytosociological and Vegetation maps (e.g., 1:5000)
- RS and aerial photography data

2) Primary data: Not required
3) Secondary data: IACS; CLC; FADN; LPIS; FSS; landscape, phytosociological and vegetation maps; habitat survey; Natura 2000 Network, RS and aerial photography data. They require an adequate level of detail to distinguish between RDP participant/non participant areas.
4) Spatial aspects: Farm-level data (RDP) will be assessed in the context of neighbouring areas to assess connectivity and diversity/spatial complexity.
5) Temporal dimension: The temporal dimension strictly depends on the frequency of land cover and land-use data. RS, aerial photography, maps and GIS-based data can help to partially overcome the temporal gaps among data.
6) Data processing: The data in raster format will be used to calculate the indicator in Fragstats, ArcGIS Patch Analyst or R.
7) Sensitivity to data quality: It is related to the availability of data regularly updated both temporally and spatially.
8) Consequences of data gaps: Data volatility can potentially limit the temporal and spatial effectiveness of comparison. The nature of habitat patch size is in fact very species-specific, and this can have implications for the generalisation of research outputs, that could vary by species and/or type of landscape. Additionally, the habitat patch size can have effects on different species at different times.
9) Other: HNV farmland refers to farmland characterised by the presence of particular land cover types and patterns (especially semi-natural vegetation and low-intensity crop mosaics) which indicate that this farmland is valuable for nature conservation. The presence of populations of particular wildlife species may also indicate this. HNV farmland may exist at different scales, from the individual parcel to an entire landscape.

4.5 Footprint (Carbon)

Climate Stability

4.5.1 Emissions from agriculture (GHG emissions from agriculture: 1 CH_4, N_2O and CO_2 including energy use

1) Type of data:
   - Area of farmland participating in RDP – IACS
   - Land cover and land use
   - Net emission of CO_2 plus all emissions of CH_4 and N_2O during the production process
   - Carbon balance: flows in and out of cropland during the production
   - Methane: enteric fermentation and emissions from manure management
   - N_2O: denitrification and nitrification processes occurring in the soil where crops are grown.
2) Primary data: Input use monitoring data at farm level (micro-level analysis) (extension of FADN)
3) Secondary data: Production of fuel, electricity, machinery, fertiliser, pesticide, and plastic used in the production processes and emissions during the production of any replacement animals not raised on the farm, annual values of CO_2 units using emission factors from literature.
4) Spatial aspects: A significant dimension of the carbon footprint (CF), which can be extended to the whole footprint analysis, is refereed to its spatial aspects. In fact, the CF is an indicator that lends itself well to the calculation of a single production unit (farm). For this the method could be a representative at the micro level. However, some problems may occur in the scaling-up as the reference database must be able to be statistically representative, not only in the quality and quantity of inputs purchased and used by farmers, but also agricultural practices implemented. Furthermore, the complexity of the analysis increases with the complexity of the considered production systems (e.g., Mixed farms compared to mono-cultural farming systems).
5) Temporal dimensions: Annual values of CO_2 units
6) Data processing: Statistical software
7) Sensitivity to data quality: High
8) Consequences of data gaps: CF measures the environmental impact of a productive activity on the global climate. The proposed indicator accounts for all GHG emissions by the agricultural sector. The unit of measurement of CF is the equivalent tons of carbon dioxide. In its initial stages, CF includes GHG absorption and emission during the life-cycle of a product or service, from the extraction of raw materials to its final use. In this

way, CF can be considered as a subset of data derived from Life Cycle Assessment (LCA). In order to compare different systems some standards exist to apply at international level. In particular, this refers to the recent introduction of new regulations published in 2013, containing 14,067 specific principles, requirements and guidelines for the CF quantification and communication of a product (CFP), based on International Standards on LCA for quantification (ISO 14040, ISO 14044) and on environmental labels and declarations (ISO 14020, ISO 14024, ISO 14025).

4.5.2 Emissions from agriculture (GHG removal from agriculture: 2 CO2 from LULUCF)

1) Type of data:
    - Area of farmland participating in RDP – IACS
    - Land cover and land use
    - Net emission of CO_2 plus all emissions of CH_4 and N_2O during the production process (chemical fertiliser application, rice paddy, pesticides, plastic film, fuel for machine, electricity for irrigation).
    - Carbon balance: flows in and out of cropland during the production
    - Methane: enteric fermentation and emissions from manure management
    - N_2O: de-nitrification and nitrification processes occurring in the soil where crops are grown.
2) Primary data: Input use monitoring data at farm level.
3) Secondary data: Production of fuel, electricity, machinery, fertiliser, pesticide, and plastic used in the production processes and emissions during the production of any replacement animals not raised on the farm, annual values of CO_2 units using emission factors from literature.
4) Spatial aspects: CF can be applied to the single production unit (farm). In this way, it could be relevant for the micro-level analysis. However, some problems may occur in scaling-up; for example, the reference database should be able to be statistically representative, not just about the quality and quantity of inputs purchased and used by farmers, but also for those implemented in agricultural practices. Furthermore, the more the variables are to be considered in the production systems, the more complex is CF analysis (e.g., mixed farms compared to monocultural farming systems).
5) Temporal dimensions: Annual values of CO_2 units
6) Data processing: Statistical software and emission factors from literature
7) Sensitivity to data quality: High

8) Consequences of data gaps: CF measures the environmental impact of a productive activity on the global climate. The proposed indicator accounts for all GHG emissions by the agricultural sector. The unit of measurement of CF is the equivalent tons of carbon dioxide. In its initial stages, CF includes GHG absorption and emission during the life-cycle of a product or service, from the extraction of raw materials to its final use. In this way, CF can be considered as a subset of data derived from LCA. In order to compare different systems some standards exist to apply at international level. In particular, this refers to the recent introduction of new regulations published in 2013, and containing 14,067 specific principles, requirements and guidelines for the CF quantification and communication of a product (CFP), based on International Standards on LCA for quantification (ISO 14040, ISO 14044) and on environmental labels and declarations (ISO 14020, ISO 14024, ISO 14025).
9) Other: CO_2 emissions from agricultural soils (LULUCF) include only ‘cropland’ and ‘grassland’ categories. These account for emissions of cropland/grassland remaining the same type of land use, and emissions from land converted to cropland/grassland.

