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Review

Mapping and monitoring High Nature Value farmlands: Challenges in European landscapes

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ABSTRACT

The importance of low intensity farming for the conservation of biodiversity throughout Europe was acknowledged early in the 1990s when the concept of 'High Nature Value farmlands' (HNVf) was devised. HNVf has subsequently been given high priority within the EU Rural Development Programme. This puts a requirement on each EU Member State not only to identify the extent and condition of HNVf within their borders but also to track trends in HNVf over time. However, the diversity of rural landscapes across the EU, the scarcity of (adequate) datasets on biodiversity, land cover and land use, and the lack of a common methodology for HNVf mapping currently represent obstacles to the implementation of the HNVf concept across Europe. This manuscript provides an overview of the characteristics of HNVf across Europe together with a description of the development of the HNVf concept. Current methodological approaches for the identification and mapping of HNVf across EU-27 and Switzerland are then reviewed, the main limitations of these approaches highlighted and recommendations made as to how the identification, mapping and reporting of HNVf state and trends across Europe can potentially be improved and harmonised. In particular, we propose a new framework that is built on the need for strategic HNVf monitoring based on a hierarchical, bottom-up structure of assessment units, coincident with the EU levels of political decision and devised indicators, and which is linked strongly to a collaborative European network that can provide the integration and exchange of data from different sources and scales under common standards. Such an approach is essential if the scale of the issues facing HNVf landscapes are to be identified and monitored properly at the European level. This would then allow relevant agri-environmental measures to be developed, implemented and evaluated at the scale(s) required to maintain the habitats and species of high nature conservation value that are intimately associated with those landscapes.

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1. Introduction

Agriculture is a dominant form of land management, accounting for almost 40% of the world's terrestrial surface (Balmford et al., 2005; Donald and Evans, 2006; Dudley et al., 2005; Gordon et al., 2010; Millennium Ecosystem Assessment, 2005; Power, 2010). Over the second half of the 20th century, regular food shortages in many parts of the world and rapid population growth, underpinned a worldwide expansion of agricultural production (Benton et al., 2003; Bignal and McCracken, 2000; Evenson and Gollin, 2003; FAO, 2011; Firbank, 2005; Gordon et al., 2010; Tilman et al., 2002), but often at high costs for biodiversity (Aavik and Liira, 2009; FAO, 2011; Stoate et al., 2009; Tilman et al., 2001). Agriculture is a major driver of contemporary global environmental change and of unprecedented rate of biodiversity loss (Amano et al., 2011; Foley et al., 2005; Plieninger and Bieling, 2013; Tilman et al., 2001; Wade et al., 2008). In recent years, broad-scale polarisation

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has been observed in agricultural landscapes, with increasing intensification of already intensively managed land being accompanied by the abandonment of less productive, more extensively managed land (Bignal and McCracken, 1996, 2000; Bratli et al., 2006; Caraveli, 2000; Dietschi et al., 2007). Intensification of agricultural practices has involved a marked increase in the use of external inputs (e.g. agrochemicals) and resulted in a massive homogenization of agricultural landscapes and loss and fragmentation of natural and semi-natural habitats (Bratli et al., 2006; Halada et al., 2011; Jongman, 2002). A similar decrease in habitat diversity and simplification of landscape mosaics through spontaneous forest encroachment has also been described as a consequence of abandonment of less productive or remote agricultural landscapes (Lomba et al., 2012; Pedroli et al., 2007; Plieninger and Bieling, 2013; Plieninger et al., 2006). The impacts on biodiversity of such changes to agricultural practices and related patterns of landscape heterogeneity have been widely described, and the role of low-intensity agriculture for agro-biodiversity conservation acknowledged (Aavik and Liira, 2009; Albrecht et al., 2007; Altieri, 1999; Amano et al., 2011; Bartel, 2009; Bignal and McCracken, 2000).

Agriculture is also the dominant land-use in Europe (EEA, 2006; Halada et al., 2011; Henle et al., 2008; Stoate et al., 2009) and it has been estimated that 50% of all species in Europe depend on agricultural habitats (Benton et al., 2003; EEA, 2009; Halada et al., 2011; Kristensen, 2003; Stoate et al., 2009; Tscharntke et al., 2005). Over past centuries, traditional agricultural systems shaped European landscapes, enhancing environmental conditions to the benefit of a wide range of wild species and habitat types, many of which are of particular nature conservation concern, e.g. listed as of conservation priority in the European Union (EU) Species and Habitats Directives (EEA, 2004, 2009a; European Commission, 2011; Halada et al., 2011; IEEP, 2007a; Plieninger and Bieling, 2013). Such inherently biodiversity-rich farming systems, including livestock, arable, permanent crop or mixed farming systems, usually rely on traditional low intensity practices (Andersen et al., 2003; Beaufoy et al., 1994; EEA, 2004; Pedroli et al., 2007; Van Doorn and Elbersen, 2012. Characterised by low livestock grazing densities, the use of fallow between arable crops and low inputs per unit of area of nutrients, agrochemicals and irrigation in arable and permanent crop systems (Beaufoy et al., 1994; Van Doorn and Elbersen, 2012), such farming systems are referred to as 'High Nature Value farmlands' (hereafter HNVf), since they contribute to maintain natural habitats and viable populations of wild species of highest conservation value (Beaufoy et al., 1994; Bignal and McCracken, 1996, 2000; Henle et al., 2008; Plieninger and Bieling, 2013).

As recent losses for ecological value in many European rural landscapes have been attributed to changing agricultural practices, nature conservation and rural development priorities have progressively converged within EU agricultural and environmental policies, thus contributing to an increased efficiency and progress towards conservation goals and targets (Jongman, 2013). In particular, there is a growing interest in maintaining traditional, extensive practices and preserving (semi-)natural habitats and other structural/functional features of rural landscapes (Bartel, 2009; Doxa et al., 2012; EEA, 2004, 2009a; EENRD, 2009; Stoate et al., 2009). To achieve such policy challenge, improved knowledge of ongoing changes in the extent, distribution and condition of HNV farmlands is essential (EEA, 2012). Even if HNVf overlap, to a large extent, with traditional agricultural landscapes, as they both often rely on low input farming systems, a spatial and typological quantification of such overlap still remains a challenge. Further, no comprehensive data exists regarding European traditional landscapes and the currently available descriptions of farming systems maintaining HNV farmlands lack the required detail or such detail is only locally available (EEA, 2004, 2012; IEEP, 2007b; Paracchini et al., 2008).

