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Editors

Birds as Useful Indicators of High Nature Value Farmlands

Using Species Distribution Models as a Tool for Monitoring the Health of Agro-ecosystems

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About the Editors

Federico Morelli is a Quantitative Ecologist, currently working as Researcher at the Czech University of Life Sciences (Prague, Czech Republic). He has been involved in several European projects modelling the impact of land use and climate change on spatial distribution of biodiversity. The main focus of his research interests is related to the response of species distribution models to multiscale predictors, the effects of landscape metrics on biodiversity patterns, the development and test of several bioindicators and the general topics of macroecology.

Piotr Tryjanowski is a professor and director of the Institute of Zoology at Poznan University of Life Sciences. His research interest includes mainly ecology of vertebrates, with particular attention to the effect of climate and environmental changes on birds and mammals. For instance, since more than 25 years he studies farmland bird populations in Poland.

Chapter 1
Introduction

Federico Morelli, Yanina Benedetti, and Piotr Tryjanowski

Abstract The decline of biodiversity in the agro-ecosystems: causes and consequences. The main differences between Western and Eastern Europe agriculture – the role of history. The development of conservation tools in Europe: from the network of protected areas and Nature2000 approach to the High Nature Value areas identification. Theories for fragmented landscapes and the application of ecological terminology for agricultural landscapes in Europe. Approaches useful to identify and characterize HNV farming systems. The HNV as support for biodiversity and public goods.

Keywords Farmland bird decline • Biodiversity conservation • Farming intensification • Protected areas • Natura2000 network • High nature value farming • HNV

1.1 The Decline of Biodiversity in the Agro-ecosystems

The agriculture is a dominant form of land use on the world's terrestrial surface, accounting for more than 40 % of land use coverage [1, 2]. In Europe, agricultural landscapes are artificial mosaics of different land use types, and represent one of the most common habitat. But during the last few decades the agricultural landscapes have been subject to a rapid and large-scale change, caused mainly by the intensification and mechanization of agricultural activities [3–8]. The agricultural intensification is devoted to feed the growing world population. However, this process is

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considered one of the chief drivers of worldwide biodiversity decline [4, 9, 10]. Agricultural intensification occurs mainly at two different spatial scales: local scale -e.g. increased use of agrochemicals or pesticides [6] and landscape scale -e.g. destruction of semi-natural and marginal habitats [11]. The latter affects the marginal and unproductive elements of farmland removing shrubs, hedgerows, isolated trees and uncultivated patches. The marginal and unproductive elements of farmland landscapes, such as shrubs, hedgerows, isolated trees and uncultivated patches, constitute key habitats for many species, for nesting, feeding and protection [12–14], as well as providing ecological corridors [15, 16] and to increase and maintain the plant communities diversity [17].

Scientists currently recognize how biodiversity loss can negatively impact on humanity in many different ways [18, 19]. The threat of biodiversity is a threat for humans for the simple reason that biodiversity is the main driver of ecosystem functioning where humans are living [20]. Then, the conservation of the biodiversity in the countryside is essential not only for intrinsic reasons, but also for very pragmatic reasons related to human benefits [21]. Mankind benefits from a range of services provided by nature [22]. From the many benefits that agriculture may obtain, some of them are directly provided by wild organisms such as pollinators or pest control in croplands provided by natural enemies [23–25].

However, the loss of biodiversity in agricultural landscapes is not uniform across Europe, and need, then, more deep understandings. Because the diversity of rural landscapes across the continent plus the inadequacy of existent datasets on biodiversity, can represent an impediment to the develop of a common strategy for all European countries [2].