4.6 Footprint (Water)

Water Quality

4.6.1 Water abstraction

1) Types of data:

- Area of farmland participating in RDP – IACS
- Land cover and land use
- Virtual water flows: Water supply, crop evapotranspiration
- Rainwater use
- Irrigation water required
- Crops yield
- Green water use and blue water use

2) Primary data: Input use monitoring data at farm level (micro-level analysis)
3) Secondary data: Irrigation water and water required in the production processes (FADN, EUROSTAT)
4) Spatial aspects: WF is a method that can be applied to microsystems such as catchments and farms. In this way, it could be a relevant for micro-level analysis. However, some problems may occur in scaling up; for example, the reference database should be statistically representative of water consumption and use by farmers, but also for

consumption by irrigation. Furthermore, the greater the number of variables considered in the production systems, the more complex is the Water Footprint (WF) analysis (e.g., mixed farms compared to mono-cultural farming systems).

5) Temporal dimensions: Annual values of m^3 units
6) Data processing: Statistical software and water consumption factors from literature
7) Sensitivity to data quality: High
8) Consequences of data gaps:
9) Other: The weaknesses of the WF are: it represents just the quantity of water used without an estimation of the related environmental impacts; the lack of required data; and the fact that no uncertainty studies are available even though uncertainty can be significant.

4.7 Landscape Metrics

4.7.1 Fragmentation of land parcels

1) Type of data:
    - Area of farmland participating in RDP (IACS)
    - Area of farmland eligible for RDP measure
    - Topographic parameters (LANDMAP)
    - Land cover (CLC)
    - Land use at cadastral level
    - Landscape, Phytosociological and Vegetation maps (e.g., 1:5000)
    - RS and aerial photography data
2) Primary data: No need for primary data
3) Secondary data: IACS; CLC; FADN; LPIS; FSS; landscape, phytosociological and vegetation maps; habitat survey; Natura 2000 Network, RS and aerial photography data. They require an adequate detail level to distinguish between RDP participant/non participant areas.
4) Spatial aspects: Although land cover/land use data are regularly updated, they are often not temporally overlapped with RDP data.
5) Temporal dimension:
6) Data processing: Fragstats, ArcGIS Patch Analyst or R.
7) Sensitivity to data quality: It is related to the availability of data regularly updated both temporally and spatially.

8) Consequences of data gaps: Data volatility can potentially limit the significant comparison, both temporally and spatially. The level of detail, disturbing agent, pattern and analysed species for landscape fragmentation has implications for the generalisation of research outputs, as responses could vary by species and/or type of landscape. In addition, the effects of habitat fragmentation on different species can occur at different times. These measures have been integrated over time with more sophisticated and innovative indices to measure specific characteristics of landscape fragmentation, including landscape division, adjacency-based metrics, cohesion, the splitting index, Shannon's Diversity Index, proximity, distance to a similar patch class and connectivity measures.

4.7.2 Habitat patch shape

Required data are the same for fragmentation of land parcels. Additional data about habitats (e.g., heterogeneity, edge per patch) may provide for the analysis of species if these are targeted in the measure.

4.7.3 Spatial complexity

Required data are the same for fragmentation of land parcels. Additional data about habitats (e.g., heterogeneity, edge per patch) may provide for the analysis of species if these are targeted in the measure.

4.8 Farm Survey

Climate Stability

4.8.1 Production of renewable energy from agriculture

1) Types of data:
    - Area of farmland participating in RDP – IACS
    - Land cover (CLC)
    - Land use
    - Tonnes of oil equivalent and % of total production of production of renewable energy from agriculture and forestry
2) Primary data: Input use monitoring data at farm level (micro-level analysis)
3) Secondary data: National data for agriculture (EurObservER barometer for data on biogas, European Biodiesel Board for data on biodiesel, PURE for data on bioethanol data prepared by DG AGRI) and for forestry and total production Eurostat – Energy statistics (Supply, transformation, consumption).

4) Spatial aspects: Farm level
5) Temporal dimensions: Annual data on crude oil, oil products, natural gas, electricity, solid fuels and renewable covering the full spectrum of the energy balances positions from supply through transformation to final energy consumption by sector and fuel type.
6) Data processing: Statistical software
7) Sensitivity to data quality: High
8) Consequences of data gaps:
9) Other: Annual data collections cover the EU, the European Economic Area countries Iceland and Norway, and the Candidate Countries FYROM, Croatia and Turkey, with time-series reaching back to 1990. Temporal coverage is from 1990 onwards.

4.8.2 Direct use of energy in agriculture

1) Types of data:
    - Direct use of energy in agriculture/forestry
    - Direct use of energy in food processing
2) Primary data: Data at farm level
3) Secondary data: Eurostat data from the joint IEA/OECD-Eurostat-UNECE questionnaires.
4) Spatial aspects: Farm level
5) Temporal dimensions: Annual and monthly data series cover EU Member States and Candidate Countries
6) Data processing: Statistical software and questionnaires.
7) Sensitivity to data quality: High
8) Consequences of data gaps: Energy consumption by agriculture may therefore be overestimated in countries with significant forestry or fisheries sectors.
9) Other: Though the quality of energy statistics is generally high, data on energy consumption by agriculture are of lower quality due to errors and incomplete data. The indicator only refers to direct use of energy by agriculture. Indirect energy used in agriculture for fertilisers, pesticides, animal feed and agricultural machinery, which are produced using large amounts of energy, is not included. Data is only available at national level. Annual data on crude oil, oil products, natural gas, electricity, solid fuels and renewables covers the full spectrum of the energy balance position from supply through transformation to final energy consumption by sector and fuel type. The measurement of energy quantities includes produced, traded (including by country of

origin/destination), transformed and consumed as well as structural characteristics of energy production/transformation installations.

4.8.3 Emissions from agriculture (Ammonia emissions from agriculture)

1) Type of data:
   - Total ammonia emissions from agriculture
   - N-fertiliser
   - Cattle dairy
   - Cattle non-dairy
   - Swine
   - Laying hens
2) Primary data: Monitoring data at farm level (micro-level analysis)
3) Secondary data: Annual data on ammonia emissions from agriculture (FADN, EEA)
4) Spatial aspects: Detail is NUTS 3; however the survey derives from GHG data on UNFCCC
5) Temporal dimensions: Annual
6) Data processing: Statistical software
7) Sensitivity to data quality: High
8) Consequences of data gaps:

Water Quality

4.8.4 Water abstraction in agriculture

1) Type of data:
   - Land cover data (CLC)
   - Land-use data and data on meadows and grassland distribution
   - Land-cover data (e.g. CLC Land cover)
   - Data on biodiversity (e.g., FBI, GIS Maps Natura 2000)
   - Land-use data and data on meadows and grassland distribution
   - Farm-input data
   - HNV created on farm under RDP
   - FADN data
2) Primary data: Soil and input use monitoring data at farm level (micro-level analysis) (FADN, IACS)
3) Secondary data: Land-cover data, habitat data, Natura2000 data
4) Spatial aspects: Farm level

5) Temporal dimensions: Annual (FBI), periodic (CLC)
6) Data processing: Statistical software
7) Sensitivity to data quality:
8) Consequences of data gaps:
9) Other: The primary data collection is enhanced by an additional survey to assess water quantity, as enacted by new updates provided by the European Commission (Reg (EU) 385/2012).

