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A model for the assessment of habitat conservation status in the EU

Joachim Maes

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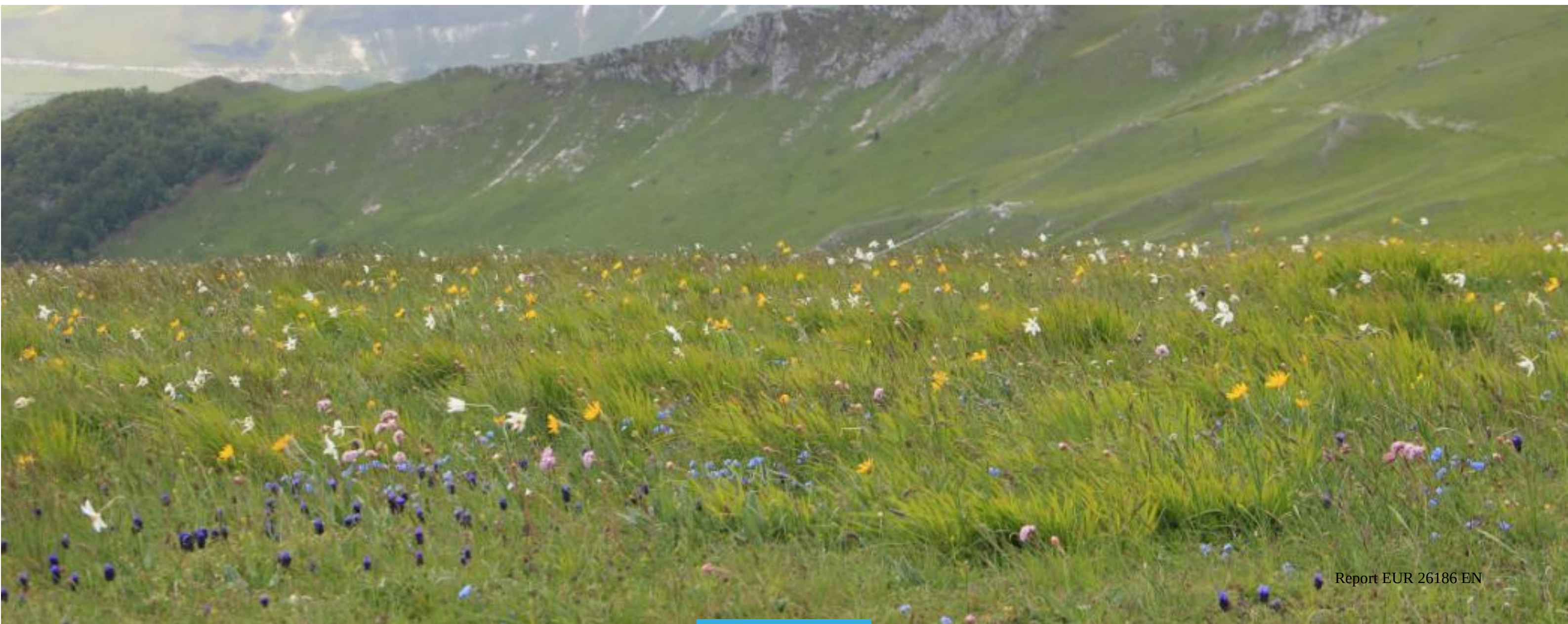

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Cover photo by J. Maes, flower field in the national park of the Sibillini mountains in Italy

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1. Introduction

The Habitats Directive, together with the Birds Directive, forms the cornerstone of the nature conservation policy in the European Union. The directive aims to maintain or restore vulnerable natural habitats and threatened species of wild fauna and flora to favourable conservation status. The directive established the Natura 2000 network of protected areas to achieve this goal. With over 26 thousand sites and covering 17.5% of the EU, this network is the largest ecological network in the world.

Under Article 17 of the Habitats Directive, Member States of the EU must submit information on how the Directive is being implemented every six years. For the reporting period 2001 to 2006, 25 Member States provided, for the first time, detailed assessments on the conservation status of each of the habitat types and species listed in the directive and found on their territory or different bio-geographical regions therein. The results of the 2001-2006 assessment reports show that for many of the habitats and species listed under the directive, favourable conservation status has not been achieved either at national or bio-geographic regional level. In fact, only 17% of all the habitat assessments and 17% of the species assessments yielded a favourable conservation status. In particular wetlands, grasslands and coastal habitats suffer from continuing degradation.

The EU Biodiversity Strategy to 2020 aims to halt the deterioration in the status of all species and habitats covered by EU nature legislation. In particular target 1 has the ambition to achieve a significant and measurable improvement in conservation status of habitats and species so that, by 2020, compared to current assessments 100% more habitat assessments and 50% more species assessments show an improved conservation status. A first milestone to measure the progress of meeting this target will be presented in 2014 when the next Art. 17 assessment reports will be made available.

This report presents a model based approach to assess how conservation status may change in the future. This approach is based on the available assessments and simulates the probability that a habitat assessment results in a favourable conservation status as a function of drivers of change. Such a modelling approach to habitat conservation status has several advantages. Importantly, it allows different biodiversity policy scenarios or measures to be analysed to see whether or not the target of increasing the number of favourable assessments will be met. Furthermore, this analysis is an input to Action 5 of the Biodiversity Strategy which aims to map and assess ecosystems and their services. By downscaling the results of the national Art. 17 assessments to a finer resolution, this model may help define the status of Europe's ecosystems. Such information is useful to determine whether or not healthy ecosystems contribute more than average to the delivery of key ecosystem services and to help define priority areas for restoring degraded ecosystems.

A first analysis of the relation between ecosystem services, biodiversity and habitat conservation status was presented by Maes et al. (1). Using multinomial regression models, they showed that habitats in good conservation status have a higher potential to deliver regulating and cultural ecosystem services and that conservation status was related to Mean Species Abundance, a global indicator for biodiversity. The authors presented evidence to support the hypothesis that actions which target the restoration of ecosystems, and the maintenance of the services they provide, are likely to have positive effects on habitat and species conservation status. This information is indeed of importance in identifying regions in which measures are likely to result in cost-effective progress towards both target 1 (nature conservation) and target 2 (restoring ecosystems and maintaining ecosystem services) of the Biodiversity Strategy.

This report uses the same methodology as outlined in (1) to model habitat conservation status as a function of drivers of change of biodiversity. The model is built on the assumption that across Europe, habitats show an average response to pressures such as land use change, nitrogen loading, pollution or poor management of the land. This assumption is necessary because it was not possible to achieve a fully harmonized assessment of European habitats and species throughout all Member States. This resulted in two main problems with the Art. 17 data: (i) the use of a different baseline to assess conservation status of habitats and (ii) differences in spatial accuracy of the data. By assuming an average response of habitats to either degradation or restoration, we argue that these differences are, to some extent, levelled when considering the data at European scale.

The objective of this report is thus to present a model to assess habitat conservation status in Europe, based on the reporting under Art. 17 of the Habitats Directive. The present work is limited to habitats and does not consider species. Modelling species conservation status requires a different approach, in particular for mobile species and vertebrates which respond differently to declining area or pollution.

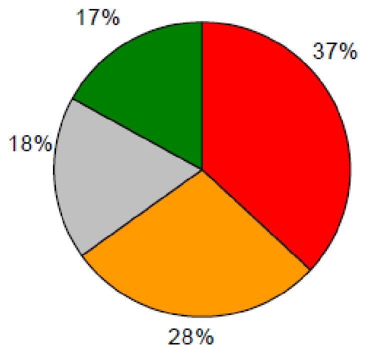
2. Article 17 reporting on the conservation status of habitats

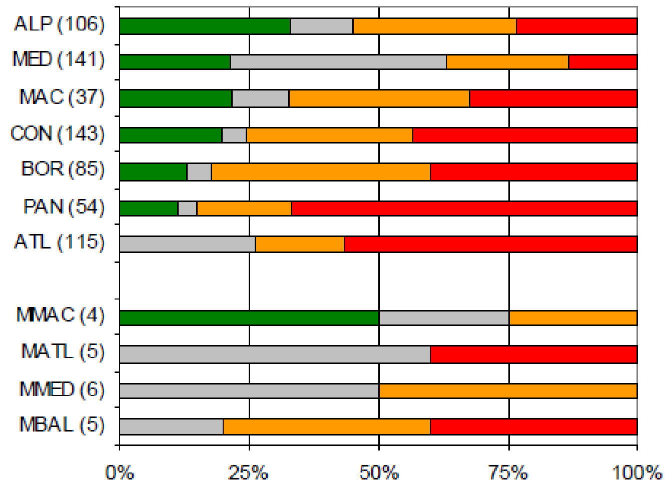
Under Article 17 of the Habitats Directive, Member States must submit information on how the directive is being implemented every six years. For the reporting period 2001 to 2006, Member States provided detailed assessments on the conservation status of each of a total of 231 habitats (and 1288 species which are not considered here).

The habitats belong to one of the following groups: coastal habitats, coastal and inland dunes, freshwater habitats, temperate heath and shrub, sclerophyllous shrub, natural and semi-natural grassland formations, raised bogs, mires and fens, rocky habitats and caves, and forests.

The conservation status of a natural habitat represents the sum of the influences on a natural habitat and its characteristic species that may affect its long-term natural distribution, structure, and functions, as well as the long-term survival of its characteristic species. The conservation status was assessed for each of the 231 protected habitats per bio-geographic region within each Member State of the EU-25 (excluding Bulgaria, Romania and Croatia who entered the EU after the assessment period).

The criteria to assess habitats are the range, area covered by the habitat within the range, specific structure and function, and future prospects. The conservation status of a natural habitat is taken as favourable (FV) when its natural range and areas it covers within that range are stable or increasing, and the specific structure and functions which are necessary for its long-term maintenance exist and are likely to continue existing for the foreseeable future. If these criteria are not met, conservation status is taken as unfavourable-inadequate (U1) or unfavourable-bad (U2) depending on the sum of the scores for each criterion. The results of the first pan-European assessment of conservation status are reported by the European Commission (2009) (7) and presented in Figure 1.





- favourable (FV)
- unfavourable-inadequate (U1)
- unfavourable-bad (U2)
- unknown (XX)

Bio-geographical regions

ALP: Alpine
ATL: Atlantic
BOR: Boreal
CON: Continental
MAC: Macaronesian
MATL: Marine Atlantic
MBAL: Marine Baltic
MED: Mediterranean
MMAC: Marine Macaronesian
MMED: Marine Mediterranean
PAN: Pannonian

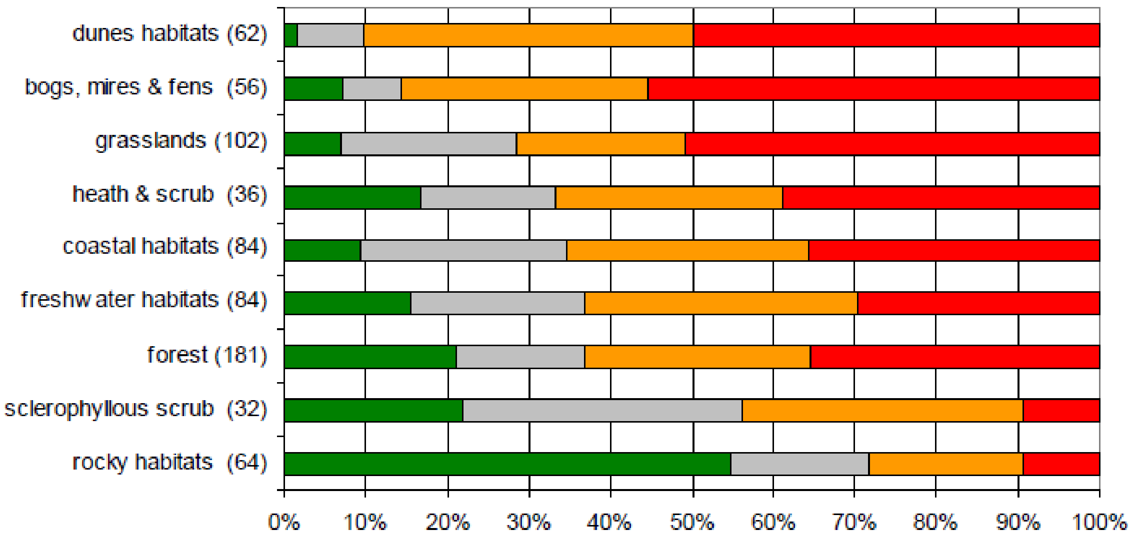


Figure 1. Pie chart: summary of the conservation status of Annex I habitats (the percentage relates to the number of assessments made). Upper bar chart: summary of the conservation status of habitat types in the different bio-geographical regions (numbers in brackets refer to the number of assessments). Lower bar chart: assessment of conservation status of habitats by habitat group (the number in brackets refers to the number of assessments carried out for each group).

