Agricultural pressures on biodiversity conservation: An analysis of the effectiveness of Natura 2000 network in Italy

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Abstract

Agricultural activities are widely recognized as one of the most important pressures affecting biodiversity (OECD, 2001). Previous studies have mostly been focusing on the loss of biodiversity occurring as a result of land conversion and fragmentation of remaining natural habitat (Harvey et al., 2004; Stolton *et al.,* 1999; Gliessman, 1999; Altieri, 1999). However, the impact of agricultural activities may not be limited to the area in which those activities are performed. The purpose of this paper is to analyse the impacts of agricultural activities on a set of European areas brought together under the Natura 2000 framework. Natura 2000 is an ecological network of protected sites across the European Union member states and those sites are granted different levels of protection, meaning that human activities, including agricultural ones, are regulated inside or around them. Against this background, it has been chosen to perform a critical analysis of the compatibility between agricultural activities and biodiversity conservation, choosing Italy as a case study. A set of composite indicators, accounting for species and habitat diversity and agricultural pressure, has been created. Subsequently, an econometric model has been developed so as to describe species diversity as a function of site geographic location, physical characteristics, level of institutional protection and agricultural pressure. Results confirm that agricultural pressures inside and outside the site are negatively correlated to species diversity. Some activities, such as cultivation, grazing, use of pesticides, forestry, burning practices and the abandonment of pastoral systems, when individually considered, have a strong negative impact on species diversity. However, an analysis of their interactions shows that the joint effect of any pair of these activities tends to have a positive influence on the status of species diversity.

Keywords: Agricultural activities, Pressure indicators, Biodiversity indicators, Protected areas, Natura 2000

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1. Introduction

Agricultural activities are mainly practiced on lands that were previously covered by forests or other natural habitats. This, in turn, involves the introduction of species of interest primarily to humans, which necessarily entail modifications and conversion of natural habitats and their communities. These impacts are also mapped at all levels of life diversity, from genes to species and ecosystems, and can affect the diversity of wild as well as domesticated species (Harvey et al., 2004).

The combination of this complex of factors undermines the capacity of agricultural areas to serve as habitat for wild species and their ability to effectively regulate populations of pests which affect crop productivity (Soil Association, 2000; Defra, 2003). As a result, a widespread decline in farm species abundance and diversity, across many taxonomic groups, has been observed both in Europe and worldwide (Stolton *et al.,* 1999; Gliessman, 1999; Kegley, 1999; Edge 2000; Soil Association 2000; Bugg and Trenham, 2003, Benton *et al.,* 2003). The observed loss of biodiversity has also resulted in a reduced capacity of agro-ecosystems to perform many essential functions such as purification of water, internal regulation of pests and diseases, carbon sequestration, and degradation of toxic compounds (Altieri, 1999).

However, agricultural activities exert an impact on biodiversity not only in the areas where they are performed but also in surrounding areas. An interesting issue arises with respect to the impact of those activities on sites devoted to biodiversity protection. Protected areas are defined as areas of land or sea dedicated to the protection and maintenance of biological diversity and natural cultural resources, managed through legal or other means[2](IUCN, 1994). The purposes of protected area management range from scientific research, to preservation of species, genetic diversity and maintenance of environmental services, to tourism, recreation, education and sustainable use of natural ecosystems resources. Due to the different priorities accorded to these management objectives, the level of institutional protection can vary across countries and regions, from strict protection to sustainable resource management.

The purpose of this paper is to develop a methodology to evaluate the magnitude of the impacts of agricultural activities on the status of biodiversity inside protected areas, exploiting the information contained in the Natura 2000 database. Natura 2000 is a network of protected areas across EU Member states, aiming at the conservation of biodiversity resources in Europe. Most of the habitats covered by this network are situated in agricultural or wooded areas. These are semi-natural areas, created and maintained by human activity, and, in many cases, their natural characteristics would disappear if agricultural work or animal rearing were

[2] The definition of protected areas adopted in this study is derived from the IV World Congress on National Parks and Protected Areas. (IUCN, 1994)

to cease. Therefore, the idea underpinning the Natura 2000 network is the management of protected sites through sustainable productive activities, rather than the exclusion of human activities (European Commission, 1999). The complete network of Natura 2000 sites constitutes a highly connected system from a functional point of view. As a matter of fact, the network does not only include important natural sites across European countries, but also contiguous land stripes in order to connect natural areas with similar ecological functions.

The remainder of this paper is structured as follows. Section 2 and 3 provide a review of relevant literature dealing with the impacts of different agricultural activities on biodiversity and a review of the most widely used agricultural pressure indicators. Section 4 describes the structure of the Natura 2000 network and database and Section 5 defines a protocol for constructing biodiversity and agricultural pressure indicators using the information extracted from the database. Section 6 describes the general features as well as the biodiversity and agricultural pressure profiles of the Italian Natura 2000 sites, identified as a case study. Section 7 specifies an econometric model to analyse the status of species diversity as a function of the geographical and physical characteristics, habitat diversity, level of institutional protection and pressure from agricultural activities. Section 8 discusses the results and Section 9 draws conclusions and policy considerations.

2. Literature review on the impacts of agricultural activities on biodiversity

A vast array of previous studies has addressed the issue of the impacts of agricultural activities on biodiversity. The literature review highlighted that some specific activities are generally associated to particularly negative effects on different components of biodiversity. Such impacts are amplified by an increasing human population and a limited arable land surface, which have resulted into an increased demand for agricultural productivity leading to more intensive agricultural practices on a global basis. In response, higher yielding crop varieties have been coupled with increased inputs in the form of fertilizers, irrigation, and pesticides and more intensive practices such as greater tillage of soil and fewer crop rotations and fallows. In addition, the simplification of agro-ecosystems and the removal of non-crop vegetation, like hedgerows, shelter belts and field margins, from farming areas, have contributed to the homogeneity of agricultural landscapes by reducing botanical and structural variation.

Irrigation practices, though essential to support agricultural production, can cause significant damage especially to wetlands and wildlife. Intensive cultivation practices place high demands on water supplies. Wetlands can be lost due to draining and direct conversion to agricultural land or because of water removal from rivers and streams for use in irrigation(Lemly, 2000).