Biodiversity (HNV)

4.8.5 % UAA under Natura 2000 (Protected forest)

1) Type of data:
   - % UAA under Natura 2000
   - Land-cover data (CLC)
   - Biodiversity (e.g., FBI, GIS maps, Natura 2000)
   - Input use
   - HNV created on farm under RDP
2) Primary data: Soil and input use monitoring data at farm level
3) Secondary data: Land cover data, habitat data, Natura2000 data
4) Spatial aspects: Farm level
5) Temporal dimensions: Periodic
6) Data processing: Fragstats, ArcGIS Patch Analyst or R.
7) Sensitivity to data quality:
8) Consequences of data gaps:
9) Other: It is not possible to define a common methodology for the whole EU. For example, Germany has taken the sampling approach for HNV farmland recognising about 1,000 sites, each of 100 ha, while some other countries, such as Sweden and UK, have landscape or countryside surveys that may be useful for developing HNV survey methods. However, surveys of established sample sites could be complemented with random sample surveys outside these sites. Random sample surveys of farming practices are undertaken as part of FSS data gathering, and could be extended to cover HNV farming criteria. These surveys should allow a comparison of trends in HNV characteristics on farms that participate in RD measures, with trends on farms that do not participate.

4.8.6 Crop diversity index

1) Type of data:

- Land cover (CLC)
- Biodiversity (e.g., FBI, GIS maps, Natura 2000)
- Land-use data and data on meadows and grassland distribution
- Farm input data
- HNV created on farm under RDP

2) Primary data: Soil and input use monitoring data at farm level (micro level analysis) (FADN, IACS)
3) Secondary data: Land-cover data, habitat data, Natura 2000 data
4) Spatial aspects: Farm level
5) Temporal dimensions: Annual (FBI), periodic (CLC)
6) Data processing: Fragstats, ArcGIS Patch Analyst or R.
7) Sensitivity to data quality:
8) Consequences of data gaps:

4.8.7 Conservation status of agricultural habitats (grassland)

1) Type of data:
    - Land cover (CLC)
    - Assessments of agricultural habitats (grasslands) that have a favourable/unfavourable-inadequate/unfavourable-bad/intermediate conservation status: hectares and % of total assessments of habitats
    - Data on biodiversity (e.g., FBI, GIS maps, Natura 2000)
    - Land use; meadows and grassland distribution
    - HNV created on farm under RDP
2) Primary data: Soil-coverage data
3) Secondary data: Land-cover data, habitat data, Natura2000 data, national data prepared by DG ENV.
4) Spatial aspects: Farm level
5) Temporal dimensions: Periodic (CLC)
6) Data processing: Fragstats, ArcGIS Patch Analyst or R.
7) Sensitivity to data quality:
8) Consequences of data gaps:

4.8.8 Farming intensity

1) Type of data:

- UAA managed by farms with low/medium/high input intensity per ha (% of total UAA)
- Areas of extensive grazing: UAA utilised for extensive grazing (UAA with livestock density<1 LU/ha of forage area) (% of total UAA)
- Inputs considered for the sub-indicator 'Farm input intensity': fertilisers, pesticides and feedstuff purchased by the holdings.
- Areas of extensive grazing: grazing livestock production (cattle, sheep, goat) with a stocking density not exceeding 1 livestock unit per ha of forage area (forage crops, permanent pastures and meadows and common land).
- Farm input

2) Primary data: Soil and input use monitoring data at farm level (FADN, IACS)
3) Secondary data: FADN and EUROSTAT
4) Spatial aspects: Farm level
5) Temporal dimensions: Annual
6) Data processing: Fragstats, ArcGIS Patch Analyst or R.
7) Sensitivity to data quality: Low
8) Consequences of data gaps:
9) Other: This sub-indicator is based on the agro-environmental indicator 15 'Intensification/extensification', which measures the trends of these inputs use.

Biodiversity Wildlife

4.8.9 Stock and Change of linear habitats and biotopes in agricultural landscapes

1) Type of data:
   - Land cover data (CLC)
   - Data on biodiversity (eg. FBI, GIS maps, Natura 2000)
   - Land use and meadows and grassland distribution
   - Farm input data
   - HNV created on farm under RDP
2) Primary data: Soil and input use monitoring data at farm level (micro-level analysis) (FADN, IACS)
3) Secondary data: Farm Bird Index at regional level (LIPU); land cover data, habitat data, Natura 2000 data at regional level
4) Spatial aspects: Farm level
5) Temporal dimensions: Annual (FBI), periodic (CLC)

6) Data processing: Fragstats, ArcGIS Patch Analyst or R.
7) Sensitivity to data quality:
8) Consequences of data gaps:

Landscape

4.8.10 Protection of Landscape and specific natural elements

1) Type of data:
   - Land-cover data (CLC)
   - Data on biodiversity (e.g., FBI, GIS maps, Natura 2000)
   - Land-use data and data on meadows and grassland distribution
   - Farm-input data
   - HNV created on farm under RDP
2) Primary data: Soil and input use monitoring data at farm level (micro level analysis) (FADN, IACS)
3) Secondary data: Land-cover data, habitat data, Natura 2000 data
4) Spatial aspects: Farm level
5) Temporal dimensions: Annual (FBI), periodic (CLC)
6) Data processing: Fragstats, ArcGIS Patch Analyst or R.
7) Sensitivity to data quality:
8) Consequences of data gaps:

