# Chapter 2
# European Wilderness in a Time of Farmland Abandonment

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**Abstract** Wilderness is a multidimensional concept that has evolved from an aesthetic idea to a science-based conservation approach. We analyze here several subjective and ecological dimensions of wilderness in Europe: human access from roads and settlements, impact of artificial night light, deviation from potential

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natural vegetation and proportion of harvested primary productivity. As expected, high wilderness in Europe is concentrated mainly in low primary productivity areas at high latitudes and in mountainous regions. The use of various wilderness metrics also reveals additional aspects, allowing the identification of regional differences in the types of human impact and a better understanding of future modifications of wilderness values in the context of land-use change. This is because farmland abandonment in the next decades is projected to occur especially at intermediate wilderness values in marginal agricultural landscapes, and thus can release additional areas for wild ecosystems. Although the subjective wilderness experience will likely improve at a slower pace due to the long-term persistence of infrastructures, the ecological effects of higher resource availability and landscape connectivity will have direct positive impacts on wildlife. Positive correlation between megafauna species richness and wilderness indicate that they spatially coincide and for abandoned areas close to high wilderness areas, these species can provide source populations for the recovery of the European biota. Challenges remain in bringing together different views on rewilding and in deciding the best management approach for expanding wilderness on the continent. However the prospects are positive for the growth of self-regulating ecosystems, natural ecological processes and the wilderness experience in Europe.

**Keywords** Wilderness · Human footprint · Artificial light · Potential natural vegetation · Harvested primary productivity · Megafauna · Farmland abandonment

## 2.1 The History and Value of Wilderness

Wilderness is a comprehensive measure of conservation value capturing both the subjective human experience, and the ecological dimension of minimally impacted ecosystems (Cole and Landres 1996; Hochtl et al. 2005). But the concept of wilderness has gone through dramatic historical changes in terms of both the context and connotation in which the term was used. During the centuries of exploration and colonization of new territories, wilderness was perceived negatively as a land that is unfavourable for human habitation and should be altered and tamed (Nash 2001).

"Wilderness" gradually entered the North American language of conservation in the nineteenth century after the end of the frontier exploration, especially promoted by the hunting community. It developed as an aesthetic and ethical concept related to the protection of pristine nature in the face of galloping technological progress and rapid disappearance of natural environments. Thus wilderness became synonymous with freedom, natural beauty, sanctuary and retreat from everything that was perceived as overwhelming in the modern lifestyle (Nash 2001).

Some have argued that past landscape modifications by human populations and pervasive human impacts across scales make the idea of wilderness inconsequential (Heckenberger et al. 2003). Wilderness also attracted considerable controversy in North America, particularly raising questions relating to equity and the rights of humans living in, or next to, areas allocated to wilderness protection (Nash 2001). The same issues were raised on all other continents that were colonized by European settlers. The establishment of protected parks and hunting reserves in South Africa was accompanied by the relocation of native populations and social strife (Carruthers 1995). Australia has also experienced some controversy surrounding the definition of wilderness and its disconnection from the culture and lifestyle of aboriginal populations (Mackey et al. 1998).

Such developments gave "wilderness" the impetus to evolve towards a more relevant concept for the twenty-first century, incorporating both human dimensions and needs as well as new research results from areas such as paleoecology or climate science (Gillson and Willis 2004). A science-based understanding of the human influence on ecosystems informs presently one of the main current conservation approaches (Brooks et al. 2006; Kalamandeen and Gillson 2007). In this context, wilderness represents one extreme of the gradient of human presence and impact across the landscape. While still retaining an aesthetical element and an existence value among growing numbers of enthusiasts in the Western industrialized countries, wilderness also refers to the biophysical reality of natural processes, ecological communities, and the resulting ecosystems that develop in the absence of human management. Therefore, wilderness is of major importance both for research and management in the areas of ecosystem services (ES) (Naidoo et al. 2008, see Chap. 3), biodiversity conservation (Watson et al. 2009), and the establishment of ecosystem baselines (Vitousek et al. 2000).