3. Methods and data sources

3.1. General approach

The probability that habitats are in a favourable conservation status was statistically modelled as a function of different positive and negative drivers of biodiversity change. Positive drivers of biodiversity were the location of Natura 2000 sites as well as the network of green infrastructure. Negative drivers of change or pressures are the transition of land for development and agriculture, nitrogen enrichment, air pollution, but also management practises such as drainage or abandoning traditional agricultural practises.

The probability of favourable conservation status ranged, evidently, between 0 and 1 depending on the combination of drivers that are exerted on habitats. A probability of 0.3 means that there is a 30% chance that a habitat in an assessment would receive a favourable conservation status. Consequently, the probability that the same habitat has an unfavourable conservation status is 70%. The choice to include pressures to the model depended on a frequency analysis of pressures that Member States had to report when submitting their habitat assessments. The 20 most reported pressures of a list of 170 were selected for further analysis. From this selection, those pressures were identified for which harmonized data is available at EU scale, e.g. air pollution, land use, eutrophication or cultivation. For other pressures, e.g. grazing, drainage or invasion by alien species, quantitative data may be available but they do not cover Europe completely. Still, these pressures were included in the model albeit as a binary variable with two possible outcomes (present, absent).

In next step, the average response of conservation status to each driver of change was calculated over habitat conservation status. We excluded pressures from further analysis in cases where habitat conservation status responded positively to increasing pressures. The rationale is that in some cases, but in particular for air pollution, distributional effects lead to increment of pollutant concentrations in rural and natural areas relative to industrial and urban sites. In a next step, the probability of conservation status was modelled, first using single response models, and secondly using multivariate models.

Finally, the regression results were used to map habitat conservation status at 10 km resolution across the EU.

3.2. Article 17 data

This EU wide assessment assigned favourable (FV), unfavourable-inadequate (U1), unfavourable-bad (U2), or unknown (XX) conservation status to 231 different habitats across 25 Member States covering seven terrestrial and four marine bio-geographical regions (totalling 2759 habitat assessments). All national assessments were collected by the European Topic Centre on Biological Diversity (ETC/BD) and are available in a geospatial database reporting habitat conservation status on a 10 km grid covering the EU-25[1]. From the dataset including 2759 habitat assessments, the following assessments were removed (1) all the assessments of offshore coastal and marine

[1] http://www.eea.europa.eu/data-and-maps/data/article-17-database-habitats-directive-92-43-eec

habitats, (2) all the assessments that resulted in an unknown conservation status, (3) all the assessments of freshwater habitats (lakes, rivers and streams). Assessments of the following broad habitat types were included (with in brackets the corresponding MAES ecosystem typology, see (2)): coastal and inland dunes habitats (sparsely vegetated habitats) , temperate heath and shrub (heath and shrubland), sclerophyllous shrub (heath and shrubland), natural and semi-natural grassland formations (grassland), raised bogs, mires and fens (wetland), rocky habitats and caves (sparsely vegetated habitats), and forests (forest and woodland). This final dataset included 1482 habitat assessments. Each assessment can be identified by a unique polygon which covers the area where the habitat is found for each bio-geographic region within every Member State. Figure 2 illustrates the Art. 17 information that is available for habitat 4030: European dry heath. It also demonstrates the data quality issues that come with the Art. 17 assessments. The most obvious difference between member states is the spatial resolution of the assessment. Some countries like France, Ireland and Poland mapped the distribution of habitat 4030 while other countries mapped the presence of heath on a grid, albeit at different spatial resolution. Some countries, in this case Spain, Estonia and Lithuania have reported an unknown status.

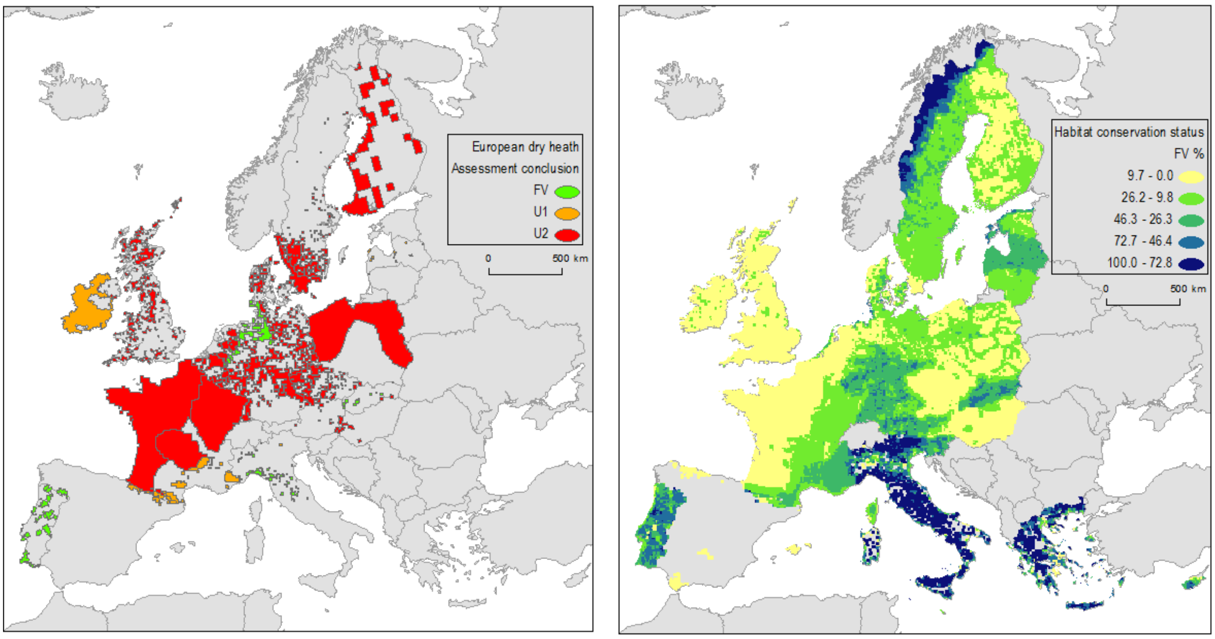


Figure 2. Data issues with the Art. 17 assessment. Left: Assessment conclusion for habitat 4030 (European dry heath); Right: The ratio (as a percentage) between the number of favourable habitat assessments and the total number of assessments on a standard 10 km resolution grid covering the EU.

A second issue is the different outcome between the national assessments of conservation status. In the Atlantic region of Germany, European dry heath was assessed at favourable conservation status (FV) while in all surrounding countries but also in the continental region of Germany, this habitat received an unfavourable-bad (U2) assessment. Although this report does not question the quality of the assessments, it is still possible, and even likely, that different references have been used across MS to assess conservation status. This is further evidenced by Figure 2 which also plots the number of favourable conservation assessments as a percentage of all the assessments (excluding unknowns). The differerences between countries are now more apparent. While large portions of Belgium, France, The Netherlands, UK and Ireland have a low number of assessments with habitats in favourable conservation status, other countries and most notably Italy and Greece, score remarkedly better. The possible use of different references against which conservation status has been assessed can be observed when visually inspecting the percentage of favourable assesments in the Baltic or Scandinavian countries. Note also that Spain has delivered mainly unknown assessments.

Clearly, these data quality issues must be considered as they are likely to influence the outcome of this modelling exercise. The final regression parameters that were derived based on Art. 17 data were thus subjected to an uncertainty analysis which will be detailed later. Figure 2 also illustrates why it is important to assume that conservation status exhibits an average response to drivers of biodiversity change across Europe and across all habitats lised under Annex I of the directive.

The European Commission provides a guidance document to assist Member States in their assessments. Member States' reports included maps of range and distribution of these habitats. The European Topic Centre on Biological Diversity (ETC/BD) collected all national assessments and made them available in a geospatial database reporting habitat conservation status on a 10 km resolution grid covering the EU-25. The database and shapefiles of Article 17 reporting are available at: http://www.eea.europa.eu/data-and-maps/data/article-17-database-habitats-directive-92-43-eec

3.3. Frequency analysis of pressures versus habitat conservation status

Member States (MS) were asked to add information on the pressures on habitats. MS had to indicate the presence of threats and pressures. The list of main pressures and threats is given in Appendix E of the Explanatory Notes of the Natura 2000 Standard Data Form[2]. They are grouped into nine major impacts and activities that influence conservation status: (1) Agriculture, forestry and animal breeding; (2) Fishing, hunting and collecting; (3) Mining and extraction of materials; (4) Urbanisation, industrialisation and similar activities; (5) Transportation and communication; (6) Leisure and tourism; (7) Pollution and other human impacts/activities; (8) Human induced changes in hydraulic conditions; (9) Natural processes (biotic and abiotic). We used the Art. 17 database to cross tabulate the frequency of each pressure over conservation status (FV, U1 or U2). The most frequent pressures were than selected for possible inclusion in the statistical model.

The results of this analysis are presented table S1 in the Annex (including all pressures) and in Figure 3 (including the most important pressures). A total of 14 856 pressures is observed in the Article 17 habitat assessments, of which 2 459 (or 16%) are assigned to assessments with a favourable conservation status while 12 397 are assigned to assessments with an unfavourable conservation status. The most frequently observed pressures on habitats in Europe were the abandonment of pastoral systems, eutrophication, the so-called modification of hydrographic functioning (which is physically modifying the course of water), grazing (which can, however, be beneficial for biodiversity, see also later), drainage, water and air pollution, urbanization and invasion by species.

[2] http://ec.europa.eu/environment/nature/legislation/habitatsdirective/docs/standarddataforms/notes_en.pdf

Figure 3 also shows the relative frequencies for each type of assessment conclusion. Clearly, the frequency of many pressures increases with decreasing conservation status or, put another way, habitats to which an unfavourable conservation status was assigned have to cope with more pressures than habitats in a favourable conservation status. This conclusion may sound obvious but this evidence is a first and important piece of information that can be derived from the Art. 17 assessments and it forms the basis of the analysis in this report. The observed relation between pressures and conservation status provides the evidence that increasing pressure on habitats is more likely to result in an unfavourable conservation status than in a favourable conservation status and it is precisely this observation that has been modelled using multinomial logistic regression models.