4.8.11 Stock and change of linear habitats and biotopes in agricultural landscapes

1) Type of data:
   - Land-cover data (CLC)
   - Data on biodiversity (e.g., FBI, GIS maps, Natura 2000)
   - Land use and meadows and grassland distribution
   - HNV created on farm under RDP
   - Farm-input data
2) Primary data: Soil and input use monitoring data at farm level (micro-level analysis) (FADN, IACS)
3) Secondary data: Land-cover data, habitat data, Natura2000 data
4) Spatial aspects: Farm level
5) Temporal dimensions: Annual (FBI), periodic (CLC)
6) Data processing: Fragstats, ArcGIS Patch Analyst or R.
7) Sensitivity to data quality:

8) Consequences of data gaps:

4.9 Mixed Method approach

Animal Welfare

4.9.1 Quality of livestock housing

1) Type of data:
   - Input – Output tables at national or regional level
   - Agriculture investments
   - Measure for the livestock sectors
   - Area of farmland participating in RDP – IACS
   - Area of farmland eligible for RDP measure
   - IACS data for CAP and RDP measures
   - FADN and agricultural census
   - Economic data of other sectors (e.g. down and upstream sectors), depending on the level of sectorial disaggregation
   - Livestock system
2) Primary data: Requires monitoring data from farm surveys. Sample strategy of selected farms should cover a representative sample of different livestock and husbandry systems and include RDP participating and non-participating farms.
3) Secondary data: FADN and Census data. They require adequate detail to be able to distinguish differences in land use and land cover with the participating and non-participating areas. This method is based on farm-level data which can be aggregated and analysed at different farm levels. Instead of spatial variations, differentiation of different farm types and livestock systems and husbandry systems are more important for animal-welfare impacts.
4) Spatial aspects: The method can be used for the assessment at different spatial levels by using different type of resolution data. However, due to the data dependency, caution is necessary in comparing results by different levels and by beneficiary/non-beneficiary analysis.
5) Temporal dimensions: Updates for data are periodic, dependent on the type of datasets and data sources. However, often these data do not overlap with RDP programme cycles.
6) Data processing: It may impair the ability to measure the impact of RDP on this public good.
7) Sensitivity to data quality:

8) Consequences of data gaps:
9) Others: Household or/and farm surveys might be needed to obtain additional farm and household data.

4.9.2 Grazing area / outdoor access

1) Types of data needed:
   - Input – Output tables at national or regional level,
   - Agriculture investments, measure for the livestock sectors
   - Area of farmland participating in RDP – IACS
   - Area of farmland eligible for RDP measure
   - IACS data for CAP and RDP measures
   - FADN and agricultural census data
   - Economic data of other sectors (e.g. down and upstream sectors), depending on the level of sectorial disaggregation
   - Animal livestock. If applied at smaller regional level, household or/and farm surveys might be needed to obtain additional data.
2) Primary data: No need for primary data
3) Secondary data: The data required are secondary data, which require adequate detail to be able to distinguish differences in land use and land cover with participating and non-participating areas.
4) Spatial aspects: The method can be used for the assessment at different spatial levels by using different types of resolution data. However, due to the data dependency, caution is necessary in comparing results by different levels and by beneficiary/non-beneficiary analysis.
5) Temporal dimension: Updates for data are periodic, dependent on the type of datasets and data sources. However, often these data do not overlap with RDP programme cycles.
6) Data processing: It may impair the ability to measure the impact of RDP on this public good.
7) Sensitivity to data quality:
8) Consequences of data gaps:

5 Comparison of the Data and Monitoring Requirements of the Candidate Methods

Although there have been recent advancements in methodologies for the evaluation of the environmental impacts of RDP, literature reviews, stakeholders interviews and focus groups previously conducted by WP4, WP5 and WP9 within the ENVIEVAL project highlighted the lack of adequate and specific data that could undermine the results of evaluation exercises. The analysis in Section 4 about the detailed description of data requirements for each selected method reported similar results. Data availability, and reliability and degree of accuracy in generalising results, are the main emerging challenges within environmental evaluation for RDPs, particularly for some public goods and selected methods. The long-term unavailability of specific datasets and the lack of appropriate micro-level data for the selected public goods when assessing a vast range of environmental variables could undermine the accuracy in the evaluation exercise. Thus, suitable data, datasets and data sources need to be identified, which are causally linked to each other and frequently monitored. The next Subsections will summarise the key aspects of the data-monitoring requirements of the candidate methods. Subsection 5.1 matches the outputs of the Section 4 about the data requirement for selected method for each public good. Additionally, Subsection 5.2 aims to score the required data in relation to the selected micro-level methods, assigning four scores on the basis of the specific quality of data, datasets and data sources. Subsection 5.3 provides for some comments of main results from Subsections 5.1 and 5.2.

5.1 Comparison of the Data and Monitoring Requirement of the Candidate Methods

The following summary tables assess the data requirements of the different methods, highlighting differences in the principal requirements with respect to data types, level of detail, spatial and temporal dimensions, data processing, applicability in case-study areas and micro/macro linkage. The assessment of the data requirements will be reviewed during and after the case study testing, with the aim of developing a classification of the data and monitoring requirements of the tested micro-level evaluation methods for the methodological handbook.

Table 3 Summary Table – Climate Stability

Dimensions	Carbon footprint	Farm Survey
Type of data	• The footprint approach requires specific data for the system referred to matter and energy flows • Required data from input – output statistics, GHG inventory and agricultural data bases (e.g. IACS, FADN, Census, Eurostat and data from EEA)	• Farm survey provides a detailed profile of the potential environmental performance of farms • The required data are relative to ammonia emissions, production of renewable energy and direct use of energy in agriculture
Primary monitoring data	• Input use	• Primary data on changes in agricultural practices and ammonia emissions are required
Sample size	• Large sample of farms (e.g. correspondent to FADN's field of observation)	• Large sample of farms (e.g. correspondent to FADN's field of observation)
Spatial dimension	• CF is an indicator that lends itself well to the calculation of a the single production unit (farm) • Method representative at the micro level	• The spatial dimension of ammonia emission data is NUTS 2 • Farm level in case of production of renewable energy and energy use
Temporal dimension	• Input-output tables periodically updated	• Ammonia emission, energy use and production are annually updated
Processing requirements	• CF can be considered as a subset of data derived from LCA approach. LCA is based on International Standards (ISO 14040, ISO 14044) and on environmental labels and declarations (ISO 14020, ISO 14024, ISO 14025)	• Data can be processed with common statistical software
Applicability in case-study areas	• The complexity of the analysis increases with the complexity of the considered typology of production systems (e.g., Mixed farms compared to mono-cultural farming systems)	• Depending on availability of required data
Micro-macro linkage	• Problems may occur in scaling-up as the reference database must be able to be statistically representative, not only in the quality and quantity of inputs purchased and used by farmers, but also the implemented agricultural practices	• Depends on availability of data required at farm level for participating and non-participating farms