1.2 Differences Between Western and Eastern Europe Agriculture – The Role of History

HNV areas are not equally distributed over Europe, but even intensity of studies on HNV farmland on birds strongly differs between areas, both in local as well as broad continental scale. Differences are connected mainly with low-intensity agricultural land use in Europe with has created many unique and species-rich assemblages [26, 27]. Paradoxically a large proportion of European species are now dependent over much of their ranges on this form of human disturbance [28]. However, the industrialization of agriculture has, directly and indirectly, caused a dramatic impoverishment of the avifauna and flora compared to the situation a century ago [29]. This has contributed not only to the current biodiversity crisis in Europe as a whole, but also to the decline in ecosystem services such as crop pollination and biological pest control [29]. Among suggested solutions to save farmland bird biodiversity are especially dedicated conservation schemes, with idea to mitigate the impacts of intensive farming, and to the support of low-intensity practices on existing high nature value (HNV) farmland. HNV farmland is present throughout Europe, although it is often restricted to upland or other areas difficult to farm, particularly in Northern and Western Europe (EEA, 2004). Eastern and Southern Europe, in contrast, generally have lower average levels of land use intensity, and healthy populations of many species declining or endangered in the north-west persist here [26, 27]. Similarly, the farmland environment in Central-Eastern Europe is generally still more extensive than in Western Europe and a larger proportion of people still live in rural areas [26] what in consequences generating different conditions for both, organisms living in agricultural areas, as well as human societies and economy. Therefore to protect declining populations living in farmland, detailed knowledge on both species and communities level is necessary [26]. It seems nearly obvious since last few years [26, 30], however, due to scientific tradition and availability of funding, the definitely majority of studies have been carried out in Western Europe [27]. In consequence this provokes a question: are findings obtained in western conditions useful to identify the fate of farmland bird biodiversity in Central-Eastern Europe? Or even more general: how results obtained in particular local conditions can be generalized for understanding farmland functioning over the whole continent? Tryjanowski et al. [26] in a review argued that is not necessary. On the other hand is easy to say that we need more detailed studies, but the intention is also to show potential benefits (even economical) from develop of this kind of study. Tryjanowski et al. [26] provided statistical evidences that agriculture differs between western (WE) and central-eastern (CEE) Europe in terms of its role in society and level of intensification. In general, in CEE national agricultural production plays a much more important role in economy and society compared to WE. Also the proportion of the human population employed in agriculture is several times larger in CEE compared to WE. Majority of these results are the effect of political dividing of the continent after the Second World War, what made a situation called "an iron curtain" [31]. At the same time, CEE countries differ in the outcomes of past agricultural intensification: in some states, such as the Czech Republic and much of Slovakia, the communist "collectivist" agriculture created large monoculture fields, not unlike those in Northwestern Europe [31]. In many CEE countries though, small family farms have retained smaller field sizes and farming methods remain as they were decades ago. In Poland, nearly half of the $>$ 2.5 million farms are still smaller than 2 ha, and this field mosaic is enriched by a dense network of seminatural field margins [32]. In some others, such as Hungary or Romania, mixed systems with intensive agriculture exist side-by-side with traditional farming in remote areas. Generally, small farms ($<$5 ha) are much more abundant in CEE than in WE, for example, there are over 50 times more such farms in Romania than in the UK and nearly 20 times more in Poland than in Germany.

The EU has so far failed to stop biodiversity loss in farmland [33, 34]. Although the action plan started few decades ago, the results are far away from the satisfactory situation. Currently published papers (a reviewed by ([27]) suggests that the management solutions developed mainly in Western Europe should not be used as a blanket prescription for the whole continent. The concept HNV farmland was not directionally tested in this particular context, but already existing results widely confirm this point of view [13, 35, 36].