This manuscript provides an overview of the characteristics of farmlands with high value for nature conservation across Europe, together with an indication of their importance to the conservation of biodiversity across the EU and the rationale for the development of the HNVf concept. Current mainstream methodological approaches for the identification and mapping of HNVf across EU-27 and Switzerland are reviewed, the main limitations of these approaches highlighted and recommendations made as to how the identification, mapping and reporting on HNVf extent, state and trends across Europe can potentially be improved and harmonised under these constraints.

2. Defining farmlands with high value for conservation

2.1. High Nature Value farmlands and support for biodiversity

The importance of low intensity farming for the conservation of wildlife and biodiversity in general throughout Europe was acknowledged early in the 1990s when the concept of 'High Nature Value farmlands' was devised (Andersen et al., 2003; Baldock et al., 1993; Bartel, 2009; Beaufoy et al., 1994; Henle et al., 2008). HNV farmlands comprise '*areas in Europe where agriculture is a major (usually the dominant) land use and where that agriculture supports, or is associated with, either a high species and habitat diversity or the presence of species of European conservation concern, or both*' (Andersen et al., 2003; Beaufoy et al., 1994; EEA, 2004; Pedroli et al., 2007). HNV farmlands relate to low external input farming systems under traditional practices which support European habitats and species of high importance for nature conservation (Plieninger and Bieling, 2013). Overall, HNVf concept relies on the assumption that many of the European habitats and landscapes considered of high nature conservation value depend on the continuation of specific low-intensity farming systems (Doxa et al., 2012; Henle et al., 2008; Peppiette, 2011), as they were often found to be positively related to high levels of biodiversity (Andersen et al., 2003; Beaufoy et al., 1994; Bignal and McCracken, 1996; EEA, 2009; Pedroli et al., 2007; Weissteiner et al., 2011). Even so, this concept does not imply a causal relation between farming practices and the existence of High Nature Value on farmlands (Andersen et al., 2003). In fact, high species and/or habitat diversity may exist alongside, or despite, current farming systems, although for most categories of HNVf there would have been a positive link at least historically (Andersen et al., 2003).

HNV farming areas still remaining in Europe are currently estimated as ca. 30% of the European Utilised Agricultural Area (UAA; EEA, 2004, 2009a; Van Doorn and Elbersen, 2012). The largest areas of traditional agricultural landscapes are found in eastern and southern Europe and contain habitat types such as semi-natural grasslands, *dehesas* and *montados* (the terms used for open, wooded pastures in Spain and Portugal, respectively), steppe grasslands, permanent crops (such as fruit and nut orchards and olive groves), and arable crops in dryland areas where naturally regeneration through one to three year fallow is used to help rebuild soil nutrients before the next non-irrigated crop is planted. HNVf are also relatively abundant in mountainous regions across Europe and contain upland grassland and heathland habitats in association with pastures, hay meadows and small areas of crops from which additional winter fodder for the livestock is produced (Andersen et al., 2003; Beaufoy et al., 1994; Calvo-Iglesias et al., 2009; EEA, 2004, 2012; IEEP, 2007b; Paracchini et al., 2008). Some of the most critical nature conservation issues in Europe relate to changes to traditional farming practices on these habitats. Many of these habitats can only be maintained by farming practices, since

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natural sources of disturbance (e.g. grazing pressure from wild herbivores) would nowadays not be enough to replace farming due to long term human management of the landscape (Navarro and Pereira, 2012; Pedroli et al., 2007; Plieninger and Bieling, 2013). Taking the land out of agricultural production is often not the appropriate choice for nature conservation, but rather it is vital to ensure that the intensity of agricultural management is appropriate (Bignal and McCracken, 1996, 2000; Prince et al., 2012). At a regional scale, maintaining active farming of HNV areas is not incompatible, but rather spatially and functionally complementary, with passive management and rewilding of abandoned land, proposed as a promising land management option for nature conservation and ecosystem services in Europe (Navarro and Pereira, 2012).

HNV farmlands have as common denominators the low intensity farming characteristics, the presence of semi-natural vegetation and species of conservation interest, and the diversity of land cover types (Andersen et al., 2003; Bartel, 2009; Beaufoy et al., 1994; Plieninger and Bieling, 2013). HNV farmlands have been described as 'mosaics' of natural and semi-natural agricultural habitats e.g. unimproved grazing land and traditional hay meadows, intermingled with other farmland features such as mature trees, shrubs, scrub or linear habitats such as field margins and hedges, significant for low intensity cropping, and the enclosed field systems or Bocage landscapes that extend all along Atlantic Europe (Bartel, 2009; Beaufoy et al., 1994; IEEP, 2007a). The heterogeneous character of HNVf landscapes provide a wider variety of habitats and resources which enable the coexistence of wildlife alongside farming activities, thus enhancing agricultural biodiversity (Amano et al., 2011; Bàrberi et al., 2010; Bartel, 2009; IEEP, 2007a). High levels of biodiversity in HNVf further support the provision of ecosystem services beyond production of food, fibre and fuel, thereby contributing, for example, to the recycling of nutrients, the control of local microclimate, and the regulation of local hydrological processes (Altieri, 1999; Amano et al., 2011; Kleijn et al., 2009).

2.2. Typology of High Nature Value farmlands

HNVf biodiversity hotspots are usually associated with low-intensity management practices are dominant (see Fig. 1). Such landscapes exhibit high levels of heterogeneity of land cover and the widespread presence of semi-natural vegetation such as extensive grasslands (Beaufoy, 2008; Bignal and McCracken, 2000; Peppiette, 2011; Weissteiner et al., 2011). Fig. 1 frames the backbone characteristics underlying HNVf concept, and the relevant features applied to define the three broad types proposed after Andersen et al. (2003), and later slightly modified (see e.g. Oppermann et al., 2012; Paracchini et al., 2008, 2006; Pedroli et al., 2007):

- Farmlands under low-intensity management with a high proportion of associated semi-natural vegetation used as a forage or fodder resource are labelled as type 1, which are by definition dependent on extensive agriculture to persist (expressed as the "Extensive Practices" and "Landscape Elements" indicators; see Fig. 1). Considered the most widespread type, HNVf type 1 consists mainly of grazed semi-natural vegetation such as grassland, scrub or woodland, or a combination of all different types (Andersen et al., 2003; Beaufoy, 2008). The high proportion of semi-natural vegetation underpins other levels of biodiversity (such as butterflies and birds) of high conservation concern and thus its high overall value (e.g. wood pastures in the Baltic region);