Table 4 Summary Table – Water Quality

Dimensions	Biophysical Model	Water footprint	Farm Survey
Type of data	• Biophysical model requires a series of input data (consumption of fertilisers, Gross Input of manure and other Inputs) • Potential surplus of nitrogen (GNS) on agricultural land and potential surplus of phosphorus on agricultural land (kg /ha/year) • Secondary data (e.g. Agricultural Census; CLC; FADN; LPIS; FSS)	• The footprint approach requires specific data for the system referred to water flows • Input – output data and agricultural databases (e.g. IACS, FADN, Census, Eurostat and data from EEA).	• Farm survey provides for a detailed profile of the potential environmental performance of farms • Required data are related to water quantity used for agricultural activities
Primary monitoring data	• Water use and fertilization input use • Monitoring data at farm level	• Water use and fertilization input use • Monitoring data at farm level	• Water use and fertilization input use • Monitoring data at farm level
Sample size	• Farm sample (e.g., FADN's field of observation)	• Farm sample (e.g., FADN's field of observation)	• Farm sample (e.g., FADN's field of observation)
Spatial dimension	• Data applied at the farm/parcel level, strictly dependent by sample size (FADN, CLC)	• CF is an indicator that lends itself well to the calculation of a the single production unit (farm)	• Farm level
Temporal dimension	• The update for data is periodic, dependent by the type of datasets and data sources, often not in sink with RDP program cycle • Gross Nutrient Balance (4 year average)	• Input-output tables often only updated periodically	• The update for data is periodic, dependent by the type of datasets and data sources, often not in sink with RDP program
Processing requirements	• GNB is calculated as the balance between inputs and outputs of nutrients to the agricultural soil	• LCA is based on International Standards (ISO 14040, ISO 14044) and on environmental labels and declarations (ISO 14020, ISO 14024, ISO 14025)	• Data can be processed with common statistical software
Applicability in case-study areas	• Depending on the availability of monitoring data on water quality	• The complexity of the analysis increases with the complexity of the considered production systems	• Depending on availability of data required.
Micro-macro linkage	• Problems may occur in scaling-up in case of database is not statistically representative	• Problems may occur in scaling-up in case of database is not statistically representative	• Problems may occur in scaling-up in case of database is not statistically representative

Table 5 Summary Table – Soil

Dimensions	Biophysical Model
Type of data	• Biophysical model requires a series of input data (e.g., crop management, soil type and agricultural inputs) • Land cover (CLC) Land Parcel Information System (LPIS - GIS data)and Land use at cadastral level • Soils data: Regional Soil Maps and slope (%)
Primary monitoring data	• No primary data are required
Sample size	• Farm level
Spatial dimension	• Data should be applied at the farm/parcel level, however they are strictly dependent by the sample size of data sources (FADN, CLC). • It is possible to have information at different level of detail and using aggregation between the results of detailed assessment.
Temporal dimension	• The temporal dimension strictly depends on the frequency of the land cover data. GIS-based data can help to partially overcome the temporal gaps among data.
Processing requirements	• Fragstats, ArcGIS Patch Analyst or R
Applicability in case-study areas	• Required case-study areas with a good availability of monitoring data on soil quality
Micro-macro linkage	• Problems may occur in scaling-up in case of database is not statistically representative

Table 6 Summary Table – Biodiversity HNV

Dimensions	**Spatial Analyses with geo-statistical approach**	**Hierarchical Model**	**Farm Survey**
Type of data	• Land cover (CLC) (i.e. semi-natural pastures and meadows traditional orchards; mosaics of low-intensity crop types; fallow land in low intensity farming systems) • % UAA under Natura 2000 • Biodiversity (e.g., FBI, GIS maps, Natura 2000) • HNV created on farm under RDP • Land use at cadastral level, • Landscape, Phytosociological and Vegetation maps (e.g., 1:5000)	• Land cover (CLC) (i.e. semi-natural pastures and meadows traditional orchards; mosaics of low-intensity crop types; fallow land in low intensity farming systems) • % UAA under Natura 2000 • Biodiversity (e.g., FBI, GIS maps, Natura 2000) • HNV created on farm under RDP • Land use at cadastral level, • Landscape, Phytosociological and Vegetation maps (e.g., 1:5000)	• % UAA under Natura 2000, Land cover data (CLC), Biodiversity (e.g., FBI, GIS maps, Natura 2000), HNV created on farm under RDP
Primary monitoring data	• Habitat survey data of RDP/non RDP areas; hierarchical sampled survey	• No primary data are required	• Habitat survey data of RDP/non RDP areas; hierarchical sampled survey
Sample size	• Farm sample (e.g., FADN's field of observation)	• Farm sample (e.g., FADN's field of observation)	• Farm sample (e.g., FADN's field of observation)
Spatial dimension	• Data should be applied at the farm/parcel level, however they are strictly dependent by the sample size of data sources (FADN, CLC).	• Data should be applied at the farm/parcel level, however they are strictly dependent by the sample size of data sources (FADN, CLC).	• Data should be applied at the farm/parcel level, however they are strictly dependent by the sample size of data sources (FADN, CLC).
Temporal dimension	• The update for data is periodic, dependent by the type of datasets and data sources, often not in sink with RDP program cycle	• The update for data is periodic, dependent by the type of datasets and data sources, often not in sink with RDP program cycle	• The update for data is periodic, dependent by the type of datasets and data sources, often not in sink with RDP program cycle
Processing requirements	• Statistical software	• Statistical software	• Statistical software
Applicability in case-study areas	• Required case-study areas with a good availability of monitoring data	• Required case-study areas with a good availability of monitoring data	• Required case-study areas with a good availability of monitoring data
Micro-macro linkage	• Problems may occur in scaling-up in case of database is not statistically representative	• Problems may occur in scaling-up in case of database is not statistically representative	• Problems may occur in scaling-up in case of database is not statistically representative