1.3 Conservation Tools: From the Protected Areas Approach and Nature2000 Network to the High Nature Value Areas in Europe

Habitats and landscapes of Europe are increasingly impacted by the intensification of agriculture [21, 29, 37], the development of infrastructure, and increase of built up areas. The impact of human development on biodiversity is, however, not uniform across the continent. The conservation of biodiversity is always dependent on how humans perceive (model) natural systems and (based on this and the economical possibilities) how the management priorities are established. With the massive habitat, species and population loss and landscape homogenization, the most obvious reaction was to preserve areas where the biodiversity is still well represented and establish (threatened) species and habitat lists, on the base new protected areas are to be delimited. Actually there are several conventions and directives that guide biological conservation in the European Union. Besides many national level protected area types, the Natura 2000 sites represent the European Union's network of protected areas, delimited using the habitat and species lists established by the annexes of Habitats and Birds Directives. Although the annexes were updated with the addition of new member states (because the addition of new habitats and species with the new areas), the basics of protected area designations remained the same across the European Union. Specifically with regard to nature conservation, the European policy strengthened the implementation of a rational development strategy by influencing the Member States to adopt international commitments such as the Convention on Biological Diversity, and through the expansion of nature conservation areas. Among the EU directives promoting nature conservation, the most important provisions were the Birds Directive and the Habitats Directive. Implementation of these two directives subsequently gave rise to a new form of nature conservation - the Natura 2000 European Ecological Network (Fig. 1.1). At the regional level of the EU, the general principles and the implementation of the nature conservation policy are complex and governed in a top-down manner [38]. Such approach is inherently at risk of being introduced locally with a low level of effectiveness and adaptability, what makes a lot of troubles with local societies understanding of nature protection [38] and hence, current mechanisms of nature protection (mainly biodiversity) in the EU need to be complemented with effective bottom-up initiatives in addition to new means of top-down approaches.

The ecological network Natura 2000 differs considerably from the previous traditional protection system in that it aims at halting the biodiversity loss and maintaining or reconstructing the favorable nature conservation status by protecting

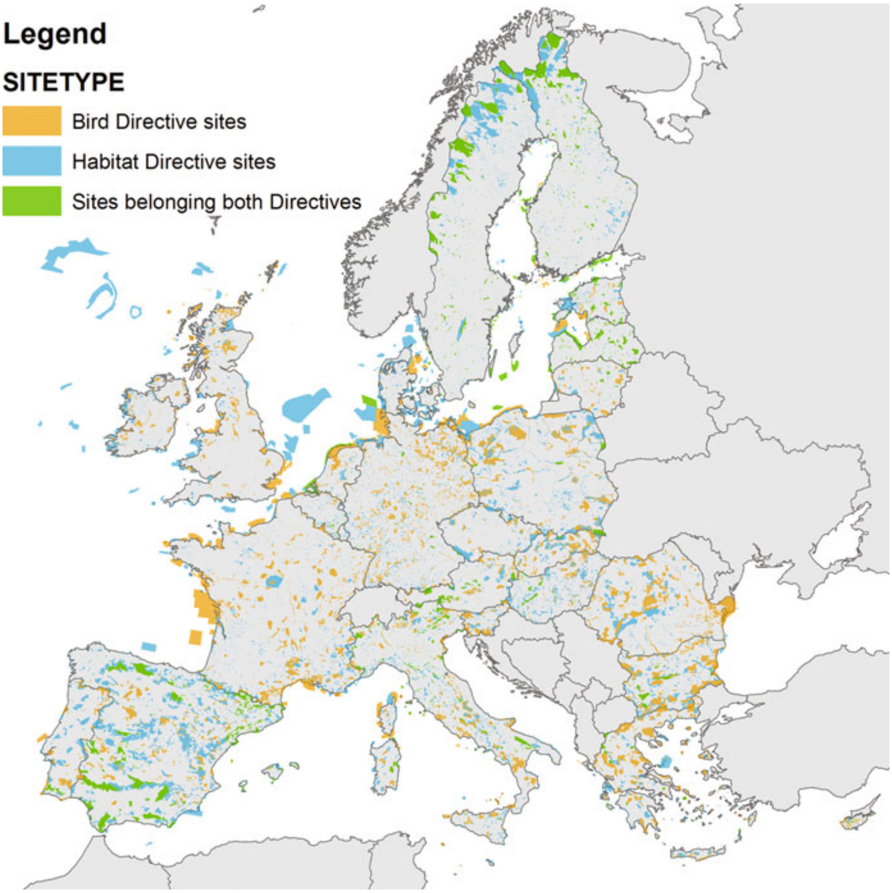

Fig. 1.1 Distribution of the network of sites Natura2000 in Europe, described as the site type category. (Copyright holder: European Environment Agency (EEA))