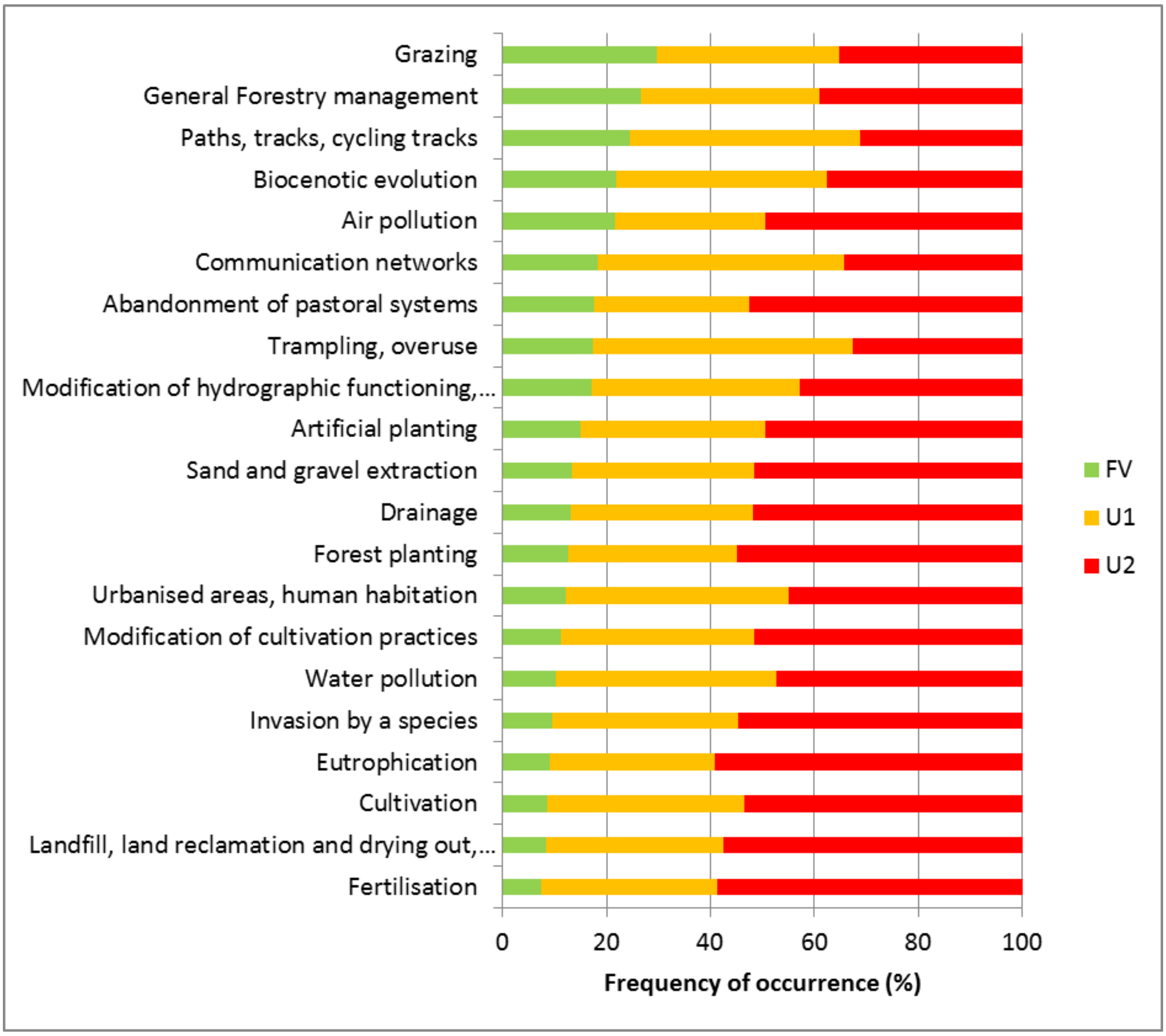


Figure 3. Break down of the most frequently occurring pressures over habitat conservation status (FV: Favourable; U1: Unfavourable – Inadequate; U2: Unfavourable – Bad).

3.4. Drivers of change of biodiversity

Based on the analysis of pressure frequencies, the following predictor variables for the habitat conservation status were selected: the proportion of artificial and agricultural land cover, the density of the road network, nitrogen deposition and exceedance of nitrogen critical loads, fertilizer input, and exposure of ecosystems to ozone (Table 1). The year 2006 was used as reference year for the collection of data.

The proportion of artificial land was estimated using the refined version of the Corine Land Cover data set for the year 2006 (3), which incorporates land use/cover information present in finer thematic maps available for Europe. Artificial land includes continuous urban fabric, discontinuous urban fabric (two classes in the refined version), industrial or commercial units, road and rail networks and associated land, port areas, airports, mineral extraction sites, dump sites, construction sites.

Also for estimating the proportion of arable land and pasture, the same dataset was used. Arable land includes non-irrigated arable land, permanently irrigated land, and rice fields.

The road network fragments habitats in small pieces and destroys connectivity. Spatial data representing Europe's road network were used to calculate the average length of major roads per km^2.

Ozone is the most important air pollutant in Europe for forest ecosystems. The ozone impact on vegetation can be calculated using the AOT40 indicator which is the accumulated exposure over a threshold of 40 ppb. AOT is expressed in $\mu g\ m^{-3} \times$ hour.

Excessive nitrogen loading is a leading cause of biodiversity loss, mainly as a result of increased nitrogen fixation for the production of artificial fertilizers and through the combustion of fossil fuels. The latter process releases nitrogen to the atmosphere and part of this atmospheric nitrogen is deposited on earth. Nutrient poor ecosystems contain more biodiversity whereas nitrogen deposition adds nutrients, which results in loss of plant species. Three possible indicators for nitrogen loading were considered: total annual nitrogen deposition; the average accumulated exceedance of nitrogen critical loads, and total annual fertilizer input on cropland.

To this list of pressures, we included also drivers of change that were assumed to positively influence habitat conservation status: the proportion of land covered by Natura 2000 sites and by green infrastructure elements.

Several of the pressures on habitats in Europe are not captured by data that reflect land use change, air pollution or nitrogen enrichment but relate to the poor management of ecosystems. From table S1, we included the most important pressures to the model as categorical predictor variables with two possible outcomes (yes: the pressure is present; no: the pressure is absent). Included drivers were the modification of hydrographic functioning, drainage, grazing, the abandonment of the pastoral system, and the invasion of alien species.

Table 1. Major drivers of biodiversity used in the habitat conservation status model.

Driver	Type	A priori direction of change	Reference
Land use change			
Proportion of artificial land use including urban and industrial land use (%)	C	-	Corine Land Cover 2006 refined; European Environment Agency; (3)
Proportion of arable land use (%)	C	-	
Proportion of pasture (%)	C	-	
Road density (km ha^{-1})	C	-	ESRI data and maps
Nitrogen enrichment			
Nitrogen deposition (mg m^{-2})	C	-	EMEP model 2006 http://www.emep.int/mscw/index_mscw.html
Average accumulated exceedance of nutrient critical loads (equivalent ha^{-1})	C	-	Coordination Centre for Effects (CCE), (4)
Fertilizer input on arable land (kg ha^{-1})	C	-	GREEN model; (5)
Air pollution			
Ozone AOT40 for forests	C	-	European Environment Agency; Interpolated air quality data.
Land management			
Modification of hydrographic functioning, general (Frequency)	B	-	European Environment Agency; Art. 17 database
Grazing (Frequency)	B	+	European Environment Agency; Art. 17 database
Abandonment of pastoral systems	B	-	European Environment Agency; Art. 17 database
Drainage (Frequency)	B	-	European Environment Agency; Art. 17 database
Invasive alien species			
Invasion by a species (Frequency)	B	-	European Environment Agency;Art. 17 database
Protected areas and green infrastructure			
Green Infrastructure - Proportion of nodes (%)	C	+	(6)
Green Infrastructure - Proportion of links (%)	C	+	(6)
Proportion of area covered by Natura 2000 (%)	C	+	European Environment Agency; Natura 2000 data.

C: continuous data
B: binary data (yes, no)

3.5. Statistical analysis

The Art. 17 assessments of conservation status have a spatial component: the presence of each habitat has been mapped at 10 km resolution (although some MS have mapped the range instead of the presence of habitats, see Figure 2). Each of these habitat maps was intersected with the spatial information of the drivers of change listed in Table 1. This data set, containing 1482 habitat assessments, was used in all statistical analyses. The resulting dataset thus contains for each assessed habitat the assessment conclusion with three possible outcomes (FV, U1, U2), average values for each continuous driver of change, the presence or absence of invasive alien species, and the presence of absence of 4 types of land management (Table 1).

3.5.1 Analysis of variance

Analysis of Variance (ANOVA) was used to calculate the average value of continuous predictor variables for each of three assessment conclusions across Europe.

3.5.2 Single response models

A single response model expresses the probability that habitats are in favourable (or unfavourable) conservation status as a function of a single driver of change. Since there are 3 possible outcomes for conservation status (FV, U1 and U2), the appropriate statistical model is a multinomial logistic regression. This procedure is an extension of the binary logistic regression model and allows for more than two categories of the dependent or outcome variable.

In a multinomial logistic regression model, the estimates for the parameters can be identified compared to a baseline category. In this study the probability of membership in the categories U1 and U2 was compared to the probability of membership in a reference category (FV). The multinomial logistic regression model with reference category FV can be expressed as follows:

$$\log\left(\frac{P(i)}{P(FV)}\right) = \beta_{1i} + \beta_{2i}x \qquad (1)$$

where *P(i)* is the probability of class membership in the categories U1 or U2, *P(FV)* is the probability of class membership in the reference category FV; *x* is the independent or predictor variable (e.g. the proportion of artificial land cover) and β_{1i} and β_{2i} are the regression coefficients that were estimated using maximum likelihood. The mathematical solution of equation 1 is given in the Supplement.

The left term of equation 1 is by statisticians referred to as the log odds. The odds ratio is the quotient of two probabilities, here for instance the probability that a habitat is in an unfavourable status over the probability that a habitat is in a favourable conservation status. One unit of increment in the independent variable x will increase the log odds with β_2. A negative slope means that, following an increase of x, it is more likely that a habitat will be in favourable status than in an unfavourable status. Vice versa, a positive slope tells that a one unit increase in x increases the odds of an unfavourable conservation status.

3.5.3. Multivariate response models

A multivariate response model expresses the probability that habitats are in favourable (or unfavourable) conservation status as a function of a combination of multiple drivers of change. The same statistical model was used. The difference with equation 1 is that there are more independent predictor variables which each have a separate regression coefficient.

Only a selection of the drivers was included in the multivariate response model. The relationship between drivers of change and habitat conservation status was defined *a priori*. Table 1 presents the a priori defined relationships with a + indicating a positive relationship and a – for a negative relationship. Variables for which this relation was rejected, were not considered in the final models.

Three different models were considered. Model 1 predicts habitat conservation status as a function of continuous drivers only (Table 1). Model 2 uses the same predictor variables as model 1 but includes the drivers binary values as well. Model 3 uses the same predictor variables as model 1 but includes a grouping variable that assigns the different habitats to the MAES ecosystem typology, which enables to model habitat conservation status separately for forests and woodlands, wetlands, grasslands, heathlands and shrub, and sparsely vegetated ecosystems.

3.6. Mapping habitat conservation status across Europe

In a last step, the models were used to map the probability of a favourable conservation status across Europe on a grid with resolution 10 km. For each grid cell, the value for each predictor variable was calculated. Next, the equations of model 1 and model 3 were applied so as to obtain a European wide map.

4. Results

4.1. Average response of habitat conservation status to different drivers of change

Table 2 shows the average values and frequencies of the both continuous and categorical drivers of change on habitat conservation status. Table 2 largely corroborates the earlier made observation that assessments with an unfavourable conservation status are subject to stronger pressures than assessments which resulted in a favourable conservation status.

The proportion of artificial land, arable land and pasture increases, on average, with decreasing conservation status. Artificial and agricultural land use almost doubles in assessments with an unfavourable bad status relative to assessments with a favourable status. Habitats in favourable conservation status also have a significantly lower density of roads.