Table 7 Summary Table – Biodiversity Wildlife

Dimensions	Statistical sampling with spatial analysis	Farm Survey
Type of data	• Richness; Abundance of agricultural birds species (FBI) (European Rural Network) • Secondary data: Area of farmland participating in RDP (IACS); Land cover (CLC) Land use at cadastral level and Habitat data (Managing Authority RDP 2007/2013)	• Richness; Abundance of agricultural birds species (FBI) (European Rural Network) • Secondary data: Area of farmland participating in RDP (IACS); Land cover (CLC) Land use at cadastral level and Habitat data (Managing Authority RDP 2007/2013)
Primary monitoring data	• No primary data are required	• Biodiversity survey data of RDP/non RDP areas
Sample size	• Farm sample (e.g., FADN's field of observation)	• Farm sample (e.g., FADN's field of observation)
Spatial dimension	• Evaluations should take place at the field/plot scale or at landscape scale (to assess wider-scale populations benefits), as appropriate for the species being studied	• Method can be applied at different spatial levels, but most useful application for RDP evaluation with detailed farm data
Temporal dimension	• Each Member State collected FBI data yearly during the period 2000 – 2012.	• Data are periodically updated, dependent by the type of datasets and data sources, often not in sink with RDP program cycle
Processing requirements	• PCA; GLM; Software R. • FBI is a multi-species index obtained by the aggregation of a set of individual species indices using a geometric mean.	• Statistical software
Applicability in case-study areas	• Required case-study areas with a good availability of monitoring data	• Required case-study areas with a good availability of monitoring data
Micro-macro linkage	• Data mainly exist at national and EU level aggregation. FBI should be calculated at a lower level, by bio-geographical areas (different agricultural habitats) on the basis of geo-referenced data.	• It depends from the data representativeness. Often data do not represent a significant sample to be up-scaled at macro level

Table 8 Summary Table – Landscape

Dimensions	Landscape metrics	Farm Survey
Type of data	• Data required mainly refers to land use, land cover, landscape and biodiversity data • Application at micro level largely relies on secondary data (e.g. Agricultural Census, IACS; CLC; FADN; LPIS; FSS); landscape, vegetation maps; habitat survey; Natura 2000 Network; RS and aerial photography data	• Land cover data (CLC) • Biodiversity data (e.g., FBI, GIS maps, Natura 2000) • Land use data and data on meadows and grassland distribution • Farm input data • HNV created on farm under RDP • Soil and input use data at farm level (FADN, IACS)
Primary monitoring data	• No primary data are required	• Biodiversity survey data of RDP/non RDP areas
Sample size	• Farm sample (e.g., FADN's field of observation)	• Farm sample (e.g., FADN's field of observation)
Spatial dimension	• Data should be applied at the farm/parcel level, however they are strictly dependent by the sample size of data sources (FADN, CLC). For example, the minimum mappable area by FADN is 25 ha, and it is not completely fit for this analysis at the micro level	• Method can be applied at different spatial levels, but most useful application for RDP evaluation with detailed farm data
Temporal dimension	• Data are periodically updated, dependent by the type of datasets and data sources, often not in sink with RDP program cycle	• Updates for data are periodic, dependent by the type of datasets and data sources. However, often these data do not overlap with RDP program cycle
Processing requirements	• Fragstats, ArcGIS Patch Analyst or R.	• Statistical software
Applicability in case-study areas	• Requires case-study areas with a comprehensive database of farm management and livestock's characteristics. • Links evaluation with contextual information and improves assessment of causal linkages (assess connectivity and pattern)	• Requires case-study areas with a comprehensive database (farm level)
Micro-macro linkage	• It depends from the data representativeness. Often data do not represent a significant sample to be up-scaled at macro level	• It depends from the data representativeness. Often data do not represent a significant sample to be up-scaled at macro level

Table 9 Summary Table – Animal Welfare

Dimensions	**Mixed Method Approach**
Type of data	• Agriculture investments, measure for the livestock sectors • Secondary data: e.g. Area of farmland eligible for RDP measure, IACS data for CAP and RDP measures, FADN and agricultural census, Economic data of other sectors (e.g. down and upstream sectors),
Primary monitoring data	• Requires monitoring data from farm surveys • Sample strategy of selected farms should cover a representative sample of different livestock and husbandry systems and include participating and non-participating to RDP
Sample size	• Farm sample (e.g., FADN's field of observation)
Spatial dimension	• Data should be applied at the farm/parcel level, however they are strictly dependent by the sample size of data sources (FADN, CLC)
Temporal dimension	• Data are periodically updated, dependent by the type of datasets and data sources. However, often these data do not overlap with RDP programme cycle
Processing requirements	• Complex sampling design of multi-level observations at farm level
Applicability in case-study areas	• Requires case-study areas with a good availability of monitoring data on livestock
Micro-macro linkage	• Mixed Method Approach allows to combine or to link micro and macro level analysis using one consistent sampling and data set

5.2 Comparative Score of the Data and Monitoring Requirement of the Candidate Methods

Based on these statements, the Summary Tables proposed below aim to score the data quality in relation to the selected micro-level methods for each impact indicator. Four scores have thus been assigned in relation to the specific quality of data, datasets and data sources: Low (+), Low/Medium (++), Medium/High (+++), High (++++). These scores represent the weighted average evaluated for each indicator related to the methods for that specific public good. For example, the score reported in the Summary Table - Soil, evaluated through the method Biophysical Model, is the result of a weighted average of the score applied to the CMEF Impact Indicators ‘Soil Erosion by Water (% of UAA affected by certain rate of soil erosion)’ and ‘Soil organic matter in arable land’, as reported in Table 3.1.

Low (+) score indicates that:

- the availability is poor for the biggest part of types of data
- sources do not provide for adequate data
- available types of data are not fit to the requirement of the selected method
- data cannot be up-scaled or aggregated
- the spatial dimension of data does not overlap to the RDP one
- the temporal dimension of data does not overlap to the RDP one
- the data processing is inadequate for the requirement of the selected method.

Generally, data quality can be considered as poor for evaluation exercise.

Low/Medium (++) score indicates that:

- the availability is sufficient for few types of data
- sources provide for few types of adequate data
- few types of data fit to the requirement of the selected method
- few types of data can be up-scaled or aggregated
- the spatial dimension of few types of data overlaps to the RDP one
- the temporal dimension of few types of data overlaps to the RDP one
- the processing of few types of data fits for the requirement of the selected method.

Generally, the quality of few types of data can be considered as good for evaluation exercise.