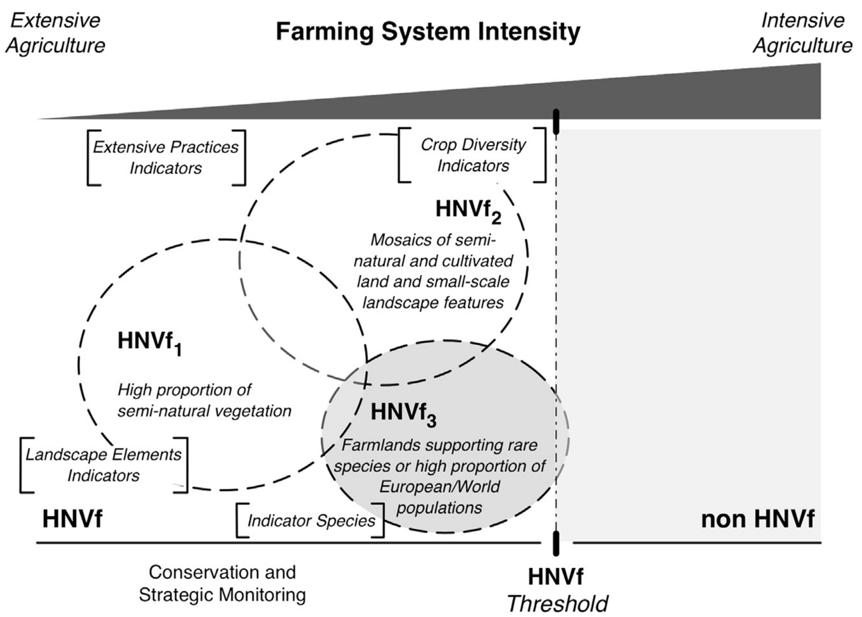

Fig. 1. High Nature Value farmlands (HNVf) conceptual framework in relation to the intensity of farming systems, and features underlying the classification of the three broad types as proposed by Andersen et al. (2003). HNVf$_1$ correspond to extensively managed farmlands with high proportion of semi-natural vegetation (expressed as the extensive practices and landscape elements indicators). HNVf$_2$ are defined as farmlands where low intensive inputs are usually associated with mosaics of semi-natural and cultivated land, intermingled with small scale landscape features (reflected as crop diversity indicators). HNVf$_3$ farmlands support rare species or high proportions of European or world populations even if coincident with more intensively farmed landscapes (indicator species). Farming systems that enhance or maintain high levels of farmland biodiversity are considered to be HNVf and thus prone to conservation and strategic conservation and monitoring programmes, whereas other intensively managed farmlands are considered to be beyond the HNVf threshold and thus considered as non HNVf. Indicators that express the extensive character of agricultural practices, diversity of crops and landscape elements support the typology of HNVf types and thus are embedded in the figure in relation to the HNVf that they define. (HNVf$_1$, High Nature Value farmlands type 1; HNVf$_2$, High Nature Value farmlands type 2; HNVf$_3$, High Nature Value farmlands type 3). Intersections between HNVf, and with non HNVf do not represent quantitative proportions, but rather they express functional relationships between the targeted agricultural landscapes.

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- Farmlands dominated by low intensity management and mosaics of semi-natural and cultivated land and small-scale landscape features are labelled as type 2 and identified by the "Crop Diversity" indicator (Fig. 1; Andersen et al., 2003; EEA, 2004; Paracchini et al., 2008). Diversity of habitats at the landscape level supports a range of species of high nature conservation concern (e.g. in the *pseudo-steppe* landscapes associated with dryland (non-irrigated) natural fallow-based cropping systems in Spain, Portugal, southern Italy and Greece); and,
- Farmlands that provide habitat used by a large proportion of the total European or global population for one or more rare species (or species of conservation concern, IEEP, 2007b, Fig. 1; "Indicator Species") are labelled as type 3. This designation was mainly developed to refer to situations where otherwise intensively managed farmland supports over-wintering or breeding of large flocks of migratory birds such as geese or waders (e.g. Friesland and Arkemheen polders in the Netherlands).

This categorisation of three broad types of HNVf expresses the relationships between the farming systems and practices, and habitats and species regarded as of high nature conservation value (Fig. 1). The potential, however, for some degree of overlap between these three types e.g. the coexistence of HNVf type 1 and 2 in the same landscape, or the fact that type 3 can occur at a relatively small-scale, in an otherwise intensively managed landscape (Andersen et al., 2003; IEEP, 2007a), can make it difficult to identify consistently the different elements of this typology in practice. The limitations associated with the implementation these three recognised types of HNVf at a landscape, regional, national or European level are considered in more detail later in the manuscript.

3. Implementation of the High Nature Value farmlands concept

3.1. A brief overview of the political context and framework

Agricultural expansion and intensification was noteworthy in the post-WWII Europe (Stoate et al., 2009; Supplementary Material 1), and in such environment the 'Green Revolution' framework established the backbone for the early stages of the EU Common Agricultural Policy (CAP) (Ewert et al., 2005; Piorr, 2003; Pretty, 2008). Initially, the CAP aimed to increase productivity and provide more food at a lower cost for EU countries, while also achieving a fair standard of living for farmers. This was achieved through stabilisation of markets (through a single market with common prices) and a more autonomous approach with less reliance on imports and preference given to member states as well as free movement of goods (Ackrill et al., 2008; EEA, 2009; Piorr, 2003; Stoate et al., 2001; Young et al., 2010, 2005).

However, prior to the introduction of the CAP, it was already policy of many European countries to encourage the technological development of agriculture in the drive for higher production. By the 1980's, the CAP and its market and structural support policies were held responsible for increasing habitat degradation, overproduction of food products, intensification of farming practices, and the concentration of production in larger, specialised farms (Donald et al., 2002; EEA, 2007; EEA, 2009; EEA, 2007; Markovic et al., 2012; Young et al., 2005), thus causing an accelerated loss of agricultural biodiversity and the homogenisation of rural landscapes (Jongman, 2002). From the early 1980s on, the CAP experienced a series of changes emphasising the control of surplus production and to provide compensation for loss of income as a result of adopting environmentally sensitive forms of farming. As an example, the 1992 reform recognised the environmental role of farming by increasing the availability of agri-environmental schemes across the EU, which was further acknowledged with the Agenda 2000 reform (1998) that introduced environmental cross-compliance and the opportunity for farmers to obtain support for additional activities other than farming *per se*. Recently (2003), changes removed the focus on production and increased the focus on environmental concerns within the CAP (e.g. Calvo-Iglesias et al., 2009; EEA, 2007).