The use of pesticides, in particular herbicides, fungicides, rodenticides and insecticides, poses both known and unknown risks to biodiversity, impacting wildlife on many different levels. Each of these impacts has the potential to interfere with the reproductive success of wildlife and further reduce the habitat quality and biodiversity of agricultural and surrounding ecosystems (Edge, 2000). It is estimated that a relatively limited percentage of the applied pesticides reach their target, while the remaining amount is released into surrounding ecosystems and enters the food chain, affecting animal populations at every trophic level (Gliessman, 1999). Birds exposed to sub-lethal doses of pesticides are often afflicted with chronic symptoms that affect their behaviour and reproductive success (Kegley, 1999). Pesticides are also known to negatively affect insect pest-predator population dynamics in agro-ecosystems (Landis, 2002) and to disproportionately effect insect predator populations, resulting in pest population resurgences and the development of genetic resistance of pests to pesticides (Flint, 1998). Finally, wetlands can be functionally lost due to contamination of the water supplies from agricultural pesticides in surface runoff from irrigated fields (Lemly, 2000)

Grazing practices are also deemed to have negative impacts on biodiversity and their severity and persistence may vary seasonally and as a function of livestock type, stocking density, timing, and duration. The environmental effects of changes in livestock farming are linked to the polarization of farming between intensification in favourable regions and abandonment of extensive systems in marginal areas. Traditional livestock grazing systems tend to be associated with higher biodiversity richness and high-value farmland. Therefore both intensification of livestock production and abandonment of pastoral systems can lead to biodiversity loss (EEA, 2007).

Finally, fire and burning practices exert their most obvious impact during a brief span of time, followed by a recovery period. However, in woody vegetation spots, species lacking persistence or post-fire recruitment may be extirpated from the site (Keeley *et al*., 2003).

3. Review of biodiversity and agricultural pressure indicators

The need for biodiversity indicators is widely recognised and international and European political institutions have provided their own definitions. Besides some differences in the formulation, there is substantial agreement on the relevant aspects to be taken into account in the description of biodiversity. The indicators proposed in this paper have been developed following the path traced by the United Nations and the European Union.

The United Nations Convention on Biological Diversity (CBD) acknowledges the role of indicators as information tools that summarise data on complex environmental issues and indicate the overall status and trends of biodiversity. The convention highlights seven focal areas in which the development of indicators seems to be necessary, including the status and trends of the components of biological diversity[3].

The European Biodiversity Strategy (European Commission, 1998) was developed in the context of the CBD, and it calls for the development of a set of indicators corresponding to the same focal areas. A report by the European Environmental Agency (EEA, 2007) provides a more detailed description of these indicators. Within the scope of this study it has been chosen to focus on indicators related to status and trends of the components of biological diversity as well as those referring to the threats to biodiversity. The indicators proposed in this paper have been developed bearing in mind the classification provided by the EEA.

The first group of indicators refers to trends in the abundance and distribution of selected species. For the purpose of this paper, two indicators are proposed within this category, species richness and species abundance. Species richness is the most intuitive indicator and the easiest to compute. It can be defined as the number of different species recorded in a particular site and it can be expressed either per unit area or per habitat type. The main shortcoming of this indicator lies in the fact that it does not take into account that processes of abundance reduction can take place long before a change in the number of species is observed (Ten Brink, 2000).

Species abundance can be defined as the number of individuals of a population living in a particular area. Populations and species constitute one of the most essential components of biodiversity and viable populations indicate the presence of healthy habitats and ecosystems. This indicator can be easily aggregated and it is cost-effective, since most of the data are collected by professionals making it possible to enlarge data availability with little extra cost (EEA, 2007; EASAC, 2005).

The second category of indicators foreseen by the EEA refers to trends in the extent of selected biomes, ecosystems and habitats. As explained for species, two indicators have been considered, habitat richness and habitat abundance. Habitat richness provides information about the number of habitats present in a specific area. This indicator, like species richness, does not reflect the conservation status of the considered habitats.

Habitat abundance, instead, reflects the ability of an ecosystem to provide goods and services, since this ability highly depends on the extension covered by the habitat, since a highly fragmented habitat tends to be less resilient and have reduced ability of recovering after a shock. Data is widely available since land cover change is the main driver of this indicator and this information is well mapped across a large number of countries. This indicator is cost effective and easily aggregated from smaller to larger spatial scales. Nonetheless, it does not

[3] The focal areas identified by the Convention are the status and trends of the components of biological diversity, threats to biodiversity, ecosystem integrity and ecosystem goods and services, sustainable use, status of access and benefit sharing, status of resource transfers and use and public opinion.

deliver information on the conditions of the remaining ecosystems, since habitat loss could be halted, but other drivers, such as direct exploitation, invasive species and pollution could still cause a decline of species and populations (EASAC, 2005)

The third category of indicators concerns genetic diversity, defined as the variety of alleles and genotypes present in a population that is reflected in morphological, physiological and behavioural differences between individuals and populations (Frankham *et al*., 2002). In this paper we explore the possibility of using the degree of isolation of a population with respect to the geographical range of its species, as a genetic diversity indicator. In other words it has been assumed that a population living at the margins of its species geographical range has higher probabilities of being more genetically diverse, since the distance hinders the breeding possibilities with other populations of the same species.

When considering threats to biodiversity, the EEA report defines three indicators, namely nitrogen deposition, trends in invasive alien species and the impacts of climate change on biodiversity. However, these indicators appeared still broad and, with the exception of the first one, not relating specifically to agriculture. As a consequence, it has been chosen to follow a review of indicators describing the level of agricultural pressure on the environment and on biodiversity, produced by OECD in 2001.

A first distinction needs to be made between indicators dealing with farm management capacity and those dealing with farm management practices. The former concerns the investment in the capacity of the agricultural sector to build and transfer knowledge to improve on-farm management practices leading to a more environmentally sustainable agriculture. The latter encompasses overall trends of farming methods, the development of appropriate institutions and standards, as well as various aspects of farm management which have significant effects on the environment (OECD, 2001). These include nutrient management, pest management, soil and land management, and irrigation and water management. Since this paper is dealing with the impact of agricultural activities on biodiversity conservation, an overview of the second category of indicators will be provided, focusing in particular on the adopted farming practices producing the more relevant pressure on biodiversity, namely the use of nutrients, pesticides and water.