Medium/High (+++) score indicates that:

- the availability is good for several types of data
- sources provide for several types of adequate data
- several types of data fit to the requirement of the selected method
- several types of data can be up-scaled or aggregated
- the spatial dimension of several types of data overlaps to the RDP one
- the temporal dimension of several types of data overlaps to the RDP one
- the processing of several types of data fits to the requirement of the selected method.

Generally, the quality of several types of data can be considered as good for evaluation exercise.

High (++++) score indicates that:

- the availability is high for nearly all the types of data
- sources provide nearly all the types of data
- nearly all the types of data can be up-scaled or aggregated
- the spatial dimension of nearly all the types of data overlaps to the RDP one
- the temporal dimension of nearly all the types of data overlaps to the RDP one
- the processing of nearly all the types of data fits with the requirement of the selected method.

Generally, the quality of nearly all the types of data can be considered as high for evaluation exercise.

Table 10 Score Table – Climate Stability

Dimensions	Carbon Footprint	Farm Survey
Type of data	++	+++
Primary monitoring data	++	++
Sample size	++	+++
Spatial dimension	++	+++
Temporal dimension	++	+++
Processing requirements	++	+++
Applicability in case-study areas	++	++
Micro – macro linkage	+	++

Table 11 Score Table – Water Quality

Dimensions	Biophysical Model	Water Footprint	Farm Survey
Type of data	+++	++	+++
Primary monitoring data	++	++	+++
Sample size	+++	++	+++
Spatial dimension	++	++	+++
Temporal dimension	++	+	+++
Processing requirements	+++	++	+++
Applicability in case-study areas	+++	++	+++
Micro-macro linkage	++	+	++

Table 12 Score Table – Soil

Dimensions	Biophysical Model
Type of data	+++
Primary monitoring data	+
Sample size	+++
Spatial dimension	+++
Temporal dimension	+++
Processing requirements	++
Applicability in case-study areas	+++
Micro – macro linkage	+++

Table 13 Score Table – Biodiversity HNV

Dimensions	Spatial Analysis with Geo-statistical Approach	Hierarchical Models	Farm Survey
Type of data	+++	+++	+++
Primary monitoring data	++	++	+++
Sample size	++	++	+++
Spatial dimension	++	+	+++
Temporal dimension	++	+	+++
Processing requirements	+++	++	+++
Applicability in case-study areas	+++	++	+++
Micro-macro linkage	++	++	+++

Table 14 Score Table – Biodiversity Wildlife

Dimensions	Statistical Sampling with spatial analysis	Farm Survey
Type of data	+++	+++
Primary monitoring data	++	+++
Sample size	++	++
Spatial dimension	+++	+++
Temporal dimension	+++	+++
Processing requirements	++	++
Applicability in case-study areas	+++	+++
Micro-macro linkage	++	+++

Table 15 Score Table – Landscape

Dimensions	Landscape Metrics	Farm Survey
Type of data	+++	+++
Primary monitoring data	+++	+++
Sample size	++	++
Spatial dimension	++	++
Temporal dimension	++	++
Processing requirements	++++	+++
Applicability in case-study areas	++	+++
Micro – macro linkage	++	+++

Table 16 Score Table – Animal Welfare

Dimensions	Mixed method approach
Type of data	++
Primary monitoring data	++
Sample size	++
Spatial dimension	+
Temporal dimension	++
Processing requirements	+
Applicability in case-study areas	+
Micro – macro linkage	+

5.3 Main Results from Comparing Methods of Data Requirements

The provided information in this Subsection come from results matching Summary Tables for the comparison of data and monitoring requirement (Subsection 5.1) and Score Tables for the comparative score of data and monitoring requirement (Subsection 5.2). Generally, in both the Subsections, the need emerges to acquire additional and more targetted information to strengthen the data requirement. This is verified both for recognised methods, e.g. Farm Survey or Statistical Sampling, and for methods such as Carbon and Water Footprint, that just in the past few years have been established as evaluation methods for Climate Stability. Moreover, differences emerge in both the methods and the different variables in the same method. For example, criticisms are highlighted for the Mixed Method Approach, for which the data quality is generally poor and inadequate for the environmental evaluation of Animal Welfare. However, in this case, criticisms are exacerbated by the fact that Animal Welfare is probably one of the most underexplored public goods in terms of RDP evaluation at micro level, and further adjustments and updates are required in terms of robustness of the method(s), particularly targeting the processing requirement. In other cases, methods are under adjustment and updates (e.g., Carbon and Water Footprint). Several limitations are also underlined about the robustness of current methodologies at micro level, particularly for the Carbon Footprint. In this case, current EU databases such as FADN and IACS cannot provide all the types of required data. Furthermore, data cannot significantly represent the complexity of the statistical universe, or the quality of data strictly depends on the types of targeted productive system to be evaluated.

Regarding Biophysical Models, the data requirement has been adequately assessed because the method has been efficiently consolidated within RDP evaluation and thus shows robustness in most of the variables within the Summary Tables Water Quality and Soil. The same trend can be highlighted for Farm Survey, that usually represents the baseline activity for farm data collection. In fact, good score values have been reported for the application of this method on the tested public good. However, for example in the case of Landscape, insufficient information is provided in relation to the sample size of the Farm Survey method. For all the public goods analysed through Farm Survey, mainly FADN data are required, even though they cannot significantly represent the complexity of the statistical universe. For Spatial Analysis with geo-statistical approach and statistical sampling, data requirements and processing show more robustness. For example, for Biodiversity HNV and Wildlife, good data quality has been reported. Although some gaps in data availability and representativeness (see Section 4.2 for further qualification) exist, they have shown their effectiveness and reliability since RDP 2000-2006, with updates in the following RDPs. Regarding Landscape metrics methods, they show a good level of reliability for Landscape, due to their consolidated trend within RDPs, as well as hierarchical models for the Biodiversity HNV assessment. The presented contents show that RDP evaluation is still challenging in terms of data requirement. There is a general lack of data at farm level that can trivialise the micro-level evaluation through the use of inadequate data and considerably undermine the representativeness of evaluation exercises. Although EU databases such as FSS and FADN aim to fill the gaps in micro-level farm/field data availability, in some cases they cannot sufficiently ensure representativeness of all farms (such as HNV farmland areas or Biodiversity Wildlife). In other cases, the high sensitivity of biodiversity data to the characteristics of species and population, or the high dependency of Carbon Footprint by the complexity of the production system, make it difficult to ensure a robust and consistent evaluation for the data requirement of Biodiversity Climate Stability or Water Quality.