Changes to the CAP over the past 30 years have done little to increase financial support to farming systems that maintain HNVf. Under the original conception of the CAP, the low-intensity nature of these farming systems and the fact that their ability to produce was constrained by the environmental conditions in which they operate, meant that they did not receive large amounts of production oriented support payments. Despite the increased focus on the environment in the CAP in recent years, HNV farming systems remain economically unviable not only because they are intrinsically unable to produce high yields to sell on the market, but also because their historic level of production-oriented support payments have been low and in most cases unable to compensate for this since the collective amount of agri-environmental payments potentially available to them has been low. Combined with commercial competition and technological change, current policies create an operating environment in which HNV farming systems face a choice between intensification (e.g. higher stocking rates, switch to fast maturing commercial breeds) or abandonment of farming altogether (Boccaccio et al., 2009; EEA, 2009).

3.2. High Nature Value farmland indicators in the assessment of the EU rural development policy

In 2005, the European Commission acknowledged that EU farmlands with High Nature Value were still under threat of intensification and of abandonment. HNVf concept was, therefore, adopted by the European Commission and all EU Member States were urged to ensure that the Sustainable Land Management elements of their individual 2007–2013 Rural Development Programmes (RDPs) targeted the "… *biodiversity and preservation of High Nature Value farming and forestry systems, water and climate change*". A suite of HNVf indicators were thus defined and included in the Common Monitoring and Evaluation Framework (CMEF; EC, 2005), the main mechanism by which the European Commission assesses the individual progress of Member States on the requirements set out in their rural development policies on biodiversity (EC, 2005, 2006a, b; Van Doorn and Elbersen, 2012).

The CMEF includes 'Baseline', 'Result' and 'Impact' Indicators designed to assess whether the HNV farmlands are being maintained (in terms of their extent and quality) throughout the period that RDP's are active (EC, 2005, 2006b). To this end, area under HNV farming, the 'Baseline Indicator', is intended to be used as reference against which the impact of RDP support to HNVf can be assessed. The 'Result Indicator' measures the total amount of hectares under successful land management, defined as the completion of land management actions aimed at conservation of agro-biodiversity i.e. contributing to biodiversity and High Nature Value farming and avoidance of marginalisation and land abandonment (2007–2013 RDPs; Beaufoy, 2008). The 'Impact Indicator' aims to evaluate changes in HNV farmlands in both their extent and condition, and thus to assess what has really been achieved in terms of HNV protection with the resources used.

Guidelines to support MS on the implementation of the HNVf indicators were provided in the documents of the European Evaluation Network for Rural Development, which are complementary to the CMEF handbook (EC, 2006b; Peppiette, 2011). Under these guidelines, it was recognised that HNVf varied markedly across Europe and that no single definition could be applied. Each Member

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State is therefore encouraged not only to decide on the most relevant data sources and methodological approaches to report on the predefined indicators, but also on whether these indicators can be used to allocate RDP resources to farmlands with HNV (EC, 2006b; Van Doorn and Elbersen, 2012).

Since the HNV Impact Indicator was designed to detect both quantitative and qualitative changes in HNV farming and forestry of Member States or regions, its operationalization relies on the implementation of a system of data collection that is sufficiently frequent, and topically and spatially precise, to capture such changes over a short period of time i.e. the seven year period of the Rural Development Programmes (EENRD, 2009; IEEP, 2007b). This has, however, proved problematic in many instances, as is detailed in the following section.

4. Improving the mapping of HNV farmlands in European rural landscapes

4.1. Current approaches to map HNV farmlands

The relevance of HNVf in the broader context of the EU commitments and efforts to efficiently halt biodiversity loss has been acknowledged from both scientific and political viewpoints (Pedroli et al., 2007). Even though few studies have focused on the description of mapping approaches for HNV farmlands (e.g. Andersen et al., 2003; Paracchini et al., 2006; Pointereau et al., 2007), efforts have been invested in the organisation of several workshops and seminars to debate current and novel approaches that could contribute to improve HNVf identification and mapping (e.g. Hoogeveen et al., 2002; Krautzer et al., 2011; Peppiette, 2011; Plieninger and Bieling, 2013; Trisorio and Borlizzi, 2011). Table 1 presents an overview of the number publications describing methodological approaches for HNVf identification and mapping in EU27 and Switzerland, and results from a wide set of EU case-studies. Due to the complexity and number of currently available publications, the extended version of the table, which is complementary to Table 1, is presented as Supplementary Material 2.

The approaches developed include the identification, description and establishment of indicators and ranges/thresholds expressing management practices that contribute or enhance HNV farmlands, or that can be applied to assign farmlands as non HNV areas (e.g. those supported by data related to farming systems; see also Fig. 1). The geographic identification of the farmlands that actually correspond to areas of HNVf has been highlighted as urgent

Table 1
Overview of the number of publications to-date focussed on High Nature Value farmlands (HNVf) identification and mapping since the concept was acknowledged by Beaufoy et al. (1994). The Assessment unit/scale was determined, whenever possible, from information provided in each publication against the acknowledged hierarchical system for the EU economic territory the EU – NUTS classification; http://epp.eurostat.ec.europa.eu/portal/page/portal/nuts_nomenclature/introduction. Data types refer to the primary and/or ancillary datasets, including Land cover, Protected Areas/Habitats, Biophysical and climatic indicators, Farming characteristics and practices, and Species data, used to HNVf identification and mapping. Methodological approaches summarize the method described in each publication, following those described formerly by Andersen et al. (2003) and Paracchini et al. (2008). HNVf types summarize the number of publications in the cases where the identification and mapping of HNVf types, following the broad types as defined by Andersen et al. (2003), was part of the aims. Bold numbers highlight the highest values determined from the considered publications for each field of information presented.