Nutrient balance is defined as the physical difference between nutrient, generally nitrogen and ammonia, inputs into, and outputs from, an agricultural system, per hectare of agricultural land (OECD, 2001). This indicator establishes a link between agricultural nutrient use and changes in environmental quality. A nutrient balance surplus or deficit, at least over the short term, does not unambiguously indicate a beneficial or harmful environmental or resource impact, it only shows the potential for environmental damage or unsustainable use of soil resources, not actual pollution or resource depletion. Nutrient balances do, however, provide a practical, and relatively low cost, estimate of potential environmental and resource sustainability effects (OECD, 2001; EEA, 2007). This indicator has been used to study the critical load producing changes in vegetation (Nordin *et al.*, 2005) and to analyse the relationship between plant diversity and soil composition (Aerts *et al.*, 2003).

Pesticide use gives a measure of trends over time, based on pesticide sales or use data. The definition and coverage of pesticide use data vary across countries, which limits the use of the indicator as a comparative index. A large number of countries report data on pesticide sales, which can be used as a proxy for their use. The main shortcoming of this indicator is that for some countries, series are either incomplete, especially over recent years, or do not exist. Moreover, a change in pesticide use may not be equivalent to a change in the associated risks because of the great variance in risks posed by different products. Previous studies have assessed the impact of pesticides use on aquatic species diversity (Relyea, 2003) and on the diversity of plant, vertebrate and invertebrate groups (McLaughlin and Mineau, 1995).

Water use intensity is defined as the share of agricultural water use out of the total national water utilisation. The indicator reveals the overall importance of the agricultural sector in total water utilisation, and whether the changing use of water by agriculture relative to other uses, both economic and environmental, is potentially intensifying the pressure on available water resources. As a result of the lack of data on total agricultural water use for a number of countries, the irrigation water use total can be used as a proxy. The main shortcoming of this indicator is that annual fluctuations may reflect changes in irrigated area and the composition of agricultural production as well as changes in water used by other sectors in the economy and fluctuations in climatic conditions. It should be noted that the computation of both biodiversity and agricultural pressure indicators requires data that may be difficult to retrieve and to compare across countries. In this paper we maintain that, at the EU level, this information can be found in the Natura 2000 database. Although this database refers only to protected areas across EU Member States, it represents a useful source, since it contains indications of both biodiversity components and human activities performed inside or around protected areas.

4. The Natura 2000 network and the structure of the database

Natura 2000 is an ecological network of protected sites aiming at guaranteeing the long-term survival of European biodiversity. This network was established according to the Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora, known as the Habitat Directive, and of the Council Directive 79/409/EEC on the conservation of wild birds, known as the Birds Directive[4]. The provisions of these directives identified a list of species and habitats to be protected throughout the European Union. In view of implementing these requirements, the European Commission has established a standard format for the collection of relevant information from member countries, in order to create an overall database, the Natura 2000 database.

The information is requested to each site managing authority and it includes the geographic location, the surface covered and the altitude of the site, as well as the biogeographic region to which the site belongs[5]. Furthermore, an evaluation of the conditions of protected habitats and species is required. In addition to that, a general description of the main features of the site needs to be provided, including geological, morphological and landscape characteristics as well as the dominant vegetation types. The protection status of the site under the national or regional legislation must be reported. Finally, information on the mapping of human activities inside and around the site, as well as their influence and intensity need to be provided. Since this information will be used to construct the indicators employed in this analysis a brief description of the structure of the database will be provided.

As far as the species ecological status is concerned, six taxa, namely amphibians and reptiles, birds, fishes, invertebrates, mammals and plants, are assessed separately, according to a set of criteria. The evaluation is based on a scale ranging from A to C. To begin with, an estimate of the size and density of each species' population living on the site is required. Ranking "A", indicates that the site population represents from 100% to 15% of the total number of specimen living on the national territory, "B", reflects a share ranging from 15% to 2% and "C", from 2% to 0%.

Secondly, the degree of geographical isolation of each population in each site with respect to the natural range of the species is required. This can be interpreted as a measure of the contribution of a given population to its species' genetic diversity, since a more isolated population is unlikely to breed with other populations of the same species, thus preserving peculiar genetic characteristics. Ranking "A" signals an almost complete isolation, "B" suggests that the population is not isolated but lives on the margins of the area of distribution, while "C" implies that the population lies in an extended distribution range.

As regards habitats, a measure of habitat relative surface, reflecting the area covered by each habitat at the site level in relation to the total area covered by the same habitat type at the

[4] The Natura 2000 network encompasses two types of protected sites, Special Protection Areas (SPA) and Special Areas of Conservation (SAC). The first category has been instituted by the Birds Directive, although it also includes protection areas for migratory species created by the Ramsar Convention on Wetlands. The second category covers sites created by the Habitat Directive in order to maintain species and natural habitats in a satisfactory conservation status. Natura 2000 sites are therefore characterized by the presence of habitat and animal and plant species of community interest.

[5] The considered biogeographic regions are the boreal, continental, atlantic, alpine, mediterranean and macaronesian regions.

national level is also required. The associated rankings can be A, indicating a share ranging from 100% to 15%, B, from 15% to 2% and C, from 2% to 0%. The Natura 2000 survey also reports information with respect to human activities performed inside or around protected sites. The types of activities considered in the database are classified in nine categories, namely agriculture and forestry, fishing, hunting and collecting, mining and extraction of materials, urbanisation and industrialisation, transportation and communication, leisure and tourism, pollution, human induced changes in wetlands and marine environment and natural biotic and abiotic processes. For the purpose of this paper only agricultural and forestry activities have been taken into consideration. Within this broad category the Natura 2000 database identifies 22 specific activities graphically displayed in Figure 4.1.

Insert Figure 4.1 about here

Site managers are required to state whether these activities are deemed to have high, medium or low intensity and whether their influence is positive, neutral or negative. Moreover they need to report the percentage of the site affected by each activity. Table 1 presents the codes employed by the Natura 2000 database to identify the different types of influence and degrees of intensity.

Insert Table 4.1 about here

5. Developing biodiversity and agricultural pressure indicators using the Natura 2000 database

The biodiversity and agricultural pressure indicators reviewed in Section 3 have been adapted to the needs of this study and to the information contained in the Natura 2000 database. All indicators have been calculated at the site level. Species diversity indicators were first calculated separately for each of the six taxa considered in the database and then averaged so as to obtain a single value for each site. Since for the purpose of this paper the indicators will be used to analyse the impact of agricultural activities on biodiversity in protected areas, the scale of analysis is the country level. The specific case study, Italy, will be presented in the following section.

