Protection outside protected areas: How are farming systems influencing biodiversity conservation in Natura 2000 areas?

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September 14, 2009

PRELIMINARY DRAFT – PLEASE DO NOT CITE OR CIRCULATE

Abstract

Increasingly over the past hundred years, areas of natural interest have being protected by imposing constraints on acceptable types of land use. However, even if a protected area is managed adequately within its borders, a number of mechanisms have been proposed through which its ecological functioning may be affected by human activities taking place in the surrounding landscape. In this paper we investigate how biodiversity on a cross-section of protected sites, the Italian portion of the European Union's Natura 2000 network, is affected by land use changes in neighboring areas. We exploit variation in space to relate indicators of success of conservation efforts to measures of landscape structure and intensity of farming.

We focus on features of the landscape that pertain to agriculture because this represents the dominant form of land use in large parts of terrestrial areas. Furthermore, the widespread decline in biodiversity observed over the past few decades in Europe has largely been linked with the intensification of farming. Besides, it has been argued that the adverse biodiversity effects of agriculture result from landscape simplification. As a matter of fact, about two Natura 2000 sites in three reported negative influences on their conservation status from agricultural activities.

Ultimately, the goal of our empirical analysis is to determine what types of sites are especially sensitive to land use change in the surrounding areas, how large the zone of influence around a site is, and what aspects of agriculture are more likely to adversely affect biodiversity.

Introduction

Ever since concerns for the loss of biodiversity began to emerge, the cornerstone of conservation strategies has been represented by protected areas (PAs) that are managed for the persistence of some species or habitats that are deemed of interest. Over the past three decades, about 26,000 PAs – which are collectively known as the Natura 2000 network – have come into existence in the European Union, covering about 20% of its territory.

Typically, designation of a site as a PA implies constraints on human activities and, more specifically, restrictions on acceptable types of land use. Even in PAs that were adequately managed, however, there have been reports of native species extinctions, invasions by exotic species, and changes in critical ecological processes (e.g. Rivard et al. 2000). One major reason may be land use change in the surroundings. In general, biodiversity within a PA may be affected by land use change in the neighboring areas through a variety of ecological mechanisms (Hansen and DeFries 2007). For example, if the effective size of the ecosystem is larger than the PA, loss of habitats in its unprotected portions will generally result in smaller populations and higher risk of extinction. It is likely that, as the effective size of the ecosystem shrinks, it is large predators that disappear first, which in turns impacts the trophic structure of the ecosystem. Also, habitats that are seasonally important may be located outside the PA's boundaries. Furthermore, different uses of the lands surrounding a PA largely entail different levels of water and air pollution, different regimes of fire and flood disturbance, and different degrees of exposure to humans.

In fact, it is often the case in Europe that PAs are embedded in landscapes that are already dominated by human activities, and where almost no genuinely natural areas remain. Yet, it may be desirable to shape those landscapes so that they contribute to rather than hinder conservation. In this respect, agriculture, which constitutes the prevailing form of land use in large parts of terrestrial areas, can play an important role. Changes in farming systems can have large impacts – whether positive or negative – on biodiversity. On the one hand, the widespread declines in wildlife observed over the past few decades have been widely blamed on the intensification of farming (Chamberlain et al. 2000; Donald et al. 2001; Robinson and Sutherland 2002). On the other, European landscapes have been shaped by agriculture over centuries, to the extent that many species depend on agricultural ecosystems for their habitats and risk disappearing if farming were discontinued. It has been speculated that at least 50% of Europe's most valuable biotopes are found on farmland that is managed extensively (Bignal and McCracken 1996).

Unfortunately, what would make an agricultural landscape more welcoming to biodiversity is usually unclear. Early research in this area focused on the effects of individual farming practices. Field or farm level experiments have been conducted to assess the biodiversity impacts of virtually every aspect of farming (to mention only few review articles: Freemark and Boutin 1995; McLaughlin and Mineau 1995; de Snoo 1999; van Buskirk and Willi 2004; Bengtsson et al. 2005; Hole et al. 2005). Taken together, the literature on agricultural practices and wildlife – in addition to emphasizing the need for reduced pesticide and fertilizer use – has generally highlighted the importance of maintaining and managing portions of non-crop areas on farm (e.g. field margins, hedgerows, and so forth). However, the effectiveness of such practices at promoting biodiversity in a real-world setting has been questioned. To some extent, the recommendations that emerge from this literature have been incorporated over the past 20 years into the EU's agricultural policy. Most notably, this has been done through so-called agri-environment schemes. While actual implementation varies across and within EU member states, the common trait of these schemes is that farmers adhere on a voluntary basis to a pre-specified set of management prescriptions and in exchange receive ecological compensation payments. Even though relatively few rigorous evaluations have been conducted of how agri-environment schemes fare at promoting farmland biodiversity (Kleijn and Sutherland 2003), the existing evidence suggests that they generally delivered only moderate improvement (Kleijn et al. 2006). For example, Kleijn et al. (2001) assessed the effectiveness of a Dutch agri-environment scheme and found that, even though participation in the program did modify farm management practices, the modified practices had no effect on either plant or bird species richness.