Appreciation of European wilderness has had a different path from that on other continents due to the long history of human occupation, agriculture and landscape management. Many of the species that used to dominate the landscape in the distant past have been hunted to extinction or have been driven away from the most favourable habitats (Barnosky 2008, see Chaps. 4, 8) and natural vegetation cover has been cut or burnt down to make space for farmland. Thus both laymen and naturalists have come to regard and appreciate this new state as the natural biodiversity of the continent. As a result of a shifting baseline syndrome, traditional agricultural landscapes have become the benchmark against which biodiversity change was measured (Papworth et al. 2009). However, a growing movement in Europe advocates now for wilderness protection and recognition, and policy steps have been taken in this direction, including a resolution of the European Parliament on wilderness in Europe (Martin et al. 2008; European Parliament 2009). Research has also been undertaken in order to identify and map wilderness on the continent (Fritz et al. 2000; Carver 2010). In this favourable context, rewilding of abandoned farmland can gain momentum as a way of expanding the areas that provide both increased opportunities for wilderness experience and more extensive self-regulating and self-sustaining ecosystems (Rey Benayas et al. 2007; Munroe et al. 2013, see Chaps. 1, 11).

Considering the diversity of possible definitions, we approach wilderness in this chapter from several points of view. In the next section we review the literature on wilderness mapping and to identify some of the most important ecological and aesthetical aspects of wilderness in Europe. We then map and discuss the spatial agreement between wilderness based on (a) human access from roads and settlements, (b) impact of artificial light, (c) deviation from potential natural vegetation, and (d) proportion of primary productivity harvested by humans, as metrics of wilderness value over space. We further explore the health of trophic chains by looking at megafauna species and their spatial concurrence with wilderness. Megafauna such as the large herbivores, apex predators and birds of prey have an important role in maintaining and returning ecosystems to a higher naturalness state through establishment of natural trophic cascades (see Chaps. 4, 5, and 8). As such we also map the distribution of high body mass species across Europe and discuss the overlaps with high-wilderness quality and farmland abandonment areas. We then explore the possible spatial and temporal dynamics of wilderness in Europe over the next few decades in the context of farmland abandonment and rewilding. We examine how aspects of wilderness could increase due to agricultural abandonment and we suggest means to maximize the potential success of rewilding efforts.

## 2.2 Measuring and Mapping Wilderness—A Brief Review of Metrics and Methods

Wilderness has been mapped and analysed across scales, from global to local level. The methodologies generally make use of available spatial data on human infrastructures, land cover, area size of ecologically intact regions, etc. as proxies for wilderness quality, but also employ expert knowledge on degree of naturalness and ecosystem modification. Despite the obvious challenges of mapping a multidimensional concept such as wilderness, studies using relevant indicators at a similar extent and resolution offer highly congruent results, likely because they share a common perception of the attributes and values of wilderness.

At the global level, Mittermeier et al. (2003) used a combination of human population density, intactness, and area size of the intact areas to define wilderness areas. Much of their assessment was based on literature and expert opinions. The wilderness areas identified coincided with the areas of the lowest human footprint identified by Sanderson et al. (2002) although the two studies used largely different metrics. The map of the human footprint at the global level used human population density, the transformation of land through the building of settlements, roads and railroads, and measures of human access. Power infrastructures were also quantified, using satellite night maps (Sanderson et al. 2002). Despite data limitations, these global studies reveal a fairly consistent big picture of the overall pattern and magnitude of human impact on the biosphere, both for terrestrial and marine ecosystems (Halpern et al. 2008).

In Australia, the Heritage Commission's National Wilderness Inventory used four metrics for defining wilderness: remoteness from settlements, remoteness from access, biophysical naturalness and apparent naturalness (Lesslie et al. 1995). In this case, thresholds were defined for minimum levels of these metrics that would characterize wilderness. Other approaches emphasize a wilderness continuum across the landscape (Fritz et al. 2000). Building on the Heritage Commission's National Wilderness Inventory research, Carver et al. (2002) added remoteness from national population centres and altitude in order to map wilderness in the United Kingdom.

Remoteness from national population centres was a measure of the accessibility to the whole British population in addition to the accessibility to the local population in the calculation of wilderness. The authors used multicriteria evaluation (MCE) and explored public perceptions of wilderness through the use of interactive tools by allowing the user to change the weights of the wilderness metrics. As expected, resulting wilderness maps were not radically different, but allowed for insights on what affects the perceptions of wilderness (Carver et al. 2002). This approach was further detailed at the level of the Cairngorms National Park, and the Loch Lomond and The Trossachs National Park in Scotland (Carver et al. 2012) at a resolution of 20 m and later expanded to cover the whole of Scotland in a study by the Scottish Natural Heritage (Scottish Natural Heritage 2012).