natural habitat types, besides protection of floral and faunal species that are unique in the European continent [38, 39]. However, even under the best protection regime only the part of the environment is protected. In case of farmland, it make generates very interesting, both from theoretical and practical point of view, consequences.

1.3.1 A Concept of Protected Areas Application to Successful Conservation

Therefore, a conceptual model of biodiversity conservation (i.e. nature protected areas as HNV and Natura 2000, species lists with various protection status) was spatially transferred over Europe, including the Eastern part of the continent, where the biodiversity patterns and species richness are largely different than in those countries, where this model of protect biodiversity appeared. Complex mathematical analyses are proposed to assess the efficiency of protected area networks and proposals were made to increase it (i.e. regarding spatial distribution, size, isolation) [40]. However, even protected areas are exposed to various stochastic and deterministic (intrinsic and extrinsic) factors. All these may induce population and biodiversity decline, addition of new (invasive) species and changes in the community structure [41] and ultimately may compromise the specific objective of the site (to protect biodiversity).

1.3.2 Theories for Fragmented Space

The theory of island biogeography (TIB) [42] is considered the most influential root of the actual models of spatial ecology [43]. TIB explains the distribution patterns of species and communities on islands, using variables such are the island area and distance from other islands and the mainland (continent). Island area influences the species number and the persistence of populations. Isolation from mainland may be decisive factor in colonization. Small islands that are distant from mainland may be species poor because the high rate of extinction and low rate of colonization. Large islands, closely situated to mainland may have species rich communities and lower extinction rates. Moreover, the biotic interactions from the islands (in relation with area and isolation) also may influence the colonization-extinction events. TIB was developed for terrestrial organisms using "binary" space: islands acting as habitats, and the sea representing an increasing risk of mortality [44].

Researchers become increasingly aware of the massive terrestrial habitat destruction and fragmentation due to the increasing and complexely interacting human impacts: land use intensification, increasingly dense infrastructural network, pollution and increasing urbanization. All these impacts result in the split of formerly "continuous" habitats in small, more or less isolated, island like patches [45]. Under these conditions, the conceptually simple TIB quickly gathered an increased popularity among terrestrial ecologists and conservation biologists [46, 47]. The proposals of nature reserve design based on TIB (i.e. [46]) represent one example on how TIB was proposed to be used in conservation biology. The conceptual base of TIB (i.e. the existence of habitats in the "non-habitat" sea) represented the basic idea for metapopulation theory and landscape ecology [45, 48].

Metapopulation theory examines the distribution and persistence of species considering parameters such are the patch connectivity, extinction / (re)colonization of the vacant habitats. The early model of Levins (1969) assumed an infinite number of identical, equally connected patches. The patches were in empty or occupied state and had equal transition probabilities. Later, the classical Levins model was relaxed, with limiting the number of patches (homogenous stochastic patch occupancy models) and later adding heterogeneity to within and between patch quality (heterogeneous stochastic patch occupancy models) [43, 47]. This later development leads to spatially realistic metapopulation theory, where the transition probability depends on the landscape attributes. “Landscape” in this sense means networks of dissimilar patches [43]. According to the degree of isolation (and implicitly movement frequency) between patches and the demographical conditions, many types of (meta) population networks were distinguished besides the classical (Levins) model: mainland – island metapopulations, patchy- and non-equilibrium metapopulations. These may not be “true” metapopulations (true meaning that the four conditions of metapopulations is simultaneously met (see details in [50]).