While efforts to improve the quality of on-farm habitats can be expected to make positive contributions to conservation, it has been argued that understanding the effects of agricultural land-use on biodiversity requires a landscape perspective. Features of the landscape may ultimately affect wildlife more than individual farming practices. The reasons why the intensification of farming has been associated with widespread declines in biodiversity might not lie in any specific practice, but in the highly homogenized landscape it has helped produce. In their review article, Benton et al. (2003) maintain that the existing evidence is consistent with this notion. They argue that, "rather than concentrating on particular farming practices, there is an identifiable universal management objective – promoting heterogeneity – that could be applied widely across agricultural systems". Indeed, it has been proposed that "structurally complex landscapes enhance local diversity in agroecosystems, which may compensate for local high-intensity management" (Tscharntke et al. 2005). In practice, however, while it is clear that important – perhaps dominant – drivers of local ecological processes may be missed if one ignores landscape factors, the links between landscape heterogeneity and biodiversity are not likely to be simple, with the relative importance of site-level characteristics and landscape structure varying across taxa and locations.

In this paper we investigate how farming systems can contribute to biodiversity conservation within PAs that are immersed in agricultural landscapes. More specifically, we are interested in how the conservation status of a cross-section of protected sites – the Italian portion of the Natura 2000 network – is affected by land use changes in the surrounding areas. We exploit variation in space to relate several indicators of success of conservation efforts to measures of landscape composition and configuration, and intensity of farming. As a matter of fact, about one third of the PAs in our sample report experiencing the negative effects of agricultural activities that take place off the site.

We hope to shed some light on three issues: 1) what types of sites are particularly vulnerable to agricultural land use change in the surrounding areas? 2) what aspects of a farming system are more likely to influence biodiversity? 3) how large is the zone of influence? From the perspective of a policy maker that has to allocate a limited budget among several types of agri-environmental measures and many locations, general answers to these questions would be very valuable because they would provide some indication of the relative size of the benefits from different courses of action.

Data and methods

The PAs that we study are located throughout Italy and belong to Natura 2000 (N2000), a European network of protected sites that were established in compliance with EU directives 79/409/EEC ('bird directive') and 92/43/EEC ('habitat directive'). The aim of N2000 is to ensure conservation of a number of species and habitat types that were designated as valuable and threatened. In our analysis we only consider the subset of N2000 comprised of 588 so-called Special Protection Areas. Compared to the remaining sites, these were generally constituted earlier, are managed with an emphasis on the conservation of birds, and tend to be located at lower elevation, often in landscapes where a substantial proportion of the land is farmed. Furthermore, there is a substantial amount of overlap between Special Protection Areas and the remaining N2000 sites.

We try to explain cross-site variation in an indicator of success of conservation in terms of two groups of landscape variables – measures of landscape structure and farming intensiveness – while controlling for site characteristics and influences from other (non-agricultural) human activities. We repeat our analysis considering landscapes at 5, 10, 15, 20, 25, and 30 kilometer buffering distances from the PAs.

A fairly detailed dataset containing information on the N2000 areas was obtained from the Italian Ministry of the Environment. The data appear to have been submitted to the Ministry over the course of a few years (mostly between 2004 and 2007). For any given site, we have knowledge of what valuable species and habitats are present. For each of those, we also observe an evaluation of the conservation status as assessed by the site manager on a 3-point scale (excellent, good,

Table 1: Site and landscape attributes that are used in the analysis

Type	Variable	Source	
Biogeographic	Site area (log) Latitude Longitude Wetland (dummy) Biog. region (dummies)	Natura 2000	
Agricultural landscape	% Utilized agricultural area (UAA) % UAA under arable crops Density of permanent crops (patches/km^2) Density of pasture (patches/km^2)	Ag. Census, Istat; CLC 2000	Calculated at 5, 10, . . . ,30 km
Intensiveness of agriculture	Cereal yield (100 kg/ha of UAA) Cattle density (head/ha of pasture) Pesticide use (active ingredient, kg/ha)	Ag. Census + other Istat; CLC 2000	

average/reduced). The dataset also includes information on general site characteristics and land use within the site. In addition, site managers were asked to indicate what human activities taking place in the surroundings of the site may negatively influence its integrity.