In conclusion, the micro-level data for the environmental evaluation of RDP should be developed in a more consistent and standardised way, for example through more targeted and accurate data collection at farm level, in order to provide for a detailed overview of the whole farming system. Moreover, one of the main pressing questions is to ensure the representativeness of the data collected at farm level. Farming systems, in fact, need to find a common baseline within all EU MS, and thus this complexity of active variables cannot be simplified through extemporaneous analysis. However, it has to be emphasised that the complexity of the agricultural systems seriously restricts the possibility of assessing specific methodologies to reduce uncertainty in measuring the complexity. Thus, it is difficult to find a common way to collect all the ranges of environmental, social and economic data describing the EU agricultural system in its entirety. This is particularly problematic for the farm level, which ENVIEVAL has identified as the most suitable level for the micro analysis. Finding methods that ensure the total representativeness of data is a crucial challenge for the project and for the evaluation analysis in general.

6 Key Aspects for the Structure of the Databases for the Case Studies from a Micro-level Perspective

This Section underlines the most relevant aspects about the state-of-the-art on data requirements of the candidate methods at micro level, to be used as the baseline for the structure of the database for case studies. The next step for the ENVIEVAL project is to build a consistent database to serve as a baseline for applying selected methods to selected public goods. Section 4 assessed the data requirements of the selected methods, while Section 5 summarised the quality of the information provided in Section 4 through matching Summary Tables for the comparison of data and monitoring requirement (Subsection 5.1) and Score Tables for the comparative score of data and monitoring requirement (Subsection 5.2). The previous contents aimed to provide a clear perspective of limitations and potentialities of each of the selected methods for the indicators applied to evaluate specific public goods. Key aspects reported below will thus represent the keystone for the database structure. This must be appropriate to highlight the potentialities of data to ensure effectiveness in RDP evaluation, highlighting which are the main gaps still existing in terms of data requirements.

Indicators and other variables: As Section 4.2 showed, the effectiveness of the indicators for micro-level evaluation is different. In fact, not all CMEF indicators can be used in case-study areas due to the lack of data collection. For example, the CMEF indicator for Climate Stability ‘Emissions from Agriculture’ is not easily quantifiable for MS where agricultural activities are limited along the years or are seasonal, or not relevant in RDPs. Moreover, some indicators (such as those for Climate Stability and Animal Welfare) require a high level of detail of data that can also be obtained through an additional data collection. However, these additional activities are costly, and are limited by current restrictions of budgetary resources, particularly for regional public institutions.

Data types: Generally, common types of data within public goods are those related to FADN, Agricultural Census and Eurostat databases. Additionally, each public good requires specific data for environmental evaluation, such as FBI for Biodiversity Wildlife, GNB for Water Quality or animal welfare indicators. Furthermore, GNB for Water Quality does not inform on the form (organic, ammonia, nitrate) in which nitrogen is in the soil, and thus is difficult to assess the real leaching quantity of nitrogen.

Sample size/population covered: Data availability and sources do not include an appropriate population in terms of size, coverage and representativeness. Most of the databases present criticisms in terms of micro-level evaluation either ‘structural’, such as FADN, or due to the relatively recent introduction within environmental exercises, such as specific data for Carbon Footprint. Regarding Biodiversity, both FSS and FADN data cannot sufficiently ensure representativeness of all the farms, particularly of the smaller ones (see for example the cases of UAA in calculating HNV farmland areas through FADN data). Additionally, FBI data strictly depends on the sampled species, and do not consider the totality of species. Also CLC does not completely fit with micro level due to the minimum mappable area is 25 ha. In the same way, Carbon and Water Footprint methods retrieve data for a number of variables within production systems, and thus their matching can be a complex task. Thus, there is not a sample able to cover the whole set of potential variables within the production systems. The optimum would consist of a sample that represents the targeted productive system, and results can just be considered as general indications that do not provide the real values of the footprint. For Landscape, farm sample cannot represent all farms. Landscape variables present a macro scale rather than a micro-scale dimension (for example, the spatial complexity of landscapes cannot be reduced to the level of complexity within the sample farm).

Data formats: All the methods in Section 4 require data at farm or parcel level. Raw data collected by EU National and local databases need to be processed to be used. Processing mainly takes place though statistical software that provides a final value. Some data are annually collected, such as FADN data or biodiversity data for FBI. All the other databases, such as FSS, have periodic updates. Conversely, sometimes data have not been updated recently, such as CLC. Furthermore, most of them cannot be easily overlaid with RDPs and in this way are less effective in environmental evaluation. In the specific case of GHG, the IPPC periodically updates its databases. For example, the last updates of 2013 are based on 2010 GHG data. Data are mainly elaborated through statistical software and GIS application, that provides the spatial dimension and distribution of such data. Periodic data collection can imply breaks, such as in the case of CLC, that has updated three times in the period 1990-2006, with a random frequency (1990 -2000-2006). This can affect the quality of data compared to RDP implementation.

Spatial aggregation: In evaluation, micro level is substantially represented by the farm, which is considered as the simplest management unit of the agricultural system. The spatial aggregation will thus consist of up-scaling and aggregating data from farm level to regional and national ones. However, as highlighted in the previous Sections, micro/macro linkage can be difficult, in relation to the criticisms, in ensuring the representativeness of assessed data to the universe of farms. Even though up-scaling could facilitate the consistency in micro/macro linkage aggregation, it has to be highlighted that the occurring risk of summarising micro-level data for a macro-level perspective cannot always be ensured to represent the complexity of the universe of the agricultural systems, and to not show the net effects of the evaluation on the public good.

Consistent integration of multiple data sources: Multiple data sources are required for micro-level evaluation, deriving from different databases and providing for different data with different metrics and terminology. Regarding the terminology to be used, ENVIEVAL partners have conventionally decided to define the farm as the baseline unit for micro-level analysis. However, it has to be underlined that the 'farm level' cannot correspond to the same meaning in different evaluation exercises as applied in MS.

Quality and consistency checks: Quality and consistency of some data require to be checked in order to establish relevant aspects. In these terms, attention should be focused on the Carbon Footprint for Climate Stability, which is probably the newest method within the whole range of selected methods. In particular, the types of data need to be evaluated so that it is the data best able to represent as many types of production systems as possible. In terms of HNV, even though they are consolidated within RDP evaluation, their representativeness should be strengthened, starting from a better accuracy in FADN collection. In addition, the FBI indicator should be adjusted by the collection of information for a wider range of species, as well as additional data collection for the current ones.