The species richness indicator was computed as the ratio between the number of species present in each site and the total number of species living on the national territory. The underlying idea is the so-called “inter-species democracy”, implying that all species are considered equally important. Species abundance was obtained using information on population size and density, which reflects what share of a species’ national population is living in each particular site.

As far as habitat diversity is concerned, it has been chosen to take into account the ratio between the number of habitats found in a site and the number of habitats recorded at a national level, in order to create the habitat richness indicator. The habitat relative surface has been used to calculate the habitat abundance indicator.

As explained in section 4, the database originally presents ordinal scale assessments of species and habitat information, based on a scale ranging from A to C. As a consequence, it has been necessary to attach a numerical value to each of the rankings. In order to treat all this information in a homogeneous way and consistently with the definitions provided by the database itself, it has been decided to attach a value of 100 to ranking "A", of 15 to ranking "B" and of 2 to ranking "C"[6]. As a result, habitat and species indicators have been computed according to equation (1)

$$Indicator = \frac{(No.\ "A" \times 100 + No.\ "B" \times 15 + No.\ "C" \times 2)}{No.\ habitats\ or\ species\ per\ site} \qquad (1)$$

The outcome of this process has been the creation of five indicators, namely species richness, abundance and isolation and habitat richness and abundance. The score of each indicator is normalized on a scale ranging from 0 to 1. In addition to these single indicators, it seemed useful to create a composite indicator, taking into account simultaneously richness and abundance, both for species and habitats. This choice is justified since, as pointed out while reviewing the indicator, species richness conveys important information but it does not appear to be a sufficient indicator of species diversity on its own. Therefore it seemed useful to couple this piece of information with the one relating to abundance, multiplying the respective scores for each species and each habitat, according to equation (2).

$$Composite\ Indicator = Richness * Abundance \qquad (2)$$

As far as pressures from agricultural activities are concerned, the data available from the Natura 2000 database are not sufficiently detailed so as to compute the different indicators reviewed in Section 3. In addition, the database already provides information on influence and intensity of agricultural activities implemented inside or around protected areas. It has therefore been chosen to compute two composite indicators, one for agricultural pressures

[6] This is an arbitrary choice and alternatives are possible. For instance, it could have been decided to attach the mean value of each interval to those rankings. However, since these indicators are used to produce biodiversity profiles at the site level, with the objective of comparing different locations, the choice of the value exerts a limited influence on the results of the analysis.

within the site and one for pressures in the surrounding areas. The main difference between them is that the spatial dimension can be considered only for activities taking place inside the sites, while for the site surroundings, it is possible to retrieve the number of different activities performed together with the influence and intensity of their impacts. The agricultural pressure index inside the sites has been computed according to equation (3),

$$Agricultural\ Pressures_{IN} = \left(\frac{\sum_n A_n^i c_n^i Influence_n^i Intensity_n^i}{A^{i=I}} \right) \qquad (3)$$

where A^i_n stands for the area of the entire nth Natura 2000 site dealing with the ith impact, c^i_n represents the percentage of A^i_n directly covered by an activity originating the ith impact. $Influence^i_n$ is the positive, neutral or negative pressure exerted by the ith activity on the nth site, while $Intensity^i_n$ stands for the high, medium or low intensity of the pressure. Finally, $A^{i=I}$ represents the total area of Natura 2000 sites dealing with any agricultural activity. This index highlights activities covering larger areas within the sites. As a general rule this delivers a rather complete measure of the relevance of impacts, but it is limited to activities being implemented inside protected sites.

In order to take into account agricultural activities around the sites, a separate index has been computed, according to Equation (4). This index conveys information on influence and intensity of pressures arising from each activity, however, since no information is available on the surface affected by outside activities, this index lacks the spatial dimension.

$$Agricultural\ Pressures_{OUT} := \sum_n \left(presence_n^i Influence_n^i Intensity_n^i \right) \qquad (4)$$

The scores attained by both agricultural pressure indices can be read on a scale ranging from -1 to 1. The development of this set of biodiversity and agricultural pressure indicators is not only a result per se, since it allows an empirical measurement of biodiversitystatus and the pressures it is subject to, but it can also serve as an input for an additional step of the analysis, since the indicators can be used as explanatory variables when modelling the linkages between biodiversity and agricultural activities. The following sections will demonstrate their potential in describing and analysing an empirical case study, namely the Italian Natura 2000 sites.

6. The Italian case study

6.1 Descriptive statistics of the Italian Natura 2000 sites

In order to introduce the application of the previously described agricultural pressure and biodiversity indicators, it seems important to provide a deeper analysis of the features of the Italian Natura 2000 sites. Italy counts 1.328 sites, accounting for about 8 % of the EU 25 sites. The North-Eastern area of the country appears to host the highest number of sites, while Sardinia records the lowest number with only 9 sites. The relative dimensions of these regions must be taken into account in order to better appreciate the real distribution of these sites. At the national level 3.7 million hectares are protected under Natura 2000 and their distribution among the regions is strongly uneven. The North-East region records the highest coverage of protected areas out of the total regional surface with 24%. Sardinia and Sicily, by contrast, have the least coverage of protected areas. Table 6.1 provides the classification of NUTS 2 macro-regions in Italy, the number of sites and the distribution of Natura 2000 protected area across the regions.

Insert Table 6.1 about here

Natura 2000 sites can be assigned different levels of institutional protection, depending on their importance of the site in terms of protected species and habitats as assessed by the national government. In the Italian case, Natura 2000 sites are clustered into twenty-six different categories, each of which guarantees a high, medium, low or no institutional protection. A single site can be listed under two or more different categories, since a portion of a site can belong to a highly protected category, for instance a National Park, while the rest may not be granted any institutional protection.

As a matter of fact, 480 Italian sites are listed, at least partially, as receiving no institutional protection. However, regional and county parks and regional and county natural reserves, both classified as highly protected, include 273 and 305 sites respectively, with coverage of 92% and 87% of the protected surface. In addition, the lowest levels of protection, like private reserves and hunting farms, cover a very low proportion of Natura 2000 sites. Table 6.2 presents these categories as well as the number of sites covered, totally or partially, by them.