The effect of nitrogen enrichment on conservation status is less evident. On average, nitrogen deposition rates did not differ substantially between the three assessment conclusions and lowest values were observed for the unfavourable inadequate status. Both fertilizer input and the exceedance of critical nitrogen load increased, on average, with decreasing conservation status. The case of nitrogen deposition certainly relates to problems of resolution of both the Art. 17 data (> 10 km) as well as of the EMEP air quality model domain (50 km). In this case, zonal statistics are expected to level any differences, particularly in areas where some habitats are in favourable status while others are assessed as unfavourable. Apart from data issues, it needs to be stressed that nitrogen deposition, and air pollution in general, is a wide-spread environmental pressure impacting almost every place on earth, even areas remote from emission sources with a supposedly high conservation status. The assessment of fertilizer is based on data with finer spatial resolution while the data for critical nitrogen loads are available for the EMEP modelling domain but consider only the portion of EUNIS habitats in each grid cell.

Accumulated ozone exposure followed the opposite trend. Ozone AOT40 levels increased, on average, with increasing conservation status contrasting the a priori assumed relationship between habitat conservation status and pressure (Table 1). Distributional effects of emission patterns and chemistry between ozone and its precursors exclude the use of ozone AOT as an appropriate predictor for conservation status. Ozone concentrations are higher in rural areas relative to cities where it reacts with NO (and other substances), released by traffic, to form NO_2 and O_2. In rural areas, with less traffic, the opposite reaction takes place and ozone is produced. This process is enhanced in summer months.

Table 2. Average response of drivers of change per assessment conclusion.

Driver of change	Conclusion of the assessment			ANOVA results	
	FV	U1	U2	F	p
Continuous drivers					
Proportion artificial land (%)	3.42	4.98	6.27	53.6	<0.01
Proportion arable land (%)	11.27	15.90	23.65	87.2	<0.01
Proportion pasture (%)	5.23	7.20	9.49	33.7	<0.01
Nitrogen deposition (mg m^{-2})	607.64	601.81	656.56	5.8	<0.01
Average accumulated exceedance of nutrient critical loads (equivalent ha^{-1})	232.80	254.87	292.38	16.9	<0.01
Road density (km ha^{-1})	0.95	1.20	1.40	34.5	<0.01
Fertilizer input on arable land (kg ha^{-1})	54.98	65.43	89.99	75.2	<0.01
Ozone AOT on forests	42 846.23	36 227.26	31 592.81	95.5	<0.01
Green Infrastructure - Proportion of nodes (%)	51.34	36.14	25.90	106.9	<0.01
Green Infrastructure - Proportion of links (%)	3.16	3.98	5.02	24.9	<0.01
Proportion of area covered by Natura 2000 (%)	33.87	24.19	17.76	126.8	<0.01
Categorical (binary) drivers					
Modification of hydrographic functioning, general (Frequency)	78	182	195		
Grazing (Frequency)	132	156	157		
Abandonment of pastoral systems	85	144	254		
Drainage (Frequency)	56	150	221		
Invasion by a species (Frequency)	38	144	220		

Habitats in favourable conservation status had, on average, a higher proportion of coverage by Natura 2000 sites than habitats in unfavourable conservation status and this difference was significant. It is still remarkable that, on average, habitat assessments yielding an unfavourable status are for 17% covered by the Natura 2000 network. This could lead to the conclusion that at EU scale, the present coverage of the Natura 2000 network is not sufficient to warrant a favourable conservation status. We refer to the single and multivariate response models as well as to the uncertainty analysis for a more in depth discussion on this conclusion.

Conservation status exhibited a mixed response to increasing proportions of land covered by green infrastructure elements. Assessments with a favourable conservation status are, on average, better covered by nodes, which constitute the core elements of green infrastructure, while assessments with an unfavourable status contain, on average, more links, which bridge the different core elements.

The frequency of 5 categorical drivers, measured as presence or absence, increased with decreasing conservation status (table 2). Modification of hydrographic functioning, grazing, and abandonment of the pastoral systems, drainage and invasion by species were all observed at higher frequencies for assessments with an unfavourable conservation status. This was especially evident for invasive species.

Two essential conclusions were derived from this first analysis of the average response of conservation status to drivers of biodiversity change. Firstly, the *a priori* formulated relations with conservation status (Table 1) were respected for most drivers i.e. habitats in unfavourable status undergo, on average, a higher pressure than habitats in favourable status. This was not the case for air quality, for nitrogen deposition and for green infrastructure links, and these predictors for habitat conservation status were therefore not considered any longer in the statistical models. Secondly, the coarse spatial resolution of the Art. 17 assessments causes the within group assessment average to move to the overall, between-group assessment average. This can be illustrated using the example of artificial land use. In Europe, about 5% of the land is claimed for residential and industrial uses. This figure is based on the relative coverage of artificial land in the Corine dataset. This percentage is almost equal for areas assessed as unfavourable inadequate (Table 2). The proportion of artificial land increases for areas assessed as unfavourable bad (6.3%) and decreases for areas assessed as favourable (3.4%) (table 2). It is likely that (future) assessments at a finer spatial resolution will cause these latter two values to drift away from the average and will yield a lower percentage in case of favourable conservation status and an equal or higher percentage in case of unfavourable bad conservation status. In part, this explains also why assessments in unfavourable conservation have relatively high proportions of coverage by green infrastructure nodes and Natura 2000 sites.

4.2. Single response models

Instead of considering the average response of habitat conservation status to drivers of change, this section examines how conservation status changes along a continuous or discrete gradient of change. Figure 4 depicts the probability that an assessment results in a particular conservation status along single gradients of pressure. The regression coefficients and model diagnostics are given in table S2.

The probability of a favourable assessment decreases sharply with increasing proportions of artificial and agricultural land use and with an increasing density of the road network. Evidently, the relation between these variables and the probability of an unfavourable bad conservation status has an opposite pattern, while the probability of an unfavourable inadequate status follows a bell shaped curve with positive skew (a tail to the right). While these probabilities clearly differ at the extremes (land which is completely artificial has a very high probability of unfavourable status and a very low probability of favourable status), the intercepts at the origin do not differ much. So the probability of a favourable conservation status if land is not taken for any kind of development is only 0.43, suggesting that other factors play a role in determining conservation status. The relative contributions of different pressures will be examined in the next section. But it also reflects to some extent the mosaic structure of Europe at the landscape scale with patchy patterns of urbanisation, agriculture, forests and semi-natural areas.

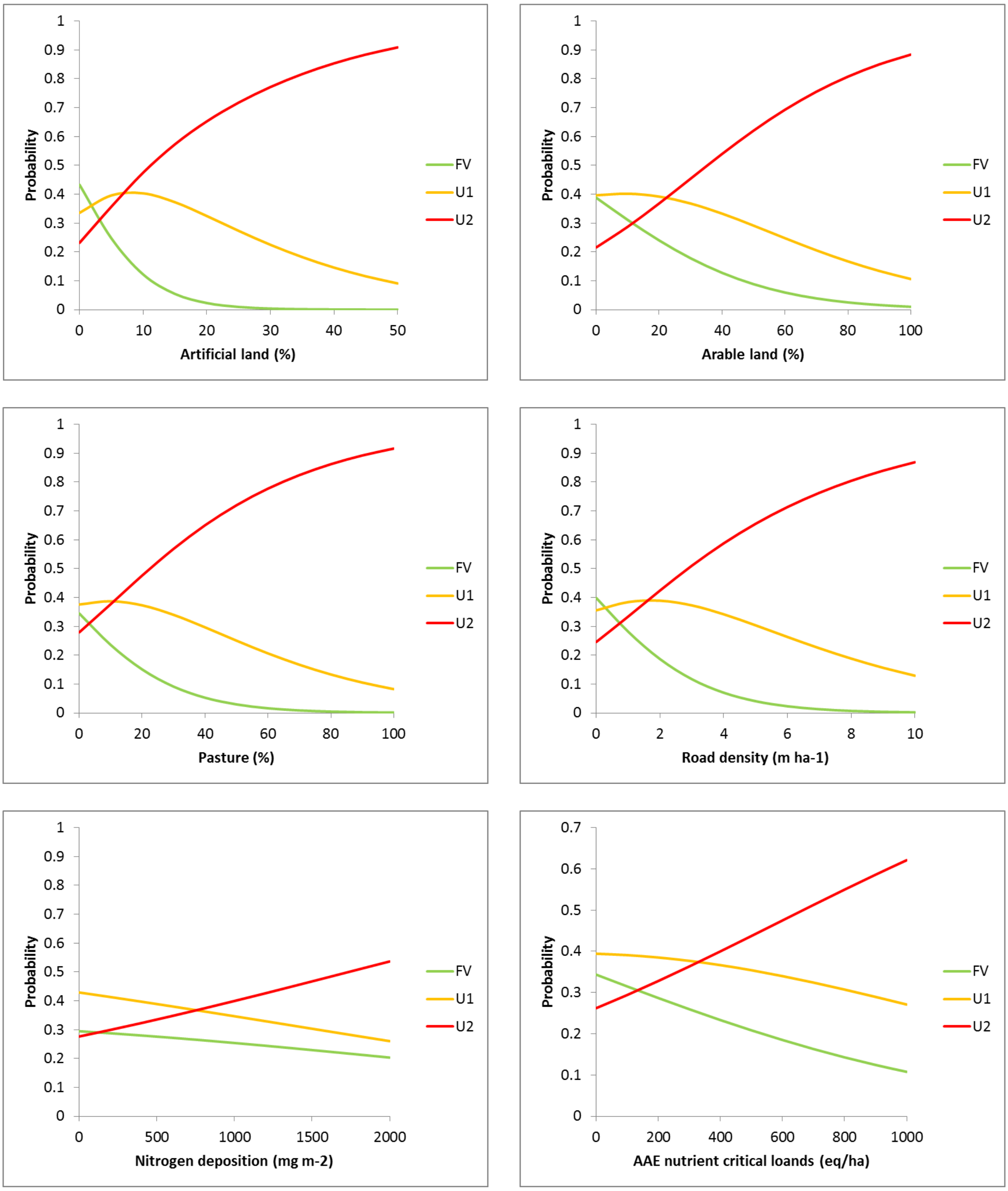


Figure 4. Single response models. The probability of habitat conservation status as a function of different drivers of change.