Landscape ecology focus on the importance of environmental conditions across spatial scale to determine the distribution of organisms. In its early form, it considered the space as the totality of “patches” of different quality. Landscape elements that positively influence the occurrence-distribution of the focal organism are regarded as ‘habitat’ otherwise they are considered “matrix” (i.e. non-habitat) [51]. The associations are, of course, species-specific and a landscape element that is habitat, favorable for one species may be ‘matrix’ for another [52]. The structure of such a patchy landscape is described by i) landscape composition (i.e., the type, size and number of patches) and ii) landscape configuration (i.e., the patches’ spatial arrangement of the patches relative to each other). The term ‘landscape complementation’ refers to the provisioning of landscape patches [53]: a landscape with high complementation means that landscape elements with critical resources are available for the organisms whereas a low complementarily means that the lack one (or more) landscape elements may limit the organism distribution.

The meaning of concepts may be different in the two approaches (metapopulation- and landscape ecology). The term “connectivity” is a (habitat) patch attribute according to the metapopulation theory (i.e. [54]). Large and closely situated patches contribute more to connectivity than small isolated ones. Therefore, the large, closely situated protected area “patches” will increase the persistence of focal organisms. Landscape ecology (however) addresses the connectivity as an attribute of the whole landscape, distinguishing two types of connectivity: structural (based on landscape elements) and functional (based on movement behavior of organisms through the landscape and its consequences) [52]. A highly connected landscape will allow movement of organisms within habitats (patches) without increasing the risks of mortality associated with inters habitat (patch, protected area) movements. Corridors are sometimes considered as permeable matrix that allow organisms to pass them and may or may not contribute to natality. Therefore, it is better for an organism to be on a “corridor” when live the habitat (patch) than in the matrix. According to this view, the areas between the protected areas should be managed in a way to allow movements of individuals across them. However, the large majority of the landscape studies still approach the landscape as the totality of patches (fragments) (review by [48], [55]).

Theories and approaches mentioned above were developed and empirically tested largely in binary type of space: organisms are linked to habitat patches that have different sizes, shape, and quality and at various distances from each other. This is understandable because island like systems are clearly delimitable and therefore useful for the development of strong theoretical framework [50]. Representation of space using patches (occasionally) connected with corridors is easy (see for example a map), and has a relatively low degree of complexity that makes them easy to understand [51]. Being such, these models are attractive especially for conservation biologists, who apply them for the understanding of the spatial distribution of organisms, proposing management interventions and protected areas (many studies). Indeed, the persistence of some species in highly fragmented landscapes, such are many intensively used agricultural landscapes from Western Europe largely depend on interconnected protected area networks [56].

1.3.3 Applying Ecological Terminology for Agricultural Landscapes of Whole Europe?

Biological conservation is largely built on “unclear certainties” reflected by terms like “habitat”, “population”, “ecosystem” and various terms denoting spatial and temporal dynamic of populations and communities such are: “turnover”, “colonization”, “extinction”, “immigration”, “emigration”, “source-sink”. All these are, nevertheless, suited for making complex spatial models. Below we show that many of these terms become vague, even questionable when applied to some species, mainly in Eastern and Central European landscapes [26, 48]. Therefore more attention should be pay when applying them.

The concept of habitat is fundamental in ecology and management for biodiversity conservation. We should understand the habitat requirement of organisms, and also, the spatial extent of that (particular?) habitat to predict organism distribution and the effect(s) of habitat loss. The term habitat is used in various ways by ecologists and conservationists. In a recent review, Mitchell (2005) distinguishes three ecological meanings of habitat: (1) the space used by organism, (2) the range of physico-chemical characteristics of the environment that determine/limit organism’s distribution (i.e. the abiotic subset of the Hutchinsonian multidimensional niche) and (3) the community concept of habitat, based on complexes of plants and animals (grassland habitat, forest habitat etc.). Shreeve and Dennis, (2004) argue that the resources define the habitat and population structure: when the resources are scarce and patchily distributed in the landscape, the focal species may show metapopulation structure. However, when resources are diffuse in the landscape, such a definition is not applicable. Fischer and Lindenmayer, (2007) define habitat as “the range of environments suitable for a particular species”. The definition (1) had no clear information regarding the factors controlling the distribution of organisms [57], definition (2) is to narrow (i.e. organisms distribution may be significantly influenced by biotic elements as well) and the habitat “hypothesis” under definition (3) should be tested (i.e. is the grassland [the only] habitat for species A?).