Insert Table 6.2 about here

As regards the distribution of protected sites across different biogeographic regions the majority of Italian sites, 46%, belong to the continental region, 37% to the alpine region, while only 17% pertain to the Mediterranean one. This seems to be linked to the previously highlighted lower number of designated sites and coverage of protected areas in southern Italy.

6.2 Agricultural pressures

Italian Natura 2000 sites affected by agricultural activities are 718. However, information is available only for 570 sites, covering about 43 % of the sites. The number of sites dealing with agriculture is close to zero in Sardinia, Lazio and Emilia-Romagna, while they reach 80% in Sicily and 74% in Campania. Nonetheless, only about 64% have provided information on human activities, which may entail an underestimation of the real agricultural pressures. The area covered by Natura 2000 sites impacted by agricultural activities is about one half of the national total, covering more than 1.8 million hectares.

The most common activities occurring in the Italian sample appear to be cultivation, grazing and forestry. Furthermore, artificial planting, abandonment of pastoral systems and burning practices are reported in nearly 18% of sites. Finally, modification of cultivation practices, mowing and cutting, use of pesticides and animal breeding represent around 7% of recorded activities.

The computation of the agricultural pressure indicators for each activity highlights that grazing and forestry appear to generate the most relevant pressures, the second being more ambiguous in terms of influence, since its positive effects nearly compensate the negative ones. It seems interesting to notice that mowing and cutting is the only activity giving rise exclusively to positive pressures, while, cultivation and grazing practices may also produce positive effects on protected sites, although negative impacts are predominant. On the contrary, the use of pesticides, fertilisation and irrigation, together with animal breeding and burning appear to produce predominantly negative and significant pressures. Table 6.3 displays the score attained by the agricultural pressure index for each activity.

Insert Table 6.3 about here

As far as agricultural pressures inside the sites are concerned, Calabria and Sicily regions attain the most negative scores, while Liguria, Lombardy and Marche record a slightly positive score. When considering pressures on the surroundings of protected areas, it appears that Veneto and Puglia attain the most negative scores, while Liguria and Abruzzo obtain a positive value. It is worth recalling that the interpretation of a positive score in the agricultural pressure index differs depending on where agricultural activities are implemented. As a matter of fact, a positive pressure index inside the site signals that the surface covered by positive or neutral impact activities is higher than the surface affected by negative ones. By contrast, a positive score of the pressure indicator around the site means that the number of positive or neutral activities is higher than the number of negative ones, since this index does not account for the spatial dimension. Table 6.4 presents the distribution of the area covered by Natura 2000 protected sites across the Italian regions as well as the value attained by agricultural pressure indices inside and outside protected sites.

Insert Table 6.4 about here

The agricultural pressure indices are also suitable for considering vectors of activities. In the Italian sample, as far as pressures inside the sites are concerned, cultivation activities are strongly correlated to the use of pesticides, fertilization and irrigation, being implemented in 72%, 55% and 80% of the sites where those activities are performed. In addition cultivation appears to be present in 67% of the sites where restructuring of agricultural landholding takes place. The use of pesticides is highly correlated with fertilisation and grazing activities are performed in 75% and 55% of the sites where animal breeding and stock feeding take place.

Forestry activities appear to be correlated with animal breeding and stock feeding, being present respectively in 70% and 50% of the sites were those activities are reported. In 50% of the sites in which forest re-planting and stock feeding take place, burning practices are also implemented.

As regards activities outside the sites, cultivation is again strongly correlated with the use of pesticides, fertilisation and irrigation, being reported for the 75%, 73% and 73% of the affected sites respectively. The latter three activities also show very high correlation among themselves. In 50% of the areas in which forestry takes place, cultivation is also performed and, in the 57% of cases, forestry is also associated with grazing activities. In 50% of the areas used for animal breeding cultivation takes place, and the same goes for the use of pesticides, fertilisation, irrigation and grazing. Burning practices are associated to grazing activities in the surroundings of 71% of protected sites. It seems interesting to notice that the activities originating the most negative pressures, as showed in Table 5, tend also to be more strongly correlated with one another.

6.3 Biodiversity profiles

As far as biodiversity profiles are concerned, the scores for species richness appear to be low, the highest being reached by Campania and the lowest by Valle d’Aosta. By contrast this region attains one of the higher scores, together with Lazio and Sicily when it comes to species abundance. The highest values for species isolation are recorded for Abruzzo and Campania.

Habitat diversity indicators tend to deliver better results across all regions, with higher scores for richness and abundance, in particular for Lazio, Puglia and Lombardy. As already mentioned in the section concerning the indicators development process, two composite indicators, one for habitat and one for species have been added to the individual indicators. Abruzzo and Puglia reach the highest values in the habitat composite indicator while the highest values for species are recorded in Lazio and Abruzzo. Their scores confirm the trend highlighted for individual indicators, since the species indicator attains lower scores than the habitat one across all regions. Table 6.5 shows the scores attained by biodiversity indicators at the regional level.

Insert Table 6.5 about here

7. Model specification and estimation results

Since biodiversity is a multifaceted concept that must be analysed taking into account, simultaneously, all the aspects highlighted in the previous paragraph, it seems interesting to use the developed biodiversity and agricultural pressure indicators in order to formally test the relationship between biodiversity conservation and agricultural activities occurring inside protected areas or their surroundings.

Biodiversity and agricultural pressure indicators, together with site geographical features and the degree of institutional protection, have been included as explanatory variables in a multiple regression model[7]. T he species composite indicator has been considered as the dependent variable to be explained in terms of a set of variables including site geographic location (x_1), site physical features(x_2), biodiversity indicators, namely habitat diversity and species isolation, (x_3), the degree of institutional protection the site is granted (x_4) and the pressures exerted by agricultural activities inside the site and in its surroundings (x_5).

The model specification is presented in equation (5):

$$\log y = \beta_0 + \beta_1 \log x_1 + \beta_2 \log x_2 + \beta_3 \log x_3 + \beta_4 \log x_4 + \beta_5 \log x_5 + \varepsilon \qquad (5)$$

As regards the physical characteristics of the site, the mean altitude is found to exert a positive impact on the overall status of protected species, either influencing the number of species or the number of individuals living in a site. As far as the biogeographic region is concerned, alpine sites appear to attain a lower score in species diversity with respect to sites located in the continental region, while in the Mediterranean region species diversity appears to be higher. Variables referring to site geographic location are classified in four macro regions, North-east, North-west, Centre and South. Results show that central and southern

[7] The logarithmic transformation of the dependent and explanatory variables was performed as this appeared to fit the data better than the linear form.

regions are negatively correlated to overall species diversity with respect to the North-west and North-east regions.