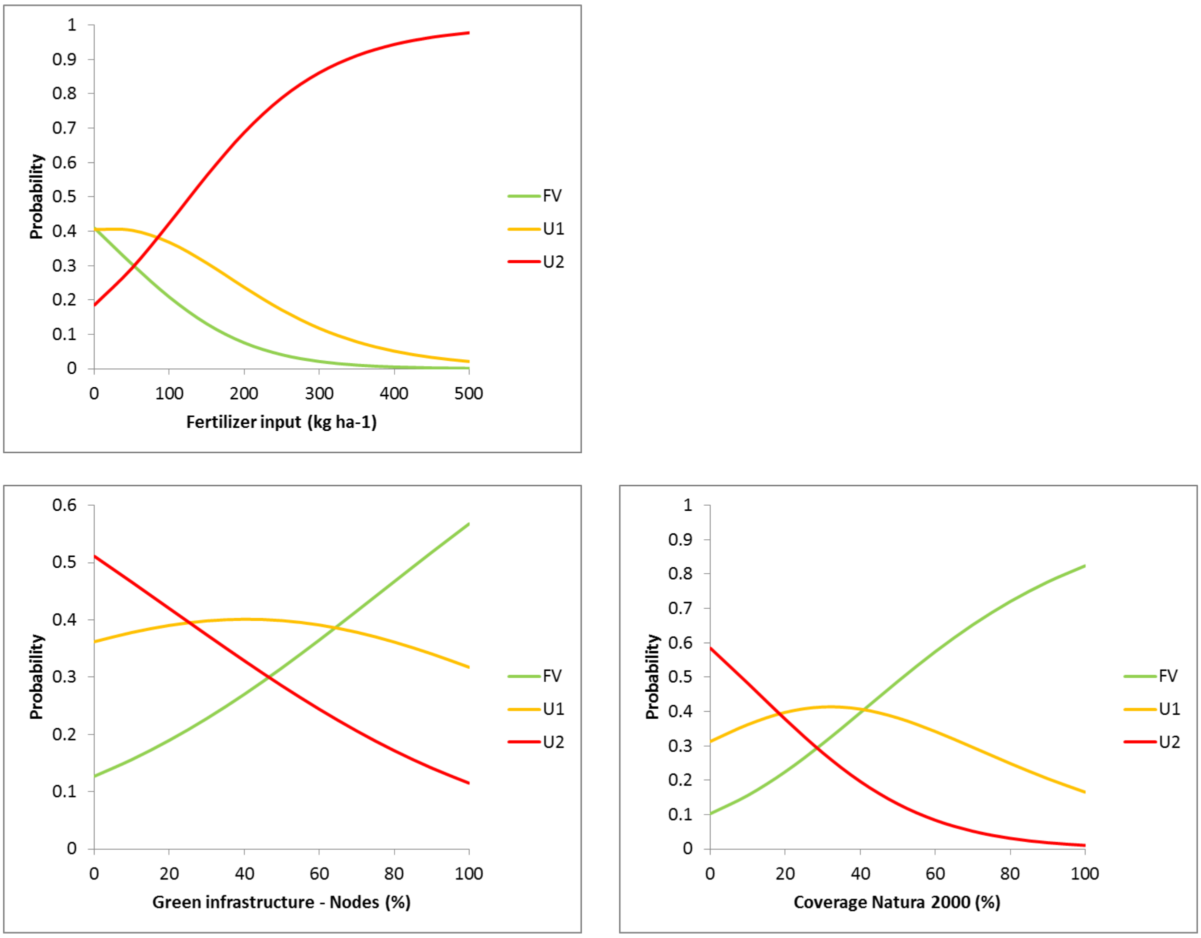


Figure 4. Continued. Single response models. The probability of habitat conservation status as a function of different drivers of change.

Nitrogen stress on habitat conservation status is expressed using three variables: nitrogen deposition, exceedance of the critical nitrogen load and fertilizer input. All pressures but the first one yielded significant regression coefficients (table S3).

Importantly, conservation status responded strongly to increasing protection (Natura 2000 network) or increasing green infrastructure (% of nodes in the GI network). The probability of favourable conservation status increases sharply with increasing coverage of protected areas or nodes in the GI network. Note also the difference with other models at the origin. In absence of protected areas or of green infrastructure core elements, the probability of a favourable conservation status is quite low (around 0.1) and certainly much lower than the probability of an unfavourable status.

Multinomial regression models can also be used when the predictor variables have discrete outcomes. Here we examine the effect of presence or absence of five pressures on habitat conservation status, based on the Art. 17 reports. Each predictor variable was encoded with a 1 if the pressure was reported (present) and with a 0 if the pressure was unreported (absent). The results of the statistical model are presented in Figure 5 and are quite interesting.

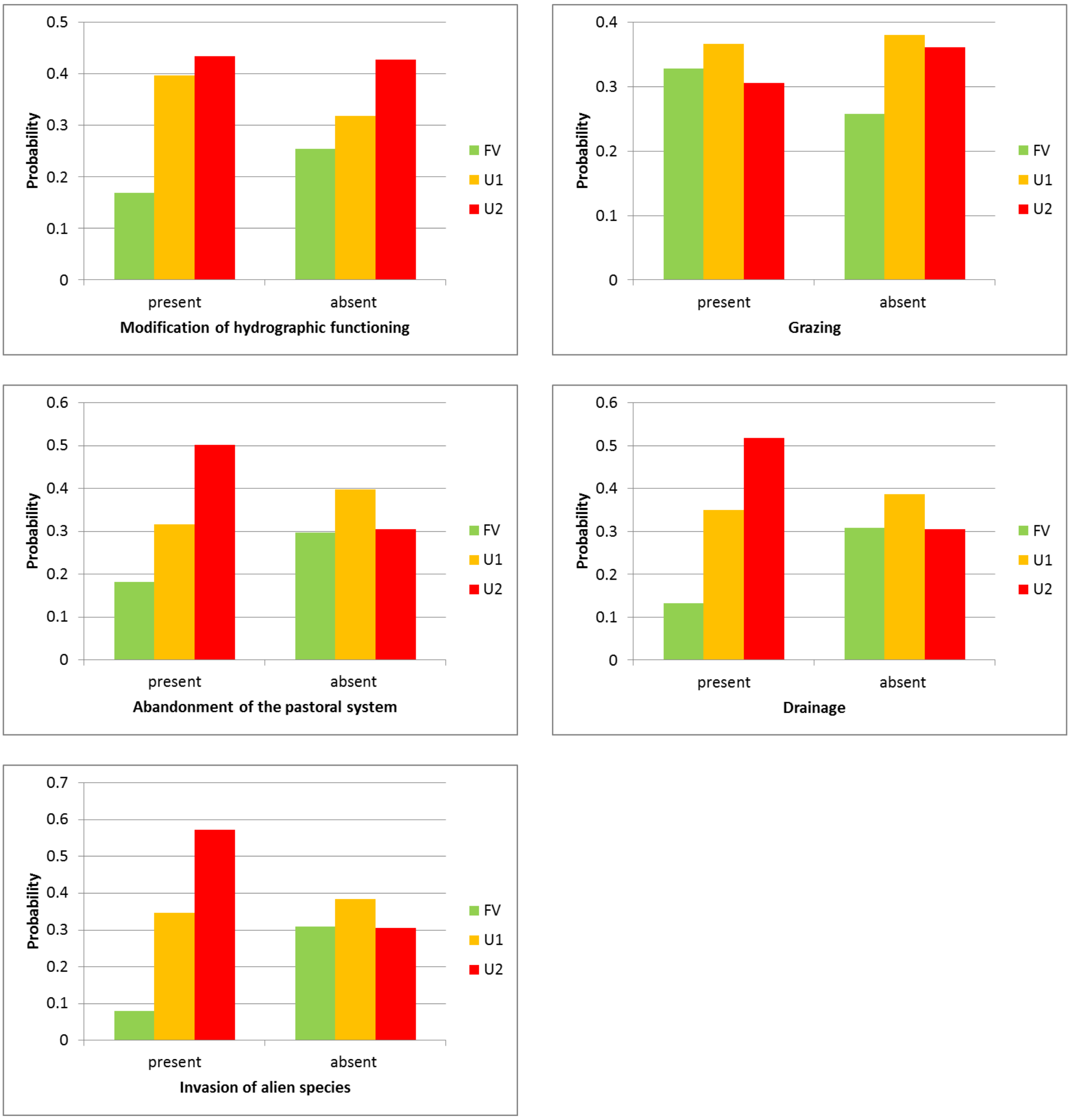


Figure 5. Single response models. The probability of habitat conservation status as a function of different drivers of change.

A striking observation concerns the direction of change. The probability of a favourable conservation status decreases when a pressure is present in all models but one, grazing. The impact of alien species is quite pronounced. Habitat assessments where invasion of alien species is reported as pressure have a much higher probability of an unfavourable status than habitat assessments where this pressure is not reported. Similar observations were made for abandonment of pastoral systems as well as water stress (two pressures). Interestingly, grazing, which was reported as pressure, results in an opposite pattern. Grazing is associated with favourable conservation status and, if reported, it actually increases the probability of the favourable conservation status.

The significance of these conclusions, even based on qualitative information based on reporting by MS, cannot be underestimated. The assessment of pressures demonstrates that management practises have a profound impact on conservation status. In particular, the physical modification of the hydrology of watersheds by lowering the water table (drainage) or by restructuring waterways, the abandonment of traditional agricultural management, and the invasion of alien species were assessed as the most important threats to habitat conservation status.

The added value of including these binary variables in the model is that we can now simulate the impact of restoration of ecosystem management on conservation status. Provided that location specific data are available, we can model the absence of each pressure which corresponds to either restoration measures (e.g. rewetting, removing alien species) or to appropriate management (extensive grazing, traditional agricultural practise). These options will be discussed in the next section where the impact of combined pressures on conservation status are analysed.

4.3. Multivariate response of conservation status to drivers

Multivariate regression models were used to predict the response of conservation status when exposed to multiple drivers of change. Three combinations of predictor variables were tested and used for analysis and mapping of conservation status (see section 4.4). The first combination included only continuous predictors: four land use variables, two nitrogen enrichment variables that resulted in significant models, Natura 2000 and green infrastructure nodes. For reasons explained above, air quality (ozone AOT40) and the proportion of green infrastructure links were not considered any more in the statistical models. A second combination added to this first set the five binary predictor variables. The third combination added to the first set an extra categorical variable that assigns each habitat assessment to one of the following MAES ecosystem types (forests and woodlands, wetlands, grasslands, sparsely vegetated ecosystems, and heathlands and shrubs). No habitats were assigned to cropland or urban ecosystems while freshwater and marine ecosystems were excluded from this analysis.

All regression coefficients and model diagnostics are available in the supplement to this report.

4.3.1. Model 1. Continuous predictors only

A first run including only continuous predictor variables delivered in first instance results that were opposed to the single model responses (Figure 4). In particular, the probability of a favourable conservation status increased with increasing values of road density and fertilizer input and decreased with increasing values of green infrastructure nodes, contrasting with the a priori signs set in Table 1. Typically, multi-collinearity in the predictor data set causes regression coefficients which flip sign after including other predictors. Multi-collinearity refers to correlated predictor variables. The density of the road network is correlated to artificial land use; fertilizer input is correlated to arable land use and exceedance of critical loads; the green infrastructure nodes are related to the Natura 2000 coverage. A common method to avoid collinearity is principal component analysis on the predictor data set after which the principal components are further used as predictors in the regression models. Here, we decided to simply exclude these three variables from the analysis. It follows that all final models are based on the following combination of continuous drivers of change: artificial land use, arable land use, pasture, exceedance of the nitrogen critical load and the proportion of coverage by Natura 2000. This combination yields a set of regression coefficients that observe the a priori assumed direction of change (positive or negative) of Table 1.

The final model to predict conservation status can be calculated using the following equations:

$$\log\left(\frac{P(U1)}{P(FV)}\right) = F_1 = 0.3210 + 0.0592 \times \mathrm{L_{arti}} + 0.0080 \times \mathrm{L_{arab}} + 0.0174 \times \mathrm{L_{past}} - 0.0190 \times \mathrm{N_{2000}} + 0.0001 \times \mathrm{AAE} \quad (2)$$

$$\log\left(\frac{P(U2)}{P(FV)}\right) = F_2 = -0.0183 + 0.0663 \times \mathrm{L_{arti}} + 0.0313 \times \mathrm{L_{arab}} + 0.0386 \times \mathrm{L_{past}} - 0.0433 \times \mathrm{N_{2000}} + 0.0005 \times \mathrm{AAE} \quad (3)$$

$$p(FV) = \frac{1}{1 + \exp(F_1) + \exp(F_2)} \quad (4)$$

$$p(U1) = \frac{\exp(F_1)}{1 + \exp(F_1) + \exp(F_2)} \quad (5)$$

$$p(U2) = \frac{\exp(F_2)}{1 + \exp(F_1) + \exp(F_2)} \quad (6)$$

where P(FV) is the probability that an assessment returns a favourable conservation status, p(U1) is the probability that an assessment returns a unfavourable inadequate conservation status, P(U2) is the probability that an assessment returns a unfavourable bad conservation status, L_{arti} is the proportion of artificial land use (%), L_{arab} is the proportion of arable land use (%), L_{past} is the proportion of pasture (%), N_{2000} is the proportion of land covered by Natura 2000 and AAE is the annual average exceedance of the critical load for nitrogen (eq ha^{-1}).