The various meanings of habitat concept, together with a high diversity of life histories of organisms (see below) may lead to increasing confusions in biodiversity conservation of Eastern European landscapes. For example, some landscape elements (such are wood pastures) are not protected as “habitats” under the Habitats Directive, therefore, not eligible for designation of SCI’s (one kind of Natura 2000 sites). However, because of the species rich fauna (species from Annex 2 of Habitat Directive and the Birds Directive) virtually entire landscapes (with elements ranging from grassland, wetland, arable land, forest, wood pastures and even buildings and villages of traditional rural communities) may be used by one or more species (especially bats, birds) and therefore need to be protected.

In context of HNV farmland, Eastern European landscapes are characterized by high level of species richness. Species protected under international (i.e. European Union) legislation may be widely distributed. Therefore, apart to some species that are linked to patchily distributed habitats, delimiting population borders for species is difficult or impossible. Most probably, contour like approach (sensu Manning et al., (2004) would reveal some distributional peaks of various species but still, it is a dangerous adventure to say for some areas that they are inhospitable (i.e. “matrix”). This is because the population density peaks (i.e. high density of individuals in a certain place) are often not fixed. In these conditions it is difficult to categorize a land as “matrix” for these species, also, the source habitats-populations may be changing (see [61]) for more reflections about the difficulties of studying metapopulations and the spatial structure of populations in very patch nature-rich areas).

The above presented aspects highlight the fuzzy being of habitats and populations, and this may characterize wide parts of Eastern European countries. If we consider space as a complex and connected (temporarily, or more permanently) network of habitats of which quality is ever changing [26, 61], concepts such are “colonization”, “extinction”, “immigration”, “emigration” may be not useful in understanding spatio-temporal dynamic of populations and communities in these landscapes. It is visualized in the Fig. 1.2.

As Fischer and Lindenmayer [51] noticed, the success of biological conservation is highly dependent on the way, how we conceptualize the ecological space and the distribution of various species and communities on it. Several organisms that have now limited distribution in some Western European countries are still widely present in Eastern Europe [26, 27]. For this reason, the habitat-matrix approach, and therefore spatial models such are area and isolation paradigm and (fragmentation) landscape models, may hold for some organisms that have patchy distributions in intensively used, fragmented landscapes, but may not be applicable for the same organisms found in traditionally managed areas.