When considering biodiversity, it seemed useful to include in the model two indicators that appear to be closely linked to the overall status of species diversity, the habitat composite indicator and species isolation. They are both positively correlated with the dependent variable and significant. This means that a more diverse and abundant natural habitat exerts a positive impact on species diversity. Moreover, it can be argued that the more isolated a population is, with respect to the geographical range of its species, the higher the level of species diversity. Furthermore, a high degree of institutional protection is positively correlated with the species diversity of the site. This can be read as a policy response to the risk of biodiversity loss, since sites hosting particularly valuable or risk-prone species and habitats tend to be granted higher protection, resulting in a better conservation of species.

When it comes to pressures generated by agricultural activities, it can be noted that both the index for inside activities and the one for outside activities are negatively correlated with the score of the species composite indicator, though only the latter is significant. These pressure indices take into account simultaneously impacts and intensity of agricultural activities, therefore this result signals that a more intense pressure exerted on the site leads to a lower level of species diversity. Table 7.1 presents the estimation results.

Insert Table 7.1 about here

The analysis of the plot of residuals of the first model showed a potential problem of heteroskedasticity. In order to correct for this, it has been decided to redefine the model using employing the site area, as a weighting factor[8]. Results provided by this model confirm the ones provided by the first one, with a slight increase in the goodness of fit of the model. In addition the agricultural pressure index for inside activities becomes significant. Results are displayed in Table 7.2.

Insert Table 7.2 about here

8 Further discussion and policy implications

The interpretation of the results delivers an interesting picture of the relations between species diversity, measured as the score of the species composite indicator, and pressures from agricultural activities inside and around Natura 2000 sites. It turns out that, for the Italian

[8] Unlike least squares, however, each term in the weighted least squares criterion includes an additional weight, w_i, that determines how much each observation in the data set influences the final parameter estimates. The weighted least squares criterion that is minimized to obtain the parameter estimates is:

$$\sigma^2 = \sum_{i=1}^{n} w_i [y_i - f(\vec{x}_i ; \hat{\vec{\beta}}_i)]^2$$

sample, sites in which pressure from agricultural activities produces particularly negative impacts, the status of species diversity is negatively affected.

Notwithstanding this, different activities may generate different impacts, as already pointed out when describing the agricultural pressure indicators. It is important to consider that both the presence of strongly negative activities and the surface affected by them significantly increase the score of the pressure indicator attained by a site. In addition, in most cases several activities are performed simultaneously inside the sites and their joint effect may modify the level of agricultural pressure. As a matter of fact, the interaction of two activities may result in a lower level of pressure than the two activities considered separately and vice versa.

It seems therefore interesting to investigate which groups of activities are negatively correlated to species diversity. In order to carry out this analysis it has been chosen to focus on the activities that originate the most negative pressures so as to study the correlation between their interaction and the score of the species composite indicator at the site level. Activities having a strong negative impact, according to their score in the agricultural pressure index, appear to be cultivation, use of pesticides, grazing, abandonment of pastoral systems, forestry management, and burning practices, as discussed in section 4.2.

The agricultural pressure index for activities inside the sites has therefore been disentangled to account for the presence of these activities. A linear regression has been run using the species composite indicator as the dependent variable and a set of dummy variables indicating the presence of the selected activities inside the sites in addition to their cross products in order to analyse their joint effects. Results show that while all activities, individually considered, are negatively correlated to the status of species diversity, the simultaneous presence of two of them tends to deliver a different result.

To begin with, cultivation appears to exert a positive impact on species diversity, when coupled with grazing and forestry management activities. The same reasoning applies to the simultaneous presence of abandonment of pastoral systems and grazing and forestry respectively. In addition, the joint presence of cultivation and the use of pesticides is also positively correlated to species diversity. These results allow concluding that the net effect of forestry, cultivation and grazing activities when combined among themselves and with other activities tend to be positive for species diversity. This is consistent with the fact that those three activities appear to generate higher positive pressures, in addition to negative ones, with respect to the other agricultural activities. Table 8.1 displays these results.

Insert Table 8.1 about here

9. Conclusions

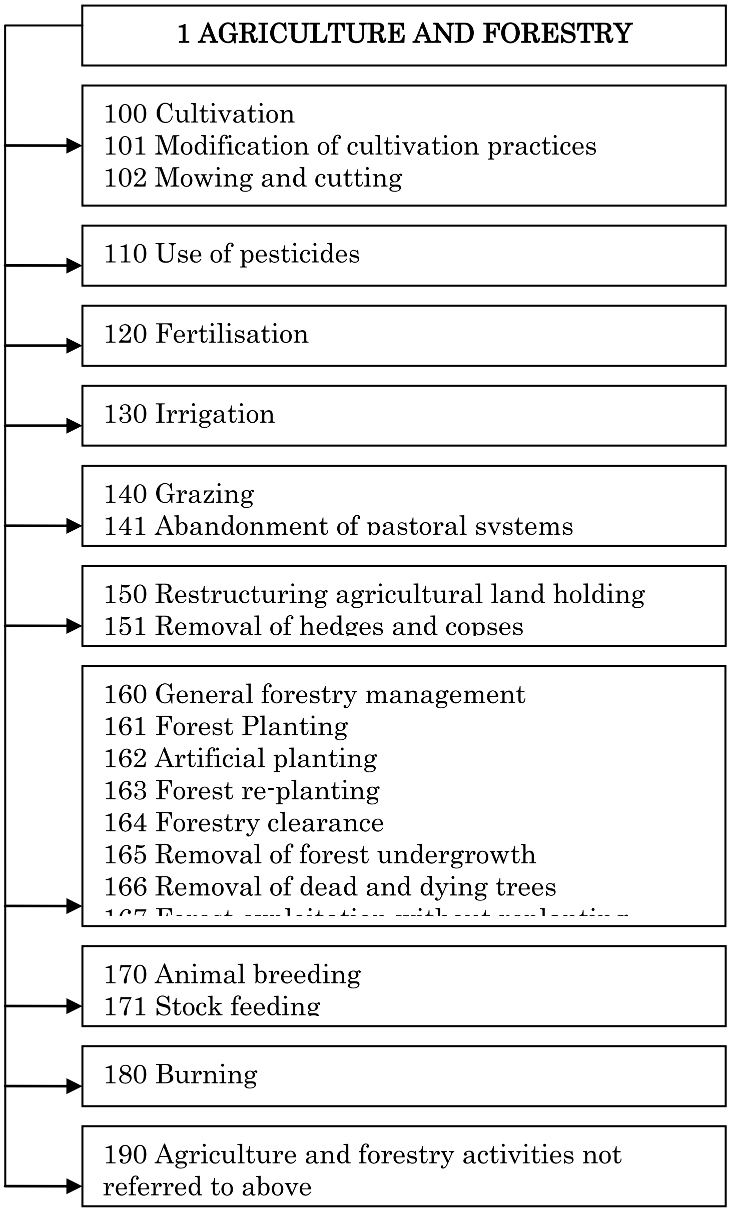
The present paper has demonstrated that an existing database, Natura 2000, can be used to compute both biodiversity and agricultural pressure indicators for the EU Member States. These indicators can be computed for each protected site and aggregated at the desired geographical scale. In addition, they are consistent with the indicators developed by international and European institution and to the ones used in the literature on biodiversity conservation.