The regression coefficients including their standard error and level of significance are repeated in Table S2. In case of a dependent variable that has continuous values, linear regression results in an explained variance, which measures the proportion to which a regression model accounts for the variation. An explained variance cannot be calculated using a maximum likelihood method but the analysis can deliver an estimate of the correct classification of all cases. So the equation is used to calculate the probability of each observation in the data and compares this probability with the observed assessment conclusion. These results are provided in table S6 and can be used to interpret to some extent the variance that is explained by the model. The percentage of correct classifications for model 1 was 43% for assessment conclusion FV, 46% for assessment conclusion U1 and 62% for assessment conclusion U2.

4.3.2. Model 2. Binary and continuous predictors

A second model includes the 5 continous variables that were retained in model 1 and adds variables that contain data on the presence or absense of drivers (or pressures). Model results and diagnostics are given in Tables S3 and S6 of the supplement. Importantly, the percentage or correctly classified cases increased, in particular for the FV conclusion assessment. Model 2 successfully predicts 54% of the FV assessments, 44 % of the U1 assessments and almost 65% of the U2 assessments. The equations of model 2 are as follows:

$$\log\left(\frac{P(U1)}{P(FV)}\right)=F_1=1.2149+0.1620\times \mathrm{M}_1 - 0.0228\times \mathrm{M}_2+0.1652\times \mathrm{M}_3+0.2180\times \mathrm{M}_4+0.5169\times \mathrm{M}_5$$
$$+0.0720\times \mathrm{L}_{\mathrm{arti}} - 0.0010\times \mathrm{L}_{\mathrm{arab}}+0.0088\times \mathrm{L}_{\mathrm{past}} - 0.0192\times \mathrm{N}_{2000}+0.0002\times \mathrm{AAE} \quad (7)$$

$$\log\left(\frac{P(U2)}{P(FV)}\right)=F_2=1.3147+0.0561\times \mathrm{M}_1 - 0.0524\times \mathrm{M}_2+0.5125\times \mathrm{M}_3+0.5082\times \mathrm{M}_4+0.7460\times \mathrm{M}_5$$
$$+0.0885\times \mathrm{L}_{\mathrm{arti}}+0.0167\times \mathrm{L}_{\mathrm{arab}}+0.0254\times \mathrm{L}_{\mathrm{past}} - 0.0421\times \mathrm{N}_{2000}+0.0004\times \mathrm{AAE} \quad (8)$$

where, in addition to previous set of equations (model 1) M_1 stands for modification of the hydrographic functioning, M_2 for grazing, M_3 for abandonment of the pastoral system, M_4 for drainage and M_5 of invasion of alien species. The M_i variables can only have two possible values: 1 means that the driver is present and -1 which means that the driver is absent[3]. So these categorical variables essentially increase or decrease the intercepts of the model. Substituting equations (7) and (9) in equations (4), (5) and (6) yields the probalities for conservation status.

It is possible to examine the interaction effects between discrete and continous drivers of change, for example, between the presence and absence of grazing and the proportion of land covered by pasture. The assumption is then that habitat status responds differently to increasing coverage of pasture at different levels of grazing. However, such interaction effects violate the initial asssumption of a single, average reponse of conservation status to drivers of change across all habitats. They also complicate to some extent the interpretation of the model coefficients.

Table 3 illustrates the resulting probabilities of a favourable conservation status given hypothetical[4] combinations of continous and discrete drivers. The rows contain four different scenarios with respect to the continous predictors and may represent values that typically refer to intensively used land, an agriculture mosaic, rural pasture and and a natural landscape, respectively. The columns contain different combinations of the categorical drivers expressend as present (yes) or absent (no). Back ground colours indicate which conservation status has the highest probability. Arguably, the probability of a favourable conservaton status increases with decreasing pressures from left to right and from the top to the bottom. It demonstrates that achieving favourable conservation status is challenging, in particular in areas with an intensive land use. By no means can this table be used to argue that achieving a good conservation status in such areas is impossible. It is sufficient to inspect Figure 4 again and observe the strongly positive relation between green infrastructure nodes and favourable status. Whereas green infrastructure was not included in the final multivariate models, Figure 4 provides evindence that increasing green infrastucture elements in agricultural and urban land may result in a positive impact on habitat conservation status. This stresses the need for better and more detailed data on small landscape elements in agricultural and urbanised areas.

Table 3 can also be used to focus some of the ongoing restoration efforts on good ecosystem management which includes combatting invasive alien species, rewetting, restoring rivers, extensive grazing and reinstalling tradional land management. Table 3 provides some insight in how

[3] This is the typical coding for sigma-restricted models.

[4] The table has only illustrative value; some combinations of drivers are unlikely to occur.

management at local or landscape scale can substantially improve conservation status, keeping constant the pressures that operate at broader geographical scales, such as land use change and nitrogen deposition. It also demonstrates well the benefits of the Natura 2000 network in achieving good conservation status as required by the Habitats Directive.

Table 3. Probability of favourable conservation status for hypothetical combinations of drivers. Background colours represent the conservation status that has the highest probability (red: unfavourable bad, orange: unfavourable inadequate, green: favourable).

Modified hydrographic functioning	yes	no	no	no	no	no
Grazing	no	no	yes	yes	yes	yes
Abandonment of the pastoral system	yes	yes	yes	no	no	no
Drainage	yes	yes	yes	yes	no	no
Invasion of alien species	yes	yes	yes	yes	yes	no
Urban and agriculture development 20% artificial, 35% arable, 5% pasture 5% Natura2000, 300 eq. ha^{-1} AAE	0.003	0.004	0.004	0.01	0.02	0.08
Agricultural mosaic 5% artificial, 15% arable, 10% pasture 17% Natura2000, 250 eq. ha^{-1} AAE	0.02	0.02	0.02	0.06	0.12	0.32
Rural pasture 2% artificial, 0% arable, 10% pasture 50% Natura2000, 50 eq. ha^{-1} AAE 2%	0.10	0.11	0.12	0.21	0.32	0.60
Nature 0% artificial, 0% arable, 0% pasture 100% Natura2000, 50 eq. ha^{-1} AAE	0.35	0.41	0.43	0.54	0.66	0.85

4.3.2. Model 3. Continuous predictors and ecosystem types

The last statistical model used the same predictor variables as model 1 but included a categorical variable that groups every habitat assessment into one of the MAES ecosystem types. The aim of this model is to contribute information that can be used for mapping the status of ecosystems. Table S5 lists the regression coefficients along with the other model diagnostics. Also this model has an increased performance with respect to correct classification of FV assessments relative to model 1 (Table S6).

Similarly as in model 2, the effect of including ecosystem typology is an increase or a decrease of the model interceps while keeping the slopes homogenous. The equations to solve p(FV) are as follows:

$$\log\left(\frac{P(U1)}{P(FV)}\right) = F_1 = \beta_1 + 0.0721\times \mathrm{L}_{\mathrm{arti}} + 0.0071\times \mathrm{L}_{\mathrm{arab}} + 0.0122\times \mathrm{L}_{\mathrm{past}} - 0.0182\times \mathrm{N}_{2000} + 0.0001\times \mathrm{AAE} \quad (9)$$

$$\log\left(\frac{P(U2)}{P(FV)}\right) = F_2 = \beta_2 + 0.0802\times \mathrm{L}_{\mathrm{arti}} + 0.0305\times \mathrm{L}_{\mathrm{arab}} + 0.0321\times \mathrm{L}_{\mathrm{past}} - 0.0437\times \mathrm{N}_{2000} + 0.0003\times \mathrm{AAE} \quad (10)$$

intercepts	β_1	β_2
wetlands	0.9812	0.6753
grasslands	0.5608	1.0563
heathlands and shrub	-0.0182	-0.0437
forests and woodlands	0.0361	-0.0496
sparsely vegetated ecosystems	-0.2102	-0.0697

where, similar as in models 1 and 2, L_{arti} is the proportion of artificial land use (%), L_{arab} is the proportion of arable land use (%), L_{past} is the proportion of pasture (%), N_{2000} is the proportion of land covered by Natura 2000 and AAE is the annual average exceedance of the critical load for nitrogen (eq ha^{-1}).

The relative value of the intercepts tells something about the relative vulnerability of the considered ecosystem types. Recall that positive intercepts increase the odds of unfavourable status while negative intercepts increase the odds of favourable status. Keeping everything else constant, wetlands are thus the most vulnerable habitats according to the analysis, followed by grasslands, heathlands and shrub, forests and woodlands, and finally sparsely vegetated habitats. This corresponds with Figure 1 which depicts the relative frequencies of habitat groups considered in the Habitats Directive. For three out of five groups, we used a one to one relation between the MAES typologies and the broad habitats defined under the Habitats Directive. This is not the case for heathlands and shrub and for sparsely vegetated habitat. The latter MAES ecosystem type contains both dunes and rocky habitats which respond quite differently to pressures. Consequently, the coefficients for sparsely vegetated habitats will overestimate the probability of a favourable conservation status of coastal dunes given land use change, nitrogen deposition and coverage by the Natura 2000 network.

4.4. Mapping conservation status

The statistical models can be used to map conservation status, or at least, the probability that habitats will be assessed as having favourable or unfavourable status. As an example, we mapped the probability of favourable conservation status on a 10 km resolution grid which covers the EU based on the regression coefficients by model 1 and model 3. Recall that model 1 used only continuous variables to predict conservation status while model 3 included five terrestrial MAES ecosystem types.

Using the regression coefficients of equations (2-6), Figure 6 maps the probability of a favourable conservation status across all habitats based on the proportion of artificial land use, arable land use, pasture, Natura 2000 sites, and the exceedance of critical nitrogen loads for every grid cell. This map should be interpreted as the average probability of habitats to be assessed at favourable conservation status, given a combination of land uses and nitrogen deposition. As can be expected, probabilities are low in areas with intensive land use and high rates of nitrogen deposition whereas they are high in Scandinavia, the Iberian Peninsula, and Europe’s major mountain chains. Note also the impact that the Natura 2000 network has on conservation status, which is well well-illustrated by the vast Natura 2000 site of Sologne in the heart of France.

Figure 6 can be compared in a straightforward manner with Figure 2. Whereas Figure 6 maps a probability between 0 and 100%, Figure 2 maps the relative frequency of a favourable conservation status based on the Art. 17 reports. Also these frequencies are presented between 0 and 100%. Comparing both figures demonstrates well the advantages of this particular statistical analysis which was made under the assumption of an average response of habitats to pressures and drivers of change. The regression models effectively allow to gap fill and downscale the Art. 17 assessment data and to provide more special detail.

Figures 7 and 8 map the probability of a favourable conservation status based on the regression coefficients of equations (9-10). Firstly, the percentage of each MAES ecosystem type was calculated per grid cell making use of the cross walk between the MAES ecosystem typology and the corine land cover classes (2). Ecosystem types that cover more than or equal to 20% of the surface area of each 10 km grid cell were mapped.