At lower spatial extents the indicators of wilderness and human footprint remain the same but higher quality data are usually available making the mapping and modelling process more reliable and accurate. For example, Woolmer et al. (2008) rescaled the human footprint methodology of the Sanderson et al (2002) for the area of approximately 300,000 $km^2$ of the Northern Appalachian ecoregion. They used ten datasets compiled from several sources: population density, dwelling density, urban areas, roads, rail, land cover, large dams, watersheds, mine sites, utility corridors for the electrical power infrastructure. The general patterns of human footprint were maintained when comparing the map based on 90 $m^2$ resolution data at ecoregional scale with the map derived from the global analysis of Sanderson et al (2002) conducted with 1 $km^2$ resolution data. However, the Spearman rank correlation coefficients between the two sets of human footprint data steadily decreased with the scale, reaching 0.41 ($p < 0.001$) at 0.1 % of the Northern Appalachian ecoregion. The difference in the human footprint scores is that the ecoregion calculation compared with the global calculation leads to a reduction in the area with low levels of human footprint (46 % ecoregion extent vs. 59 % global extent) and an increasing of the area with moderate or high levels of human footprint (34 % ecoregion extent vs. 21 % global extent), evening out more the distribution of human footprint scores. A key finding was also that three parameters models add the most information to the calculation of human footprint while the model incorporating human settlements, roads and land-use was the best approximating model from all combinations of the ten datasets considered.

In Europe, an increased wilderness momentum has led to efforts by different actors to protect wilderness and advance a progressive wilderness research agenda (Jones-Walters and Čivić 2010). A continental level map of wilderness continuum has been produced using population density, road and rail density, linear distance from the nearest road and railway line, naturalness of land cover and terrain ruggedness (Carver 2010). This analysis identified wilderness areas concentrated in the Scandinavian Peninsula and the mountainous regions of Europe, revealing a strong positive altitudinal and latitudinal relationship. The same pattern was maintained even if terrain ruggedness was eliminated from the calculation. Beside the Scandinavian mountains and arctic areas, the Pyrenees, The Eastern Mediterranean islands, the Alps, the British Isles, the south-eastern Europe and the Carpathians also had significant areas of wilderness (Carver 2010) but one has to temper this with the knowledge that the current spatial data often misses historical information on local land use management such as past deforestation, drainage and grazing by domestic livestock. Currently, the wilderness mapping is being updated through the project of the European Wilderness Registry, which will record the most important wild sites, thus facilitating priority setting for protection.

## 2.3 Wilderness Metrics

The set of metrics used in the wilderness mapping literature can be divided into two major dimensions of defining wilderness: the subjective or perceived wilderness experience and ecological intactness. Most wilderness metrics attempt to describe both aspects. For example, the presence of roads and human settlements indicate both easiness of access, visual impact, and the ecological impact of these infrastructures. Yet some indicators address the two dimensions separately as it is the case with apparent naturalness and biophysical naturalness (Lesslie et al. 1988). For the purposes of this chapter, we chose a series of four metrics: two that describe both the subjective human experience of wilderness and the ecological impact, and two that have mainly an ecological dimension. The metrics used here quantify human impact thus wilderness increases with the decrease of the metrics.

Remoteness from roads and human settlements is an important dimension in the feeling of solitude intrinsic to the wilderness experience. However, roads and other human access infrastructure have also a strong impact on wild populations and ecosystems. The most obvious impact is road mortality, shown to affect mammals (Philcox et al. 1999; Seiler 2005; Grilo et al. 2009), birds (Orlowski 2005), reptiles (Iosif et al. 2013) and amphibians (Patrick et al. 2012). But impacts of roads, traffic and human access can be much more profound, affecting population and community structure (Habib et al. 2007), trophic interactions (Kristan III and Boarman 2003; Whittington et al. 2011), ecosystem functioning and structure (Christensen et al. 1996; Hansen et al. 2005; Rentch et al. 2005), and environmental conditions through high pollution levels (Hatt et al. 2004). Roads can favour the expansion of invasive species (Jodoin et al. 2008; Vicente et al. 2010), and of exotic and human-favoured predators (Alterio et al. 1998). They also expose forest habitats to edge effects (Tabarelli et al. 2004). These ecological impacts of roads and human settlements alter a range of ecological conditions compared with the context that would exist without these human infrastructures. Here we evaluate human access from roads and settlements by calculating the cost distance to paved roads and settlements according to the Naismith's rule which assumes differentiated relative traveling times depending on terrain, land cover, and river networks (Carver and Fritz 1999). We extracted the data on paved roads from the Eurogeographics Road database and the Open Street Map database, land use data from Corine Land Cover 2000 and 2006, and terrain ruggedness data from the Shuttle Radar Topography Mission (SRTM) at 1 km resolution. The range of the human access score values is expressed from 0 to 1. In Europe, the mountainous areas, the Iberian Peninsula, the Balkans, Scotland, and Scandinavia are the least accessible regions and the least impacted by roads and settlements (Fig. 2.1a).