The achieved results allow concluding that a significant link exists between the score in the species diversity indicator and the pressure index accounting for the impact of agricultural activities performed inside Natura 2000 sites. As a consequence, species diversity tends to be higher in site in which the pressure from agricultural activities happens to be lower. Nonetheless, this does not imply that a tighter protection would necessary result in an increased species diversity, since the interaction of several activities, each having a negative impact when individually considered, has been found to exert a positive impact on this indicator. The idea underpinning the creation of the Natura 2000 network, that certain human activities performed inside a site can contribute to biodiversity conservation, is not contradicted by the empirical results for the Italian case study. However, biodiversity protection policies need to be focused on avoiding the most negative impacts enhancing the positive interactions among activities rather than forbidding the implementation of the negative ones.

As far as the performance of indicators is concerned it seems important to notice that species isolation performed particularly well in this case study. This can be explained considering that the more isolated a population is, with respect to the geographical range of its species, the higher the probability that it is granted a higher level of protection or that the activities performed in the site are compatible with conservation. The agricultural pressure indices, created to reflect the overall level of agricultural pressure on a site, deliver negative and significant results. The overall performance of biodiversity and agricultural pressure indicators is satisfactory and, since the data are available at the EU level, the model can be replicated and results obtained for different countries could be easily compared. Such comparisons could be interesting since the choice regarding the level of protection granted to sites and the site surface affected by different activities may vary substantially across countries.

Figures

Figure 4.1: Classification of agricultural activities in the Natura 2000 database



Source: Natura 2000 database, own elaboration

Tables

Table 4.1: Influence and intensity of agricultural activities

$Influence^{i}_{n}$	:= +1 if the i-th activity has a positive (+) pressure
	:= 0 if the i-th activity has a neutral (=) pressure
	:= -1 if the i-th activity has a negative (-) pressure
$intensity^{i}_{n}$	:= 2 if the i-th activity has a high-intensity pressure
	:= 1 if the i-th activity has a medium-intensity pressure
	:= 0.5 if the i-th activity has a low-intensity pressure

Source: Natura 2000 database, own elaboration

Table 6.1: Description of NUTS 2 regions in Italy

NUTS 2	Description	Number of sites	Area (%)
IT	Italy	1328	100%
IT1	North-West	195	13%
IT2	Lombardy	190	8%
IT3	North-East	375	24%
IT4	Emilia-romagna	136	6%
IT5	Centre	227	12%
IT6	Lazio	48	7%
IT7	Abruzzo-molise	32	13%
IT8	Campania	27	6%
IT9	South	37	7%
ITA	Sicily	47	3%
ITB	Sardinia	9	0%

Source: Natura 2000 Database, own elaboration

Table 6.2: Typologies of institutional protection in the Italian sample

Description provided by the Natura 2000 database	Level of institutional protection	No. Sites
No protection	None	480
National park	High	101
National natural reserve	High	69
Cross-regional natural park	High	3
Regional natural park	High	273
Regional natural reserve	High	305
Natural monuments	High	3
Fauna protection oasis	Medium	97
Natural beauty	Medium	244
Urban green area	Medium	1
Land use rights limitation for hydro-geological issues	Medium	289
Safeguard areas for superficial water and groundwater resources for human consumption	Medium	7
Private potection areas	Low	8
No-hunting areas	Low	1

Source: Natura 2000 database, own elaboration

Table 6.3: Score of the agricultural pressure index by activity

Activity	Negative impacts	Positive impacts	Agricultural pressure index
Cultivation	-0.024	0.009	-0.015
Modification of cultivation practices	-0.002	6.61E-05	-0.002
Mowing and cutting	-8.24E-05	0.002	0.002
Use of pesticides	-0.012	0	-0.012
Fertilisation	-0.0058	5.39E-06	-0.0054
Irrigation	-0.002	0.0001	-0.002
Grazing	-0.085	0.008	-0.077
Abandonment of pastoral systems	-0.024	0.003	-0.0204
Restructuring of agricultural land holding	-0.0007	0	-0.0007
Removal of hedges and copses	-0.0003	0	-0.0003
General forestry management	-0.039	0.029	-0.0107
Forest planting	-3.86E-05	3.21E-05	-6.54E-06
Artificial planting	-0.010	0.001	-0.008
Forest re-planting	0	8.49E-06	8.49E-06
Forestry clearance	-0.0001	0	-0.0001
Removal of forest undergrowth	-0.001	2.03E-05	-0.0015
Removal of dead and dying trees	-0.001	6.45E-05	-0.0014
Forest exploitation without replanting	-0.001	0	-0.0013
Animal breeding	-0.010	0.0005	-0.0102
Stock feeding	-0.001	0	-0.0017
Burning	-0.043	0	-0.043
Agriculture and forestry activities	-0.015	1.88E-05	-0.0154