In the most basic analysis we perform, we estimate a logit model where the dependent variable is an indicator of whether or not off-site farming was mentioned as adversely affecting conservation. We then proceed to estimate linear regression models where the outcome we want to explain is the share of protected bird species (or habitats) that are in poor conservation status [1].

Data about the structure of the landscapes surrounding the PAs were obtained from land cover maps produced by the Corine Land Cover project for the year 2000 (CLC 2000). We used GIS software to extract information about landscape composition and configuration at different buffering distances from the sites. The measures of landscape structure that we use are listed in table 1 along with the other variables that appear in the analysis.

Intensiveness of farming in the landscape is measured by means of three indicators: cereal yields (100 kg/ha), pesticide use (active ingredient, kg/ha), and cattle density (heads per hectare of pasture). Obviously, no measurement of these quantities was available at the landscape level, so these variables had to be estimated from aggregate data provided by ISTAT, Italy's National Institute of Statistics. In general, the value of an indicator for a given site and a given buffering

[1] In fact, this work is in progress

Table 2: Summary statistics (20-km landscape)

	Mean	St.Dev.	Min	Max
Negative effects from off-site agriculture	0.34	0.48	0	1
Site area (ha)	7800	16414	0.75	143311
Elevation (m)	572	717	0	3350
Wetland	0.23	0.42	0	1
Alpine region	0.25	0.43	0	1
% UAA	42.6	18.2	4.1	79.9
% arable of UAA	50.4	32.5	0.1	99.5
Density of pasture (patches/sq km)	0.15	0.16	0	0.87
Density of permanent crops (patches/ sq km)	0.21	0.24	0	1.15
Ceral yield (100 km/ha)	56.9	24.4	13.2	104.5
Cattle density (heads/ha of pasture)	12.2	39.5	0.08	340.4
Pesticide use (a.i., kg/ha)	6.9	5.5	0.2	35.6
N	305			

distance was computed as a weighted average over the provinces that overlap with the buffer. In the case of cereal yield, for example, the weight given to the yield of the i-th province is equal to the share of the buffer's arable land that falls within province i.

Clearly, the data for the analysis had to be collected from a variety of different sources which did not always share the same time or spatial reference. However, even if some of the variables that we use might involve substantial amounts of measurement error, we argue that they represent good proxies for the long-term phenomena we are actually interested in.

Preliminary results

Logit analysis

As a first step, we use a logit specification to model the probability that PA integrity is negatively affected by off-site agriculture. This analysis was repeated considering landscapes at different buffering distances from the sites (from 5 to 30 km in 5-km steps). We only report estimates from the 20-km model, which is our preferred specification.

Table 2 presents summary statistics for the 20-kilometer landscape. We are only able to use 305 out of 588 existing Special Protection Areas. The great majority of the remaining sites had to be excluded because they had incomplete information on the independent variable. However, missing values do not appear to imply any major sample selection issues. In addition, some purely marine areas were dropped.

We estimate three versions of the model using different sets of explanatory variables: 1) only biogeographic characteristics; 2) biogeographic characteristics and landscape attributes; 3) biogeographic characteristics, landscape attributes, and indicators of agricultural intensiveness. Estimates are presented in table 3. In addition to the coefficients displayed in the table, each model also included latitude, longitude, and a constant term.

The results from the most basic specification (column 1) suggest that PAs in the alpine region – and more generally those that are found at higher elevations – are less likely to experience negative influences from off-site agriculture. On the other hand, PAs that host substantial amounts of wetland habitats appear to be much more vulnerable to farming activities in the surroundings. It is somewhat disturbing that the coefficient on area is positive. However, when other variables are included in the model, the coefficient on area – while remaining not statistically significant – changes sign.

When landscape attributes are introduced in the model (column 2), they both turn out largely significant and improve model fit substantially. However, including the indicators of agricultural intensiveness also (column 3) only produces a small improvement in fit. None of the newly added variables turns out statistically significant. Remarkably, the coefficients on the landscape variables remain substantially unaffected.

The risk to a PA's integrity appears to increase at a decreasing rate as the share of the surrounding landscape that is occupied by agriculture grows. This suggests that, as bits of a largely natural landscape are progressively converted to agricultural uses, damage to wildlife is done early on, but at some point the relationship levels off and further conversion produces relatively little additional damage.

Negative influences on conservation are less commonly reported in landscapes where arable crops account for a smaller share of the farmed land, i.e. where agriculture is more varied.

Density of grassland and permanent crops are respectively associated positively and negatively with adverse consequences for PAs. On the one hand, this is consistent with the findings of many other studies that have highlighted the importance of grassland for biodiversity conservation. On the other, there is no immediate explanation for the sign of the coefficient on permanent density. That coefficient, we speculate, might be capturing the effect of a landscape where a lot of sources of intense agrochemical pollution are present. Indeed, orchards produce high value crops and are usually treated with substantially higher amounts of plant protection products than other crops.