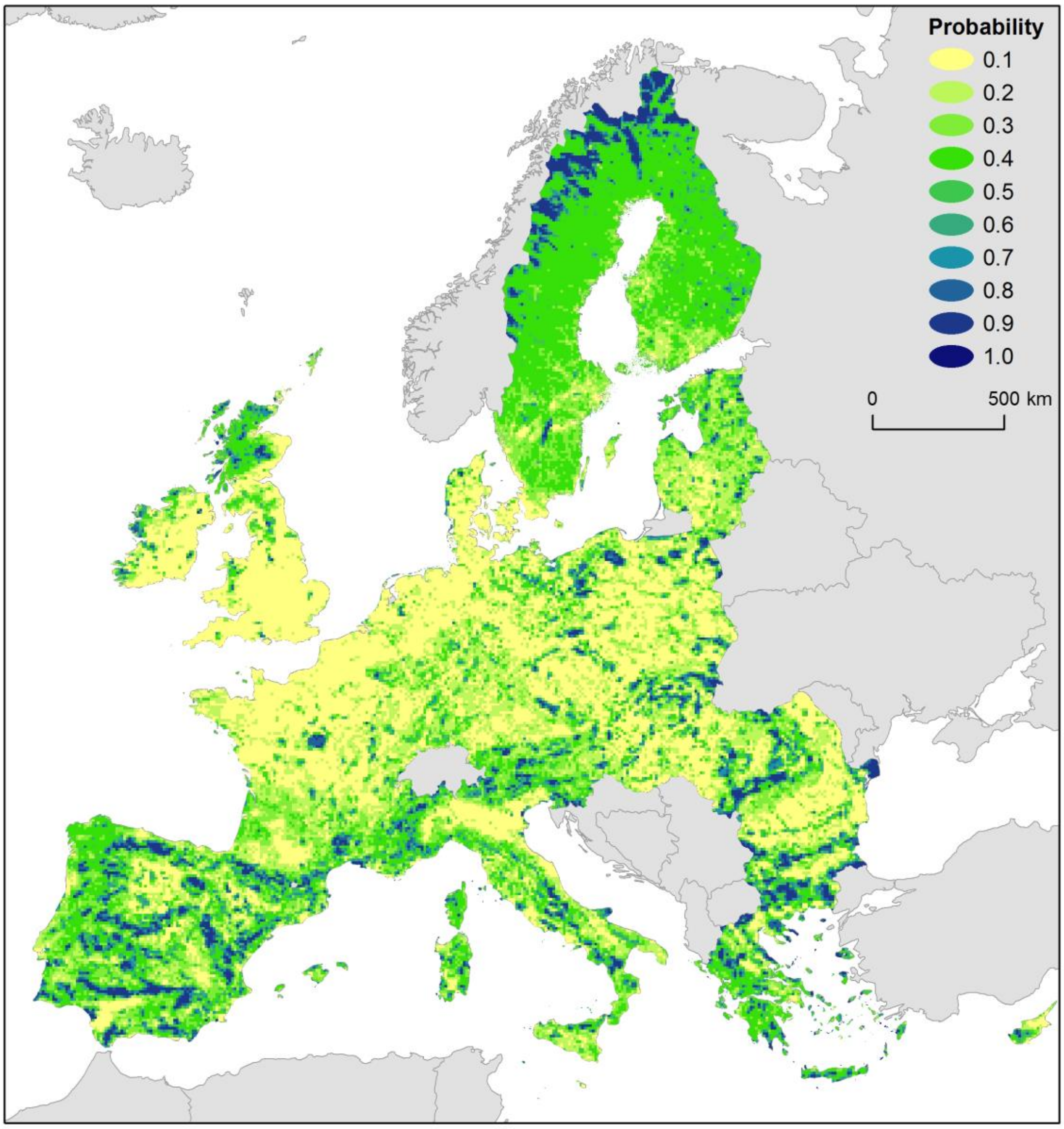


Figure 6. Modelled probability of favourable conservation status in the EU-27 based on the results of Model 1.

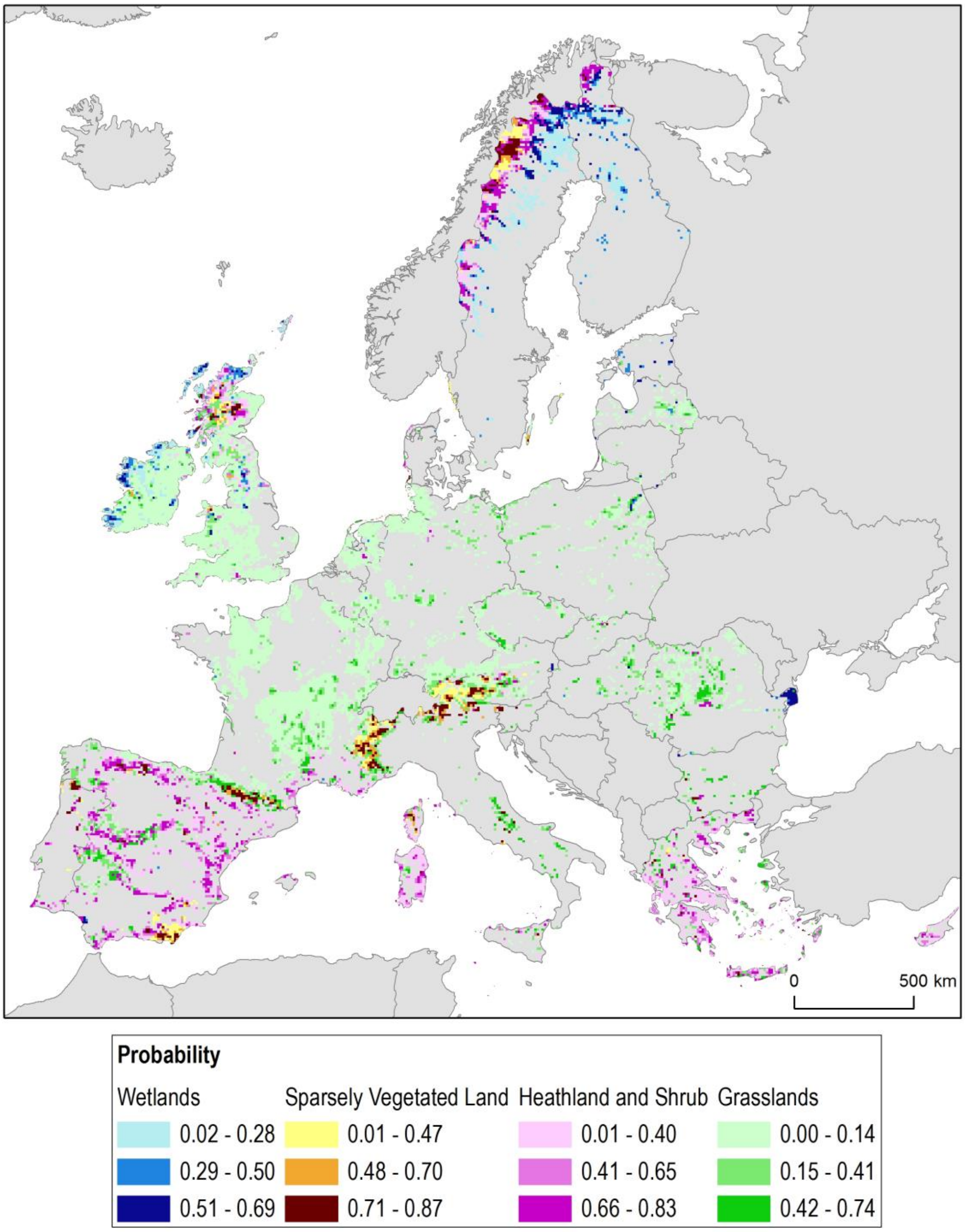


Figure 7. Modelled probability of favourable conservation status in the EU-27 based on the resuls of Model 3.

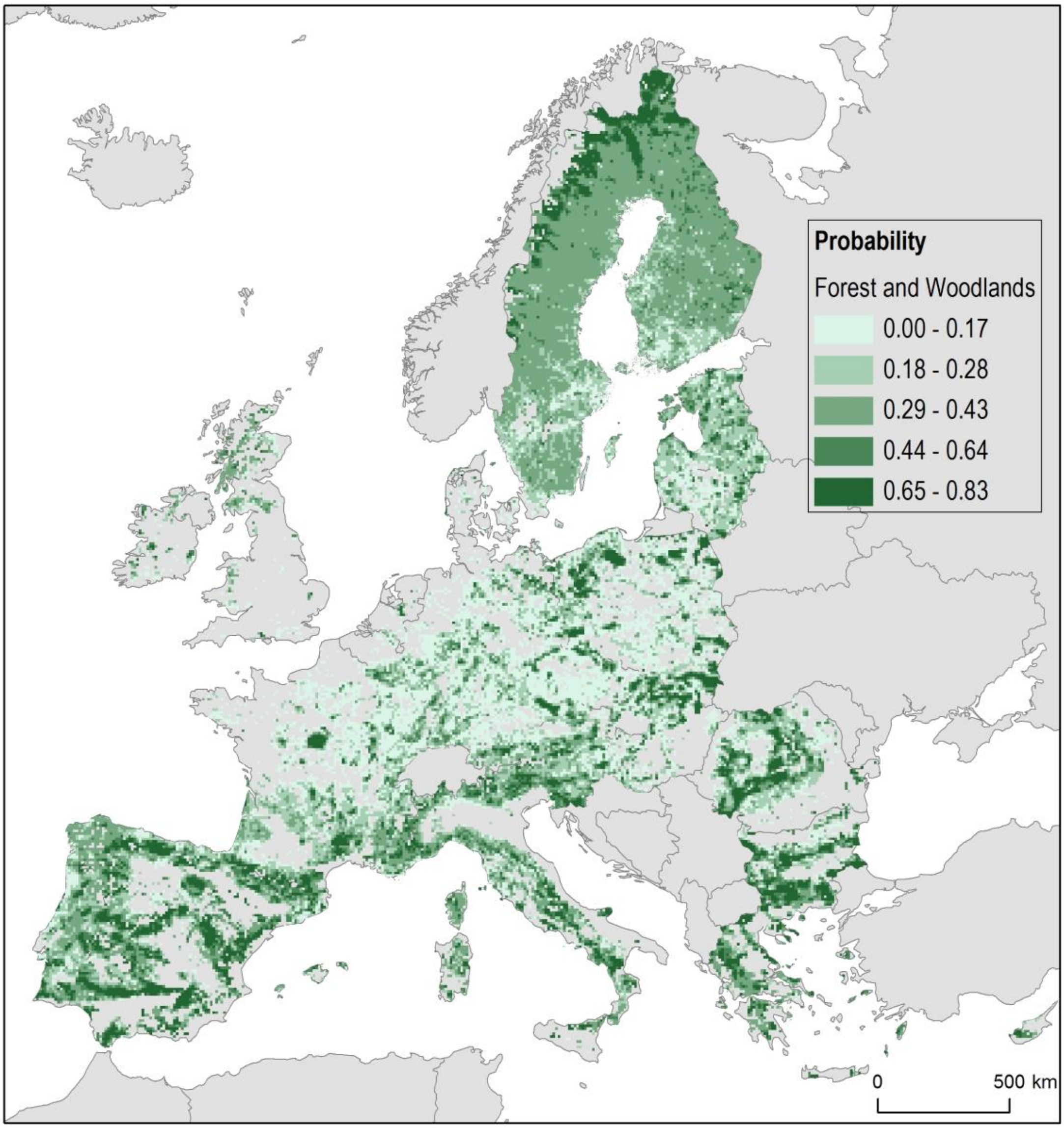


Figure 8. Modelled probability of favourable conservation status in the EU-27 based on the resuls of Model 3.

4.5. Uncertaintly assessment

The Article 17 reporting on habitat and species conservation status constituted an unparalleled assessment involving hundreds of people in national and regional administrations and research institutes from 25 EU Member States (7). However, it was not realistic to assess European habitats using a harmonized approach throughout all Member States. This resulted in two main problems which were already pinpointed in the introduction of this report: (i) the use of a different baseline to assess conservation status of habitats and (ii) differences in spatial accuracy of the data. The European Topic Centre on Biological Diversity provides a detailed report on the completeness, quality and coherence of the data (8).