Source: Natura 2000 database, own elaboration

Table 6.4: Descriptive statistics and scores of the agricultural pressure indicators across Italian regions

Region	N. of sites	Area	Alpine sites	Continental sites	Mediterranean sites	Sites affected by agricultural activities	Agricultural pressure index (IN)	Agricultural pressure index (OUT)
Piedmont	136	288884	65	71	0	26	-1.88E-05	-1.447
Valle d'Aosta	27	114103	27	0	0	3	0	-0.029
Liguria	32	69738	20	11	1	21	9.42E-06	0.75
Lombardia	190	296006	99	91	0	35	4.77E-06	-0.381
Trentino A. A.	195	327745	195	0	0	21	-7.17E-06	-1.812
Veneto	119	442048	44	75	0	53	-3.59E-05	-2.347
Friuli V.G.	63	143783	25	38	0	37	-5.26E-06	-2.2
Emilia Romagna	139	246889	0	139	0	129	0	0
Toscana	86	179924	0	33	53	59	-3.03E-05	-1.226
Umbria	40	74161	0	35	5	24	-3.56E-05	-1.591
Marche	101	211110	0	101	0	31	4.37E-06	-0.917
Lazio	48	249019	7	1	40	28	0	0
Abruzzo	30	497867	12	17	1	23	0	0.25
Molise	2	813	0	0	2	0	-9.60E-06	-1.25
Campania	27	214803	0	0	27	15	7.69E-06	0
Puglia	16	207124	0	0	16	1	0	-2.454
Basilicata	17	34068	0	0	17	2	-1.69E-05	-0.875
Calabria	4	27081	0	0	4	2	-0.0001099	-0.5
Sicily	47	125215	0	0	47	19	-0.0001671	-2.16
Sardinia	9	16137	0	0	9	5	-7.78E-06	-0.5

Source: Natura 2000 database, own elaboration

Table 6.5: Scores of biodiversity indicators across Italian regions

Region	Species richness	Species abundance	Species Isolation	Habitat richness	Habitat Abundance	Species composite	Habitat Composite
Piedmont	0.029	0.032	0.047	0.045	0.008	0.012	0.013
Valle d'Aosta	0.009	0.043	0.04	0.005	0.008	0.013	0.00
Liguria	0.047	0.018	0.028	0.011	0.007	0.006	0.008
Lombardia	0.035	0.015	0.039	0.102	0.014	0.005	0.006
Trentino A. A.	0.016	0.012	0.028	0.01	0.029	0.002	0.007
Veneto	0.041	0.026	0.064	0.095	0.023	0.01	0.011
Friuli V.G.	0.044	0.024	0.044	0.026	0.015	0.008	0.008
Emilia Romagna	0.067	0.018	0.047	0.033	0.006	0.013	0.026
Tuscany	0.04	0.02	0.04	0.09	0.04	0.01	0.04
Umbria	0.033	0.009	0.025	0.091	0.004	0.005	0.020
Marche	0.02	0.02	0.04	0.01	0.05	0.01	0.13
Lazio	0.045	0.045	0.093	0.231	0.031	0.025	0.014
Abruzzo	0.061	0.036	0.161	0.094	0.088	0.024	0.342
Molise	0.056	0.008	0.05	0.075	0.15	0.004	0.00
Campania	0.095	0.036	0.053	0.019	0.036	0.017	0.069
Puglia	0.077	0.025	0.153	0.191	0.00625	0.019	0.188
Basilicata	0.064	0.021	0.049	0.137	0.056	0.012	0.035
Calabria	0.05	0.02	0.05	0.11	0.08	0.01	0.00
Sicily	0.029	0.041	0.08	0.127	0.002	0.016	0.106
Sardinia	0.054	0.009	0.01	0.004	0.016	0.011	0.004

Source: Natura 2000 database, own elaboration

Table 7.1: Estimation results for the linear model

Species composite indicator	**Coefficient**	**P>|t|**
constant	-6.871	0.019*
Alpine region	-1.950	0.068*
Mediterranean region	1.375	0.054*
Mean altitude	0.457	0.058*
Centre	-1.950	0.073*
South	-2.978	0.061*
Habitat composite indicator	0.313	0.027*
Species isolation	0.330	0.004**
High institutional protection	0.672	0.042*
Agricultural pressure indicator (IN)	-0.268	0.138
Agricultural pressure indicator (OUT)	-1.820	0.001**
	R2	**0.97**

Statistical significance of 0.1%. 5% and 10% is indicated by ***. **. * respectively

Table 7.2: Estimation results for the model using the site area as a weighting factor

Species composite indicator/ site area	**Coefficient**	**P>|t|**
constant	-7.267	0.013*
Alpine region	-1.905	0.052*
Mediterranean region	1.400	0.041*
Mean altitude	0.458	0.051*
Centre	-1.918	0.057*
South	-2.940	0.048*
Habitat composite indicator	0.310	0.023*
Species isolation	0.373	0.004**
High institutional protection	0.676	0.030*
Agricultural pressure index (IN)	-0.309	0.094*
Agricultural pressure index (OUT)	-1.893	0.001**
	R2	**0.98**

Statistical significance of 0.1%. 5% and 10% is indicated by ***. **. * respectively

Table 8.1: Analysis of the joint effect of the agricultural activities producing the most negative impacts

Species composite indicator	**Coefficient**	**P>|t|**
cultivation	-4.744881	0.000***
grazing	-4.889758	0.000***
abandonment of pastoral systems	-5.784019	0.000***
forestry	-5.30294	0.000***
burning	-2.703086	0.007**
use of pesticides	-5.499375	0.014*
cultivation*grazing	3.309734	0.007**
cultivation*abandonment of pastoral systems	2.578816	0.111
cultivation*forestry	2.576466	0.023*
cultivation*burning	1.829332	0.215
grazing*abandonment of pastoral systems	3.141094	0.020*
grazing*forestry	4.024879	0.000***
grazing*burning	2.164852	0.131
abandonment of pastoral systems*forestry	3.110142	0.022***
abandonment of pastoral systems*burning	2.304787	0.176
forestry*burning	1.533392	0.332
cultivation*use of pesticides	5.028024	0.074*
use of pesticides*abandonment of pastoral systems	3.231685	0.605
use of pesticides*forestry	3.671611	0.382
use of pesticides*burning	2.011668	0.710
	R2	**0.29**

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