Estimates comparable to those in table 3 were also obtained using alternative metrics of land-

Table 3: Logit parameter estimates (20-km landscape; std. err. in brackets)

	(1)	(2)	(3)
Log Area	0.0214	-0.0251	-0.0230
	(0.0735)	(0.0790)	(0.0809)
Elevation (100m)	-0.1020**	-0.0487	-0.0569
	(0.0398)	(0.0442)	(0.0469)
Wetland	0.7204**	0.5707*	0.6183*
	(0.3124)	(0.3321)	(0.3444)
Alpine	-1.1326*	0.1089	-0.0952
	(0.5935)	(0.7685)	(0.8196)
UAA		0.1105**	0.1331**
		(0.0499)	(0.0578)
UAA^2		-0.0013**	-0.0015**
		(0.0005)	(0.0006)
Arable		0.0233**	0.0205*
		(0.0099)	(0.0111)
Pasture Density		-2.0866**	-2.1250*
		(1.0546)	(1.1689)
Permanent Density		1.2985**	1.2726*
		(0.6532)	(0.6732)
Cereal Yield			0.0064
			(0.0130)
Cattle Density			-0.0042
			(0.0041)
Pesticide Use			-0.0154
			(0.0332)
N	305	305	302
Log-likelihood	-164.36	-154.53	-149.49
Pseudo-R^2	.163	.213	.229
AIC	342.7	333.1	329.0

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4: Marginal effects at median of data

	MFX	Std. Err.	p†
UAA	-0.0002	0.0028	0.935
Arable	0.0051	0.0020	0.009
Pasture Density	-0.4567	0.2504	0.068
Permanent Density	0.2842	0.1271	0.025
Wetland	0.1349	0.0792	0.088

†p-value on hypothesis that marginal effect is zero

scape structure (e.g. mean size of pasture or perennial patch). Logit models estimated using landscapes at different buffering distances also produced similar estimates. The 20-km landscape, however, was the one that provided the best fit. Because the PAs of our analysis were designed to protect bird species, a relatively wide zone of influence does not seem implausible.

Because logit models are non-linear, the coefficients can be difficult to interpret. The marginal effects at the median of the data were computed for model (2). For selected variables, table 4 displays the effects of a marginal change on the probability of damage from off-site farming. Perhaps the most interesting fact that emerges from the table has to do with the effect of UAA. Our estimates suggest that the risk to wildlife grows with UAA but it tends to level off at some point. The typical PAs in our dataset appears to be embedded in a landscape that is at or beyond that point. If this were actually the case, converting some farmland back into more 'natural' uses – in addition to being costly – would only provide modest benefits, if any.

Some remarks on the preliminary results

To different extents, human activities on about 20% of the EU's territory are regulated or restricted to ensure that valuable and threatened species and habitats persist. Unfortunately, no matter how well a protected area is managed within its borders, its ecological functioning will generally be affected by land use in the surroundings. In this study we attempt to assess how farming systems in the landscapes that encompass the PAs of Italy's Natura 2000 network could be remodeled in order to contribute to biodiversity conservation. Agriculture is the dominant form of land use in large parts of terrestrial areas: about half of Italy's total surface is accounted for by utilized agricultural area. Furthermore, farming has often been mentioned as a major driver of biodiversity decline.

From a policy-making standpoint, three aspects are particularly important of the relationship between PAs and the agricultural landscapes that surround them: what types of sites are especially sensitive to land use change in the surroundings; how large the zone of influence is; and what aspects of agriculture are more likely to have a positive or negative influence on biodiversity.

While the results we present in this paper are still preliminary and there are obvious data limitations, our analysis hint at some possible answers to those questions.

Unsurprisingly, the PAs that appear to be most sensitive to the surrounding landscape are those that are predominantly comprised of wetland habitats. Many interactions among components of an ecosystem can occur through water. Water carries nutrients – most notably nitrogen and phosphorus – and pollutants, and allows many terrestrial and aquatic organisms to move.

At this stage, we have not made any explicit attempts to tackle the second question. So far, however, our analysis, suggests that the zone of influence around a site might well extent to a 20-kilometer radius. A relatively wide area of influence does not seem given that the PAs in our sample were mostly designed to preserve birds.

With regard to the third question, our results are consistent with the hypothesis that what makes an agricultural landscape hostile to wildlife may not be the intensiveness of farming per se, but rather the homogenization of the landscape that usually accompanies industrialized farming. Attempts to revert small portions of farmland to nature may not produce much benefit to species that are currently threatened. In many agricultural landscapes, it would probably be more effective to increase the diversity of agricultural uses, so there would no longer be by one or few dominant crops.

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