Assessment unit/scale		Data types	Methodological approaches	HNVf types			References
				Type 1	Type 2	Type 3	
European	3	Land Cover (3) Protected/Sensitive Areas (2) Biophysical environment (0) Farming Systems (1) Species Data (3)	Land cover approach (0) Farming system approach (0) Species approach (0) Combined approach (3) Other approaches (0)	3	3	3	Andersen et al. (2003); Paracchini et al. (2008); EEA (2012)
National	**20**	Land Cover (14) Protected/Sensitive Areas (4) Biophysical environment (2) Farming Systems (12) Species Data (7)	Land cover approach (0) Farming system approach (1) Species approach (1) Combined approach (5) Other approaches (13)	12	12	9	Beaufoy et al. (1994) which provides information on 7 national studies; Belényesi and Podmaniczky (2007); Pointereau et al. (2007); Elbersen and Eupen (2008); Danckaert et al. (2009); Pointereau et al. (2010); Olivero et al. (2011); Stefanova and Kazakova (2012); Poux and Ramain (2012); Oppermann et al. (2012); Trisorio et al. (2012); Elbersen et al. (2012); Jones (2012)
NUTS 1	11	Land Cover (9) Protected/Sensitive Areas (4) Biophysical environment (1) Farming Systems (4) Species Data (4)	Land cover approach (3) Farming system approach (0) Species approach (0) Combined approach (6) Other approaches (2)	8	7	4	Poetsch (2013); Bartel et al. (2011); Danckaert et al. (2012); Riedel et al. (2012); Kovář et al. (2012); Beaufoy et al. (1994); Kurlavičius (2012); Aquilina and Ivanovic (2012); Cierna-Plassmann (2012); Cunder (2012)
NUTS 2	2	Land Cover (0) Protected/Sensitive Areas (1) Biophysical environment (1) Farming Systems (0) Species Data (0)	Land cover approach (0) Farming system approach (0) Species approach (0) Combined approach (0) Other approaches (2)	2	0	0	Sullivan et al. (2011); Galdenzi et al. (2012)
NUTS 3	2	Land Cover (0) Protected/Sensitive Areas (1) Biophysical environment (0) Farming Systems (2) Species Data (1)	Land cover approach (0) Farming system approach (0) Species approach (0) Combined approach (1) Other approaches (1)	2	2	2	Samoy et al. (2008); Acebes et al. (2013)
LAUs	5	Land Cover (4) Protected/Sensitive Areas (0) Biophysical environment (0) Farming Systems (5) Species Data (1)	Land cover approach (0) Farming system approach (1) Species approach (0) Combined approach (4) Other approaches (0)	5	5	0	Carvalho-Santos et al. (2010); Doxa et al. (2010); Almeida and Pinto-Correia (2012); Almeida et al. (2013); Pinto-Correia and Almeida (2013)
Total	43	Land Cover **(31)** Protected/Sensitive Areas (12) Biophysical environment (4) Farming Systems **(24)** Species Data **(16)**	Land cover approach (3) Farming system approach (2) Species approach (1) Combined approach **(19)** Other approaches **(18)**	**32**	29	18	

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in the EU context and they are targeted for monitoring in the context of RDP's and other environmental policies (e.g. EC, 2006b; EEA, 2004). In addition, the identification and selection of effective spatially-explicit indicators that could be used as expressing landscape and/or crop heterogeneity in relation with the acknowledged biodiversity levels and management practices has been encouraged (e.g. Beaufoy, 2008; BioBio, 2012; EEA, 2012; EENRD, 2009; European Commission, 2010, 2011; Wascher et al., 2010).

The Nature of Farming by Beaufoy et al. (1994), established an essential benchmark for the identification and mapping of HNVf, not only by compiling information regarding the main characteristics of low intensity farming systems, and identifying potential indicators, but also by presenting preliminary spatially-explicit mapping exercises of such landscapes for selected countries (HNVf assessment at the national level, Table 1; see also Supplementary Material 2). In addition, Beaufoy et al. (1994) acknowledged land cover types as proxy indicators of farming systems intensity. As a follow-up, the first European assessment of farmlands with High Nature Value was presented by Andersen et al. (2003) in a report for the European Environmental Agency countries (HNVf assessment at the European level, Table 1; see also Supplementary Material 2). This had the aim of establishing indicators for HNV farming, evaluating its potential spatial distribution in Europe and assessing the potential implications for the CAP and for EU's environmental policies (Andersen et al., 2003; Paracchini et al., 2008; Peppiette, 2011).

Due to the inherent distinct characteristics of HNVf types, Andersen et al. (2003) further advocated the need to implement different methodological approaches to address the mapping of HNVf types 1, 2 and 3. The framework proposed by Andersen et al. (2003) to assess and estimate the distribution of HNVf in Europe relied on the selection of land cover information (classes of CORINE Land Cover with a close relationship to semi-natural vegetation) and farming system data (derived from the Farm Accountancy Data Network, FADN) to provide a spatially-explicit representation of HNVf types 1 and 2 (Paracchini et al., 2008). The resulting map was then refined using data on indicator bird species (expressing HNVf type 3). This approach allowed a first European perspective of the distribution of HNVf to be obtained. It also established a common framework for the analysis and interpretation of HNVf coverage over Europe. Three methodological approaches were proposed: i) the land cover approach, based on land cover data and built on the assumption that some land cover types and features can be used as proxy indicators of HNVf (e.g. Corine LCCs that express potential low-intensity agricultural areas, applicable to HNVf types 1 and 2; Andersen et al., 2003); ii) the farming system approach, based on data reflecting farming practices (e.g. from FADN) and built on the assumption that such data can assist the identification of those systems that promote the maintenance or enhancement of nature value, applicable to HNVf 1 and 2; and, iii) the species approach, based on indicator species data and built on the assumption that it is the presence of such species that defines the High Nature Value (Andersen et al., 2003; Beaufoy, 2008).

Such approaches have, since then been applied and described spanning all relevant spatial scales and decision levels (Table 1; see also Supplementary Material 2 for more detailed information). Some have been used at the European scale (EEA, 2012; Paracchini et al., 2008), but most have been attempted at the national (Belényesi and Podmaniczky, 2007; Pointereau et al., 2007; Trisorio et al., 2010; Van Doorn and Elbersen, 2012), regional (NUTS 2; Galdenzi et al., 2012; Sullivan et al., 2011) or local scales (e.g. Local Administrative Units, LAUs; e.g. Carvalho-Santos et al., 2010; Doxa et al., 2010). In addition to these diverse methodological frameworks, a set of ancillary approaches, often based on multi-scalar information, have also been used to produce more robust and realistic HNVf identification and mapping (Table 1; see also Supplementary Material 2).