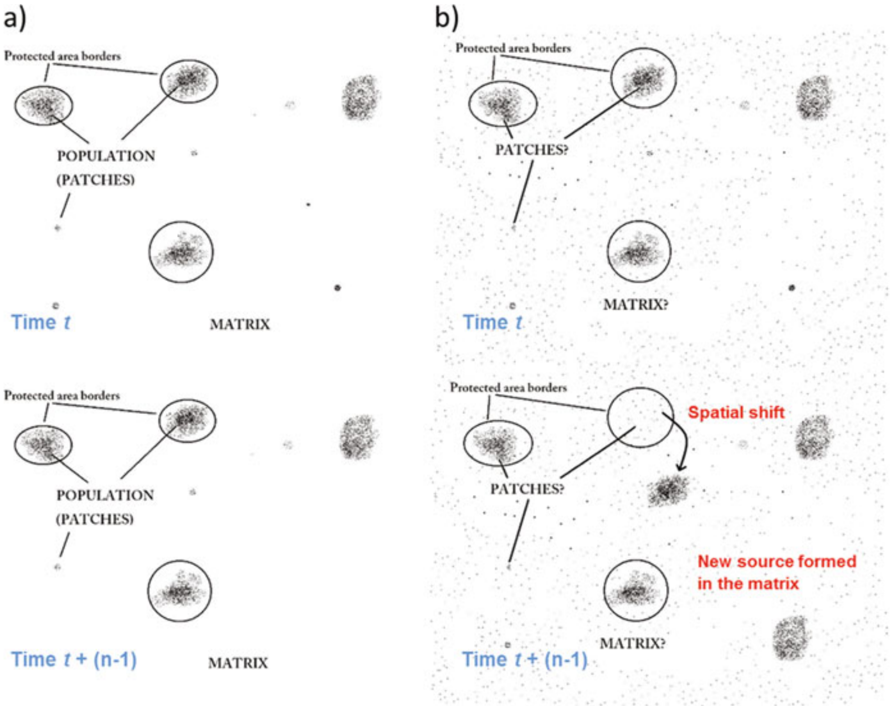

Fig. 1.2 A schematic representation of the possible distribution of an organism in a landscape with obvious habitat – matrix character (**a**) and in a landscape where the habitat – matrix character is not obvious. In the case of (**a**) the population borders of the organism are well delimitable and the various spatial models that incorporate turnover, extinction, colonization, connectivity, landscape composition and configuration may work. Moreover, protecting species and communities in this landscape can be realized by delimiting areas borders. Contrary, all these concepts and measures for protecting biodiversity may not work in the landscape (**b**). The drawing represents a snapshot for two moments (time t and time t + [n – 1]). The spatial arrangements of populations from (**a**) cannot change because the matrix is inhospitable (thus, the mortality risk is high). Here local extinctions may occur (small populations may be more prone), followed by recolonisation. In the case of landscape (**b**), the "matrix" may become important habitat and source of individuals for the entire landscape. Here spatial shifts of high population densities may occur (populations may even "leave" the borders of protected areas) and new source populations may appear in the matrix. Protecting biodiversity in landscape (**b**) by delimiting (and fixing) areas with high density, and ignoring the potentially source character of the "matrix" can be detrimental
The graph was conceptually prepared thanks to courtesy of Dr. T. Hartel during a work with the paper [26]

1.4 HNV Farming Definition

In an effort to protect farmland biodiversity, several studies were performed to assess the quality of agricultural landscapes, and in defining high nature value (HNV) farmland [62, 63]. Originally, the term HNV was introduced by Baldock

[64] and Beaufoy [65]. Despite the difficulty of defining HNV farming, the concept has continued evolving. More recently Andersen [66] proposed a conceptual definition for HNV farmland as 'those areas in Europe where agriculture is the dominant land use and where agriculture supports or is associated with either a high species and habitat diversity or the presence of species of European conservation concern or both'. This was subsequently followed by a mapping approach at EU level [2]. HNV farmland (represented by a binary indicator) is defined as one of the following three types [66]: farmland with a high proportion of semi-natural vegetation, farmland dominated by low intensity agriculture or a mosaic of semi-natural and cultivated land and small-scale features, and farmland supporting rare species or a high proportion of European or World populations. The first two types are identified on the basis of land cover data (CORINE database) and agronomic farm-level data (in particular the Farm Accounting Data Network), and the third type of HNV can only be identified by means of monitoring species occurrence.