Artificial night light has a similar dimension in the definition of wilderness. Light pollution has been decried for its impact on the visibility of the natural night sky (Cinzano et al. 2000), diminishing the night wilderness experience. But artificial light has also strong ecological impacts (Longcore and Rich 2004; Navara and Nelson 2007; Hölker et al. 2010b; Gaston et al. 2013), affecting invertebrates (Davies et al. 2012, see Chap. 6), fish (Becker et al. 2013), mammals (Boldogh et al. 2007) and bird populations (Montevecchi et al. 2006). Direct mortality (Hölker et al. 2010b), impacts on trophic relations and community structure (Perkin et al. 2011), disruption of migratory routes (Gauthreaux Jr et al. 2006) by night light lead to profound modifications of ecosystems functions (Hölker et al. 2010a). Nocturnal species such as bats and moths (see also Chap. 6) receive the brunt of the impact. We assess the impact of artificial light on ecosystems and wilderness experience by using the satellite data of the upwards emitted and reflected artificial light with a spectral range of 0.5–0.9 μm in Europe from the Visible Infrared Imaging Radiometer Suite (VIIRS) of the Soumi National Polar-orbiting Partnership (SNPP) for the year 2012 (NOAA National Geophysical Data Center 2012) with a resolution of 15 arc sec (approximately 450 m). We apply a kernel function to distribute the impact over a radius of approximately 10 km (Fig. 2.1b) as a conservative approximation meant to cover the night glow effects reported in the literature (Kyba et al. 2011) along with the direct ecological impacts (Longcore and Rich 2004). In each pixel, the light impact score is the sum of all the impact scores from the surrounding light sources and it represents a relative measure aimed at encompassing both the ecological aspect and the impact on the subjective wilderness experience (Fig. 2.1b).

The last two metrics that we consider here are qualitative and quantitative measures of the human modification of ecosystems and thus they convey mainly, although not exclusively, an ecological significance. Anthropogenic change of natural habitat is one of the major drivers of biodiversity loss (Pereira et al. 2010) and it has been studied extensively for a large range of taxa (Bolliger et al. 2007). The most conspicuous element of habitat loss is the change in vegetation, and intact vegetation cover has been used before as a wilderness indicator (Bryant et al. 1997). Human changes in vegetation tips the balance in favour of species benefiting from human presence and impacts habitat-sensitive ones (Leu et al. 2008). Therefore we use here the deviation from potential natural vegetation (dPNV) as a qualitative measure of the human impact on the landscape. We used the potential natural vegetation (PNV) classes of the map developed by Bohn et al. (2000). We calculate the similarity of current land cover to PNV by estimating the probability that the CORINE 2000 land cover class in any one location in Europe belongs to the local PNV type (Bohn et al. 2000). The probability of agreement was classified in four classes with different scores: assumed = 1, most probable = 0.75, probable = 0.5 and possible = 0.1. The resulting map was combined with the grazing density data from Food and Agriculture Organization, which was previously linear transformed to a scale from 0 to 1, where 1 represents a density of 20 heads/km$^2$ or more. We used