Such exercises include the mapping of the distinct types of HNVf that can then be used to evaluate and monitor farmlands of high conservation value at the landscape level (e.g. see number of publications targeting the three types of HNVf, Table 1; see also Supplementary Material 2). In addition, data drawn from statistical or biological surveys, details of the biophysical environment, and the occurrence of protected/sensitive areas has also been used in some of the most relevant ancillary approaches. The occurrence of protected/sensitive areas has been the most frequently applied for HNVf mapping (Table 1; see also Supplementary Material 2).

Recently, a novel spatial modelling approach was proposed by Paracchini et al. (2008) to identify European HNVf. This approach was built on a multi-criteria analysis of land cover classes (from CORINE land cover classes; Paracchini et al., 2006), selected according to an environmental gradient, and overlaid with relevant areas for nature conservation. This produced a spatially-explicit representation of potential European HNV farmlands based on a 1 km^2 grid.

Nevertheless, most recently proposed European-scale approaches seem to lack the spatial and temporal resolution which is necessary when looking at national and regional (e.g. NUTS 2) scales. Hence, although common frameworks to identify, map and monitor have been developed and described (e.g. Andersen et al., 2003; EC, 2006b; Paracchini et al., 2008), the recent approaches implemented at national and/or regional scales are utilising a wider set of new, more specific datasets such as national surveys (e.g. biodiversity and farm systems; Samoy et al., 2008), biophysical properties based on soil datasets and topographic maps (Aquilina and Ivanovic, 2012), and national systems of protected areas/habitats (Belényesi and Podmaniczky, 2007).

4.2. Caveats associated with identification, mapping and monitoring

Some of the most relevant caveats associated with the identification and mapping of HNVf across the European landscapes arise from the inherent characteristics of the concept, as defined first by Beaufoy et al. (1994) and more recently by Andersen et al. (2003), Parachnini et al. (2008, 2006) and also EENRD (2009); IEEP (2010).

HNV farmlands are, by definition, landscapes where low intensity agriculture is dominant, and are characterized either by high cover of semi-natural vegetation/habitats (HNVf type 1), high density of small scale landscape elements (HNVf type 2), or those landscapes, often more intensively managed, that support species with high conservation interest (HNVf type 3). As a result, one of the as yet unanswered questions is how to implement and operationalize a low-intensity farming based concept that can also accommodate the more intensively managed farmlands supporting species of conservation interest (HNVf type 3)? A further question concerns how to balance the need to identify HNVf type 3 farmlands with the need to establish a threshold for farming practices intensity above which farmlands are then considered as non HNV?

Even if the three broad classes of HNVf are intended to be a continuum and not precise categories with sharp boundaries, they nevertheless seem to hamper a more accurate, straightforward and coherent implementation of the concept. The establishment of a commonly agreed and acceptable threshold expressing the intensity of the underlying farming practices (see Fig. 1) is, therefore, a pressing need if agricultural landscapes with High Nature Value are to be defined accurately (Andersen et al., 2003; Beaufoy, 2008; EEA, 2012; IEEP, 2007a).

The three broad HNVf classes (and thus the concept itself) rely, to some extent, on land cover and farming systems data as the two

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main sources of information. Such data are clearly related to the main methodological approaches that have been applied (see Section 4.1). Whilst land cover and farming systems approaches have been broadly applied (e.g. Oppermann et al., 2012; Peppiette, 2011), they have also caused difficulties with HNVf implementation, particularly given the lack of adequate spatial (and temporal) coverage for some MS (e.g. Beaufoy, 2008; EEA, 2012; Paracchini et al., 2008; Peppiette, 2011). In addition, the lack of accurate and robust data on the distribution of farming systems has been reported for many MS, and even when such data are available they often lack a spatial component or are under strict privacy protection and therefore inaccessible (e.g. Beaufoy, 2008; EENRD, 2009; IEEP, 2010; but also see Krautzer et al., 2011; Paracchini et al., 2008; for exceptions). The lack of consistency in relation to the spatial and temporal resolution of farming system data held at EU member state level is also an important consideration (e.g. Paracchini et al., 2008), since this puts constraints on identifying and discriminating HNVf landscapes using a common framework at the European level. Similar limitations have also been acknowledged for data on land cover (e.g. EEA, 2012; IEEP, 2010; Paracchini et al., 2008). One of the most relevant limitations of land cover maps is their coarse spatial and thematic resolution, since that limits the ability to establish direct and accurate correspondences between land cover types and natural and semi-natural habitats (e.g. the inability to make a clear distinction between semi-natural and more intensively managed grasslands; Beaufoy, 2008; Peppiette, 2011), that could otherwise provide a good preliminary approximation for identification and mapping of HNVf types 1 and 2. Also, as land cover maps do not take into account, explicitly, the intensity of land management, it is not possible to discriminate between different farming intensities and therefore between HNV and non HNV areas (EEA, 2012; Weissteiner et al., 2011).

Limitations on the spatial accuracy in existing datasets have been widely debated in the context of the EU mapping of HNV farmlands based on Corine Land Cover (Andersen et al., 2003; Paracchini et al., 2006; EEA, 2012), and also with regard to HNVf mapping at other scales (e.g. Beaufoy, 2008). Low spatial resolution often result in insufficient mapping detail regarding landscape elements e.g. scattered trees, hedgerows (see Section 2.2. for more details), since these usually fall far below the minimum size for mapping units (e.g. 25 ha in the case of the Corine land Cover; Beaufoy, 2008; EEA, 2012; Paracchini et al., 2008, 2006). In addition, higher spatial resolution on land cover data has been assumed to be useful tool to improve landscape analysis and the determination of factors such as edge density and mean patch size, which can be important in the identification and mapping of HNVf type 2 (Peppiette, 2011; see also Section 2.2). A major lack of adequate temporal resolution has also been observed for land cover and farming system datasets. Given that the frequency of acquisition/update of most of the relevant datasets is not adequate, this puts constraints on the ability to monitor trends in HNVf and thus to report on the HNVf result and impact indicators (see also section 3.2). This therefore compromises the evaluation and monitoring of the Member States RDPs and ultimately the EU efforts for conservation of agricultural landscapes (e.g. see Peppiette, 2011).