Summarized, the HNV is an indicator referred to farming systems which include semi-natural habitats, low intensity farming and diverse, small-scale mosaics of land-use types [35] (Figs. 1.3 and 1.4). The high nature values (HNV) farming is present in all European countries, with a diversity of types and extensions. The need for measures to prevent the loss and monitoring in real time the quality of HNV areas and to mitigate the loss of biodiversity is widely recognized, but requires urgent attention. One of the reasons is due to the deep differences between agro ecosystems of Central-Eastern and Western Europe, differences that can explain some lack of achievements of several conservation policies, and later also in practice. Several recent studies showed how agri-environmental measures adopted in the countries of European Community may be ineffective in order to guarantee the stop on biodiversity in some intensive farmland [26]. Therefore, more studies

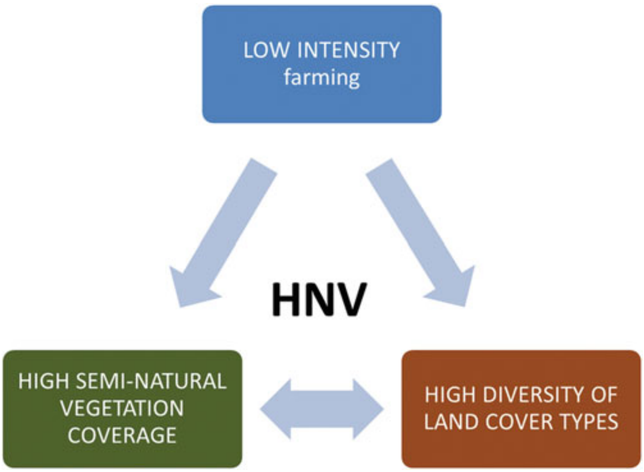

Fig. 1.3 Schematic representation of the concept used to define the high nature value farming in Europe, as provided in [63]

Fig. 1.4 Example of agricultural landscape from Central Italy mirroring the main characteristics of high nature farmlands, with the typical spatial disposition of land use features as a chessboard (Photo: F. Pruscini)

focusing strategies to increase the effectiveness of agri-environmental measures for conservation are necessaries.

1.5 Approaches to Characterize HNV Farming

Many different approaches were used in order to identify HNV farming zones in Europe, greatest combining farm systems, land cover/land use, or indicator species [67]. However, are the same elements that previously were elaborate by [66] and later developed by [68]. Follows the characteristics associated with these methods are described:

1.5.1 Land Cover Approach

The agricultural habitats with potential HNV are analyzed based on Corine land cover classes (LCCs) (Table 1.1) [68]. The CORINE classification has a low level

Table 1.1 Corine land cover classes (LCCs) considered potentially related to agricultural land

Code	Land cover class
2.1.1	Non-irrigated arable land
2.1.2	Permanently irrigated land
2.1.3	Rice fields
2.2.1	Vineyards
2.2.2	Fruit trees and berry plantation
2.2.3	Olive groves
2.3.1	Pastures
2.4.1	Annual crops associated with permanent crops
2.4.2	Complex cultivation patterns
2.4.3	Land principally occupied by agriculture with significant natural vegetation
2.4.4	Agro-forestry areas
3.2.1	Natural grasslands
3.2.2	Moors and heath lands
3.2.3	Sclerophyllous vegetation
3.2.4	Transitional woodland-scrub
3.3.3	Sparsely vegetated areas
4.1.1	Inland marshes
4.1.2	Peat bogs
4.2.1	Salt marshes

Source: [69]

of detail, the minimum resolution is 25 hectares units, which does not allow the distinction between intensively used grassland or extensive. Therefore, to refine the selection criteria, it is necessary to consider the environmental area and add additional information such as the land elevation, soil quality, slope inclination and distribution of relevant species [68].

1.5.2 Farm System Approach

These type of approaches are based on diverse features as for example, low levels on agrochemicals, farm size and high crop diversity [67] (Table 1.2). If combined with land cover approach, is possible to obtain maps of high detail resolution [63].

The farm systems methods use a features classification on production, inputs and management that are distinguished as following [63, 69]:

1. High Nature Value cropping systems, are characterized for their low intensity arable systems. It can also include livestock without being a main source of income;
2. High Nature Value permanent crop systems, are characterized by low intensity olives and other permanent crop systems;