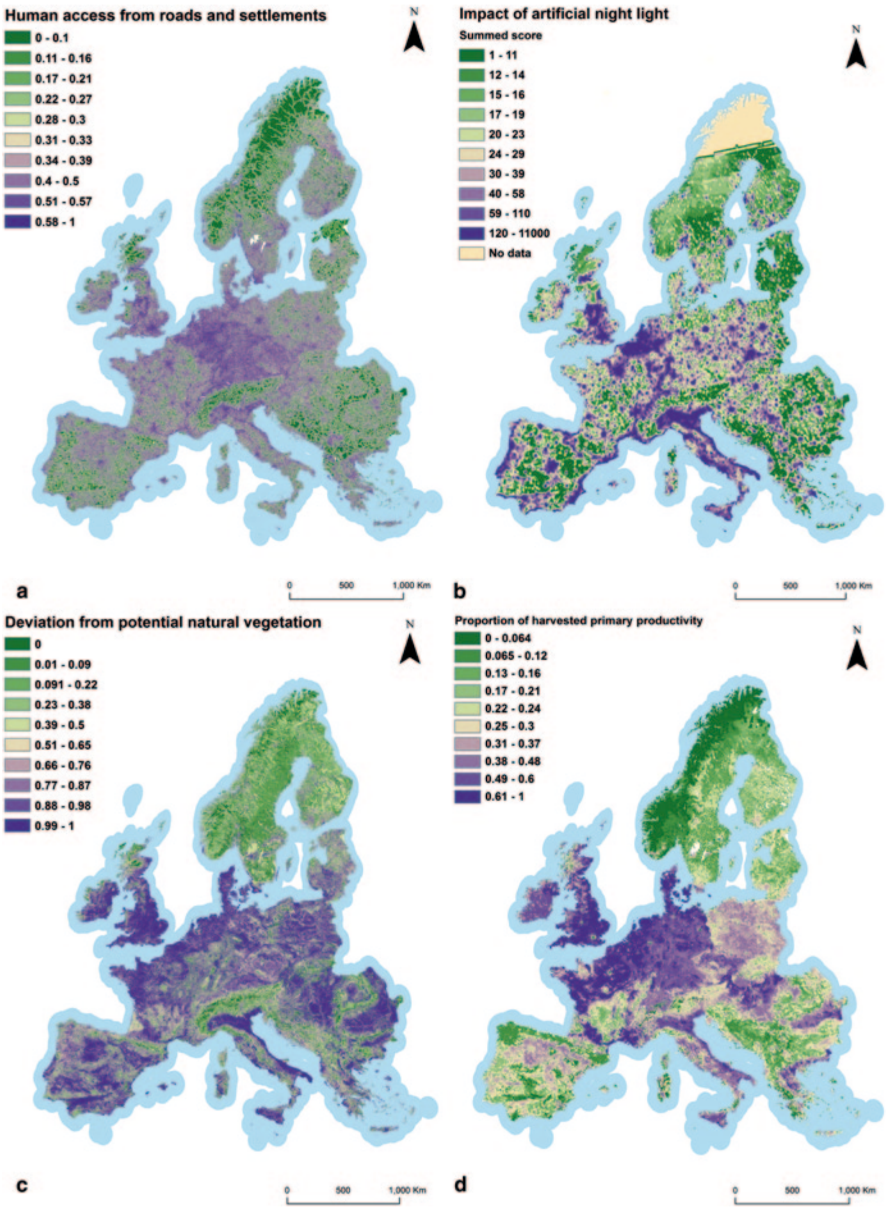


**Fig. 2.1** Wilderness areas according to four metrics. **a** Access from roads and human settlements. **b** Artificial night light. **c** Deviation from potential natural vegetation. **d** Proportion of harvested primary productivity out of the potential primary productivity. Wilderness value increases with the decrease of the metrics

grazing density to account for human transformations in semi-natural grasslands. We expressed the dPNV value by subtracting from 1 the score calculated according to the described methodology. (Fig. 2.1c).

Through agriculture, hunting, fishing and forestry, humans are removing significant quantities of biomass from the ecosystems. Primary productivity (PP) is the foundation of trophic networks and it influences the structure and functions of ecosystems in a domino effect across trophic levels (Haberl et al. 2004). Humans have reduced drastically the PP available to other species and this has changed the composition of the ecological communities (Barnosky 2008; Pereira et al. 2012). We map the proportion of human harvested PP out of the total potential PP in Europe as another indicator of wilderness and using the data analysed in Haberl et al. (2007). We calculated the harvested PP by extracting net PP remaining in ecosystems after harvest from the net PP of the actual vegetation. We then calculated the proportion of harvested PP by dividing net harvested PP by net PP of the potential vegetation. The data are calculated based on country-level statistics of the Food and Agriculture Organization (Haberl et al. 2007) while potential PP is estimated using the Lund-Potsdam-Jena dynamic global vegetation model (Sitch et al. 2003). Some abnormalities can be noticed in the harvested PP map which are due to the assumptions of the model and the FAO national level data. The map has to be interpreted with this limitation in mind (Fig. 2.1d).