Similar issues also apply to the use of ancillary data of a spatially-explicit nature. In fact, data concerning vegetation cover (Acebes et al., 2013; Galdenzi et al., 2012) and International Bird Areas (Belényesi and Podmaniczky, 2007) have been applied at local scales, however the limitations for use of such data type at a European scale have already been described and acknowledged. Further, the available information frequently lacks a direct spatially-explicit component, which is an essential element for HNVf mapping (e.g. EEA, 2012; Peppiette, 2011).

Caveats have also been reported for data on indicator species distributions (e.g. birds, butterflies; see section 2.2) at an EU level when seeking to use these for the identification of farmlands assignable to HNVf type 3 (Bartel, 2009; Boccaccio et al., 2009; Paracchini et al., 2008). Even so, the use of plant indicator species appears to constitute an even more complex challenge, since there is no consensus in relation to which plants species should be used to identify such landscapes, and those that have been used are mostly derived from national/regional expert judgement (e.g. Beaufoy, 2008; Paracchini et al., 2008). As indicator species are often rare, their current distribution is usually restricted (expressed as a low number of populations) and/or is poorly known, thereby limiting their application in HNVf type 3 mapping. Conversely, in the case of more broadly distributed, one of the remaining challenges is which criteria (e.g. minimum thresholds for proportion of global or European populations) should be defined to ascribe a given landscape as HNVf type 3. Hence, the limitations of datasets on farmland-related biodiversity are largely associated with the fact that such data vary markedly in their spatial and temporal resolution, geographic extent and level of detail recorded (e.g. Beaufoy, 2008; Peppiette, 2011).

Overall, the data-related challenges highlighted above are, at least to some extent, surpassed by the lack of any common EU guidelines indicating the methodological approach to be followed by Member States when reporting on the indicators established within the CMEF (EC, 2006b). Each country does have to report on baseline, result and impact indicators (see Section 3.2; EC, 2006b; EENRD, 2009) and express these in hectarage terms. However, although guidelines are available on the potential broad approaches to take (Beaufoy, 2008), there are no guidelines provided, for example, on the minimum data standards that should be employed or the way that regional and national information on HNVf should be structured at Member State level. The resulting diversity of HNVf datasets (e.g. the different methodologies employed; the different scales and resolutions at which HNVf is identified) across the EU means that integrating data drawn from Member States to obtain a combined EU perspective is at present difficult, if not impossible. This is at odds with the expectation that the information collected by Member States would be based on a Common Monitoring and Evaluation Framework in order to allow the condition of HNVf across the EU to be compared and contrasted.

4.3. New perspectives for successful and cost-efficient HNVf mapping

Reporting on HNVf extent and dynamics is mandatory for all Member States in the context of the assessment of their RDP's (Sections 3.1 and 3.2). The lack of specific rules or quantified criteria established at EU level for identifying HNVf does, however, mean that while some Member States have already made good progress, it is clear that others have done very little (Beaufoy, 2008; Peppiette, 2011; Van Doorn and Elbersen, 2012). As has already been highlighted, this compromises the ability to produce an accurate and more realistic spatially-explicit assessment of the state and trends of HNVf across Europe.

A major challenge is therefore to develop an effective common monitoring framework, integrating both data quality standards and methodological guidelines that could provide not only a means to overcome the major issues highlighted above, but also a cost-effective way to map HNVf at any scale. We propose a novel *bottom-up* approach to address this challenge (outlined in Fig. 2).

This proposed framework is built on the need for strategic HNVf monitoring based on a hierarchical, *bottom-up* structure of assessment units, coincident with the EU levels of political decision and

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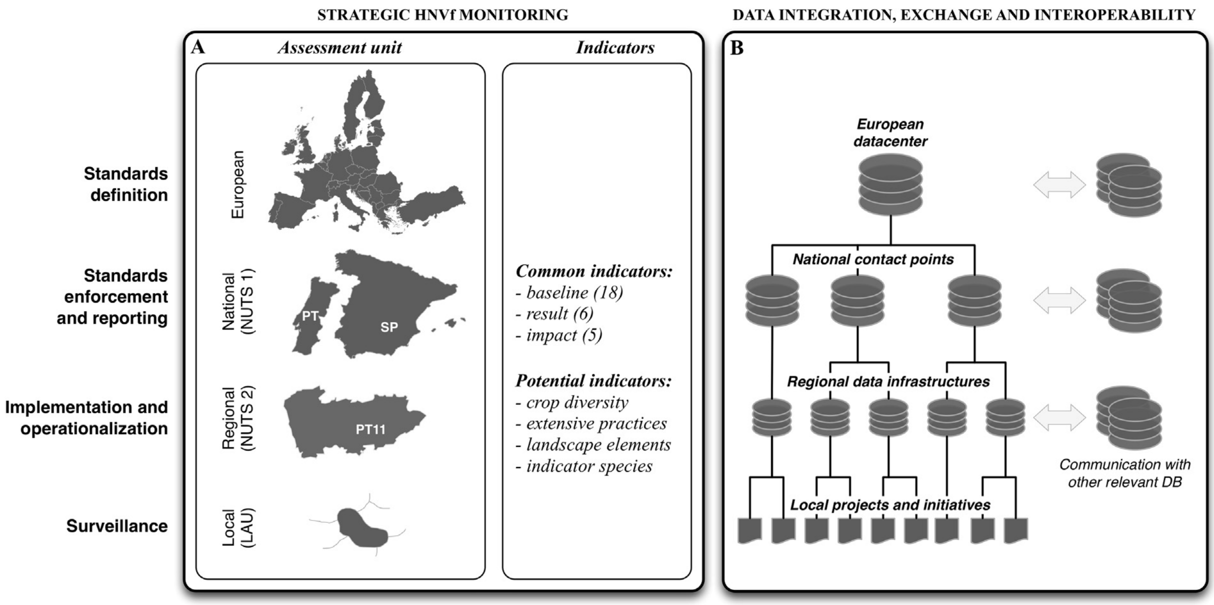