The four resulting maps based on the selected metrics show a common pattern of high human footprint in the lowlands of central Europe (Fig. 2.1). The most unaltered values of all metrics occur in high mountainous areas and Scandinavia. But the differences at intermediate values of wilderness provide a key signal to what are the strongest determinants of human footprint at regional level in Europe. For example, although the dPNV is very low in almost all of Scandinavia (Fig. 2.1c), the proportion of harvested PP is comparatively higher, consistent with high forestry harvest in the Nordic countries (Fig. 2.1d). The reverse pattern is noticeable in the Iberian Peninsula where although the drier climate restricts high harvesting of PP, the current vegetation is quite far from PNV as measured in our map and consistent with the degradation of the Mediterranean habitats (Myers et al. 2000). In the same region, the significant differences between the inland and coastal values of the night light impact and human access (Fig. 2.1a and b) indicates the high difference between the human population densities inland compared with the coastal regions. These differences in the distribution of human populations are masked in the PNV score and harvested PP maps (Fig. 2.1c and d). The map of artificial light (Fig. 2.1b) also points out to a discrepancy in the relative wilderness values in East and South-East Europe compared with the dPNV score map for example (Fig. 2.1c). The lower economic activity in this area results in lower light impact although the level of vegetation change is very high (Doll et al. 2006).

The lowest wilderness areas in Europe have usually low scores for all the wilderness dimensions considered, and they represent mainly areas of high human densities and intense economic activity. Conversely, high wilderness areas are the wildest from all the points of view taken here. But the areas of intermediate wilderness values are strongly impacted by only one or two metrics with very low wilderness values. Especially dPNV and harvested PP have a farther reach, affecting even ecosystems where infrastructure and artificial light impacts are reduced. These indicators are connected with more extensive land-uses such as agriculture and forestry, and less with high human population densities and infrastructure.

The synergies and interactions between the different elements of our wilderness mapping emphasize even further their ecological significance. In areas of high habitat quality the road mortality can be higher in absolute terms because it affects more abundant populations (Patrick et al. 2012) while road lighting can increase the impact of the road itself on the local ecological communities by favouring certain types of predation (Rich and Longcore 2005) or providing additional perches for improved hunting efficiency of raptors such as kestrels (Sheffield et al. 2001).

## 2.4 Wilderness Conservation

The designation, coverage and implementation of protected areas and Natura 2000 sites vary widely across European countries. However, looking at the continental map, we discern some regional patterns in wilderness protection. Many mountainous areas in the Pyrenees, the Apennines, the Massif Central and the Carpathians are covered by Natura 2000 sites and, to a lesser extent, by nationally designated protected areas (Fig. 2.2) (European Environment Agency 2012a, b). Large protected areas included both in the Natura 2000 network and in the national networks protect the Scandinavian mountains. As already pointed out in the literature (Gaston et al. 2008), many of the designated areas overlap because countries have co-designated under Natura 2000 and their own national systems. However, important differences between the two protected areas systems can also be noticed (Fig. 2.2). For example, the Iberian Peninsula and South-Eastern Europe seem to have a much larger area under protection by the Natura 2000 network than from nationally designated protected areas. Conservation seems to have benefitted in these areas from a push from the European conservation policies (European Council 1979, 1992). Meanwhile, Germany and France have smaller and fewer terrestrial protected areas under the Natura 2000 network than under the national network.

It has been suggested in the literature that the designation of protected areas has been done opportunistically and thus that they are more likely to cover low productivity, high altitude, wilderness areas (Pressey et al. 1993; Margules and Pressey 2000). Although largely lacking continental coordination, Natura 2000 network has some features common with systematic conservation planning and aims to protect species and habitats threatened at continental level (Gaston et al. 2008). Surprisingly however, the terrestrial Natura 2000 sites have a lower continental average proportion of harvested PP than nationally designated protected areas: 26.7 % for Natura 2000 sites against 34.3 % for the nationally designated protected areas. The continental average values for the impact of artificial night light in Natura 2000 sites is 38 while in nationally designated protected areas network is 31, showing the same pattern as in the case of harvested PP. However, we have to keep in mind that

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