Fig. 2. Novel bottom-up approach to assess the extent and future trends for High Nature Value farmlands (HNVf). The proposed hierarchical outline relies on a multi-scale, strategic HNVf monitoring of common indicators (A), as defined by the Common Evaluation and Monitoring Framework (CMEF) in the context of the Rural Development Programmes, and on a collaborative network for an effective integration, exchange and interoperability of available datasets (B). Built on hierarchical units of assessment, ranging from local scales (e.g. LAU's, where surveillance campaigns are expected to be implemented), to regional (e.g. NUTS 2; where EU policies are implemented), national (e.g. NUTS 1, assessment unit coincident with EU reporting obligations), and European scales of implementation and reporting. Such assessment units are, to some extent, partially coincident with the common indicators (NUTS 1 and 2, depending on the MS), and more refined levels have been included to accommodate data from other potential indicators, usable to retrieve more detailed mapping on HNVf. Data integration, exchange and interoperability would also follow a similar bottom-up feeding structure, such that, data regarding more refined indicators (potential indicators) from multiple local projects and initiatives would be integrated within regional data infrastructures (coincident with the regional assessment unit), which in turn would provide such information to the national contact points, that would aggregate the information into the common indicators, and thus report to the European datacenter. LAU's refer to Local Administrative Units; NUTS 2, to basic regions for the application of regional policies, and, NUTS 1 to the major socio-economic regions, as defined by Eurostat (http://epp.eurostat.ec.europa.eu/). Numbers presented in brackets correspond to the specific indicator designation as described under the CMEF.

devised indicators (Fig. 2A), to be linked strongly to a collaborative European network providing the integration and exchange of data from different sources and scales under common standards (Fig. 2B). This approach is based on the progressive simplification and aggregation of the monitoring objectives and expected outputs as one moves to larger spatial scales, with the ultimate aim of obtaining a cohesive, European wide, representation of HNVf that can contribute effectively to policy implementation and decision making.

This hierarchical approach starts at the local surveillance level (LAU), where local authorities, in collaboration with farmer associations, NGOs and other organized groups, can contribute (according to their own background and objectives) to a regional integrated database that aggregates all contributions under a common surveillance framework (Fig. 2). These regional structures therefore ensure the implementation, coordination and operationalization of all surveillance efforts in order to be able to report the data at the national level. In order for this framework to be feasible, it is critical to implement and enforce a set of guidelines and standards that not only allow the production of a consistent report on HNVf indicators throughout Europe, but also ensure more efficient communication about HNVf within and among MS.

Such standards and guidelines should therefore address the need for: i) **clarification of HNVf related concepts**, not only with regard to clearer definitions of HNVf types but also the connections between them, and potential limitations for surveillance and monitoring; ii) **a description of common guidelines for surveillance methods and protocols**, specifically in relation to the need for spatially-explicit, more informative and accepted indicators; iii) **an effective communication and reporting structure** within the system, namely the necessity for a clear and transparent reporting chain (from local to European), so that the assessment of common aims and needs can progress easily through the different hierarchical levels; iv) **data integration and interoperability**, not only within the proposed HNVf framework but also with regard to other relevant databases related to specific areas that overlap the HNVf concept (e.g. biodiversity, remote sensing data, farm structure), highlighting the importance of following the existing guidelines for spatial data interoperability derived from the INSPIRE Directive (EEA, 2007); and, v) **data exchange and property rights** not only within the framework but also as an EU wide communication strategy both at technical and scientific levels. The combination of these five conditions are essential to ensure a common structure from which different institutions and stakeholders can obtain and contribute with valuable information to better monitor and preserve HNVf.

Although designed to comply with the requirements for reporting on HNVf, this novel framework should also be integrated as a functional component within other collaborative networks that combine past, ongoing and future environmental monitoring programmes. Such integration could allow access to a growing assemblage of tools, methods and available datasets, thus improving the capability for HNVf identification and monitoring at several spatial scales. Candidate programmes range from the Global to the European scales. For example, the Global scale could include integration with the Group on Earth Observation Biodiversity Observation Network (GEO BON; www.earthobservations.org; Battrick, 2005; Metzger et al., 2010) and the Global Monitoring for Environment and Security (GMES; http://copernicus.eu/). Examples of relevant European scale initiatives include e.g. the European Biodiversity Observation Network (EBONE; Halada, 2009); the EuMon platform for steering monitoring efforts in Europe (http://

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eumon.ckff.si/); and FP7 projects such BIO_SOS and MS MONINA (Jongman, 2013).

For example, the habitat mapping based on high resolution remote sense imagery from the BIOSOS framework (Jongman, 2013), could not only enhance the mapping of HNVf but also support the spatial discrimination of broad HNVf types and even be used for regular monitoring of trends in the extent and quality of HNVf. Additional enhancement could be achieved by integrating indicators derived from other sources (often restricted due to data sensitivity reasons), such the Farm Accountancy Data Network (FADN, http://ec.europa.eu/agriculture/rica/), the Land-parcel Identification System for implementing the CAP (LPIS; http://ies.jrc.ec.europa.eu/), the Land Use/Cover Area frame Statistical Survey (LUCAS; http://epp.eurostat.ec.europa.eu/), the EU Agri-Environment Indicators (http://epp.eurostat.ec.europa.eu), or indicators for biodiversity in low-input farming systems derived from EU-funded research such as the BioBio project (Herzog et al., 2012; Jongman et al., 2012).

5. Summary and Conclusions

Assessment of the extent, condition and dynamics of HNV farmlands in EU Member States is mandatory under the Common Monitoring and Evaluation Framework. Guidance on the potential approaches to take is available, but the lack of specific rules and quantified criteria for identifying HNVf does mean that Member States have difficulties to develop a common level of assessment. This compromises the ability to produce an accurate and realistic spatially-explicit information on HNVf across Europe.

A hierarchical, bottom-up, approach to the collaborative monitoring of HNVf is proposed as a novel way to identify, map and report on HNV farmlands at the European level. This framework is built on the need for strategic HNVf monitoring based on a hierarchical approach, coincident with the EU levels of political decision and targeted at a limited set of standard indicators. The implementation of this framework requires a collaborative European network that can harmonise and exchange data from different sources and scales under common standards. The development of such an approach is essential if the range of threats facing HNVf landscapes are to be identified and monitored properly at the European level. This will allow decision making on relevant agri-environment measures to be developed and implemented at the scale required to maintain the habitats and species of high nature conservation value that are intimately associated with those landscapes.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jenvman.2014.04.029.

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