We used a Monte Carlo analysis to test the robustness of the regression coefficients obtained from the first multinomial logit model, which predicts conservation status based on a combination of artifical land cover, arable land cover, pasture, coverage by the Natura 2000 network and exceedance of critical nitrogen loading. The Monte Carlo analysis addressed the following question: how well does model 1 predict the probability of a favourable conservation status if the regression coefficients are based on a subsample of only 200 instead of 1482 assessments. Figure 9 contains a flowchart that demonstrates the general idea of the Monte Carlo procedure to test data uncertainty.

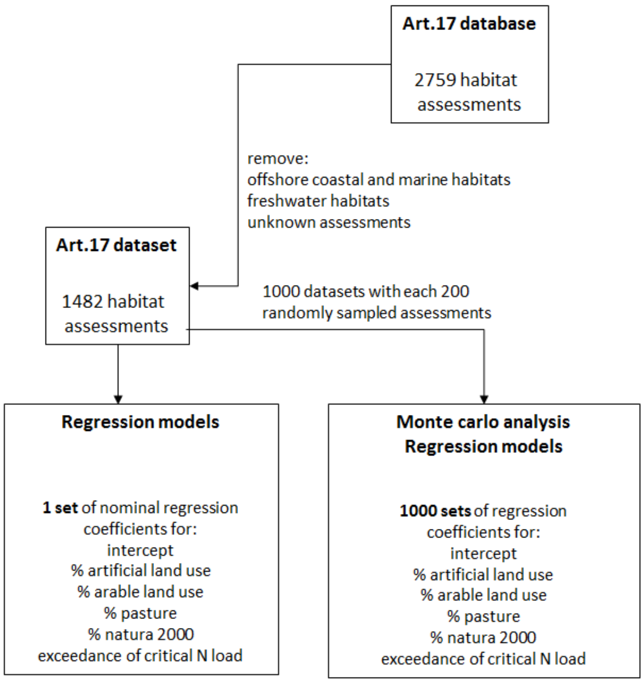


Figure 9. Flow chart of the Monte Carlo assessment on the regression models.

We thus randomly resampled 200 habitat assessments out of a total of 1482 habitat assessments used in this study and recalculated the regression coefficients. We repeated this procedure 1000 times. This resulted in a distribution representing the uncertainty in each regression coefficient, which is explained by a normal distribution characterized by an average and a standard deviation. Table 4 presents the results of this analysis and compares the regression coefficients obtained from a nominal model run (and corresponding to the regression coefficients of equations 2and 3) with the average coefficients based on 1000 models, each using 200 resampled assessment conclusions. Table 4 shows that both sets of coefficients are virtually the same.

Furthermore, the direction of change of each regression coefficient based on the Monte Carlo models was compared with the a priori assumed direction of change in Table 1. These results are also reported in Table 4. Let's examine the Natura 2000 coverage as predictor for habitat conservation status. In table 1, we assumed that the Natura 2000 network positively influenced the favourable conservation status. This hypothesis was accepted by the nominal regression model based on all 1482 habitat assessments. Following model 1, every unit of increase of the natura 2000 network decreases the odds of an unfavourable status. Put another way, it increases the probability of a favourable status. The Monte Carlo analysis corroborates this observation. Only 2 models out of 1000 models flipped the sign of this relationship and resulted in higher probability of the unfavourable status for every increment of the Natura 2000 network. The other 998 models confirmed the a priori direction of change as well as the positive relation between the network and favourable conservation status.

In general, the conclusion is that the relationships we observed between drivers of change included in the statistical model and favourable habitat conservation status reflect a meaningful and robust statistical pattern which is present in the Art. 17 data.

Figure 10 shows the distribution of probabilities that were obtained for 1000 model runs, given average values for the predictor variables.

Table 4. Uncertainty assessment on model 1. A comparision of the nominal model coefficients with the average regression coefficients based on 1000 Monte Carlo (MC) runs. The last column presents the number of Monte Carlo models that correctly prediced the a-priori sign of the reponse of each predictor variable.

Regression coefficients	**Level of response**	**Nominal model coefficients**	**Average coefficient of 1000 MC runs**	**Standard deviation of 1000 MC runs**	**Number of models with a correct a priori sign**
Intercept	U1	0.321	0.352	0.497	
% Artificial land use	U1	0.059	0.067	0.054	908
% Arable land use	U1	0.008	0.008	0.014	717
% Pasture	U1	0.017	0.019	0.032	725
% Natura 2000 coverage	U1	-0.019	-0.021	0.012	979
Exceedance of the critical nitrogen loads	U1	0.0001	0.0001	0.001	538
Intercept	U2	-0.018	-0.004	0.623	
% Artificial land use	U2	0.066	0.074	0.057	912
% Arable land use	U2	0.031	0.032	0.015	979
% Pasture	U2	0.039	0.043	0.032	934
% Natura 2000 coverage	U2	-0.043	-0.047	0.017	998
Exceedance of the critical nitrogen loads	U2	0.001	0.001	0.001	665

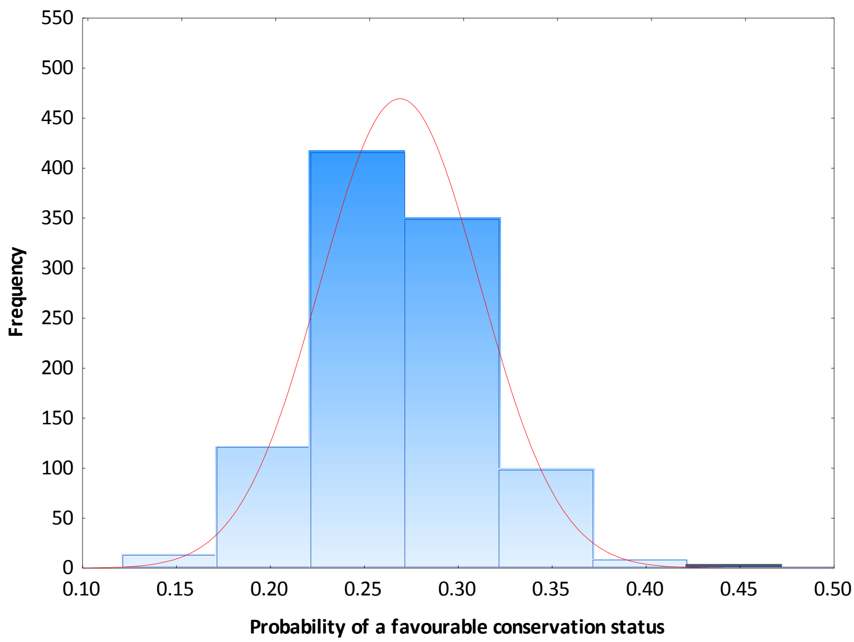


Figure 10. Uncertainty assessment on model 1. Distribution of probabilities of favourable conservation status based on 1000 Monte Carlo models using the following values for the predictor variables artificial land use: 3.42%; arable land use: 11.27%, pasture: 5.23%, Natura 2000: 17%; AAE: 232.80 eq. ha^{-1}). The nominal probability based on model 1 is 0.27.

A second question follows from the Monte Carlo assessment: What is the lowest number of assessments that we need to extract at random from the Art. 17 data to still produce a robust model. In the first Monte Carlo procedure, we reproduced the results 1000 times, each time based on 200 randomly drawn habitat assessments from the 1482 assessments that are available in the Art. 17 reports and that were considered in this study. So what would happen if we took only 100 assessments at random, or 50, or only 20? Figure 11 provides some insight in the minimum number of habitat assessments that are needed to reproduce a reliable model that predicts the probability of a favourable conservation status as a function of drivers of change. The figure plots the number of sub samples taken in 7 Monte Carlo procedures against the coefficient of variation which is the ratio between the standard deviation and the average probability calculated using 1000 models. The bottom line is that with relatively few habitat assessments conservation status can be modelled across Europe. It supports again the observation that Art. 17 habitat assessments provide a powerful dataset to simulate conservation status in the EU.

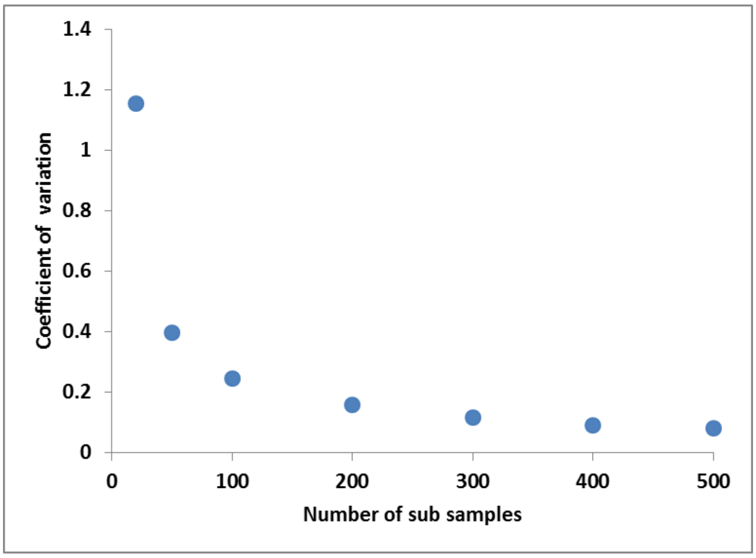


Figure 11. Uncertainty analysis. The number of sub samples that are randomly taken from the Art. 17 assessments versus the coefficient of variation of the probability of a favourable conservation status

5. Discussion and final remarks

- Habitat conservation status constitutes a policy relevant indicator to assess the state of ecosystems and biodiversity in Europe and to measure progress to the biodiversity targets. The indicator is expressed as a probability between 0 and 100% that habitats are assessed at a favourable conservation status, which allows a straightforward interpretation.

- A first test of the model will be the Art. 17 status reports that will become available in 2014. These reports can be used to validate the model predictions against a new set of status data and will allow us to improve the model performance.

- The Habitats Directive aims to bring vulnerable and threatened habitats in the EU at favourable conservation status. Using the models presented in this report can support achieving this policy goal. In particular, scenarios on land use change, nitrogen deposition, and protected areas in combination with local management can explore how policy measures can increase or decrease the probability of a favourable conservation status. This model can thus be used to assess under which scenarios target 1 of the EU Biodiversity Strategy can be achieved.

- The combination of drivers of change which operate at a large spatial scale with pressures that act on local to regional scale is a promising approach and warrants further research. There is certainly a need for more and better data on the management of ecosystems.

- The Art. 17 database contains much information on species protected under the Habitats directive. Modelling species requires, however, a different approach than the one addressed in this study since many species are mobile. Such an assessment should include predictor variables that describe the climatic suitability of species and connectivtiy between suitable habitats.

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Supplement tables

Table S1. Frequency analysis of pressures versus habitat conservation status. For each presssure, the frequency of occurrence in the Art. 17 database is given as well as the break-down (as a percentage) over three assessment conclusions (FV: Favourable conservation status; U1: Unfavourable inadequate conservation status, U2: Unfavourable bad conservation status). Pressures were ranked in decreasing order of frequency.

Rank	Pressure	Frequency	FV	U1	U2
1	abandonment of pastoral systems	483	17.6	29.8	52.6
2	eutrophication	470	9.1	31.7	59.1
3	Modification of hydrographic functioning, general	455	17.1	40.0	42.9
4	Grazing	445	29.7	35.1	35.3
5	Drainage	427	13.1	35.1	51.8
6	water pollution	425	10.4	42.4	47.3
7	Urbanised areas, human habitation	425	12.2	42.8	44.9
8	invasion by a species	402	9.5	35.8	54.7
9	General Forestry management	402	26.6	34.3	39.1
10	Biocenotic evolution	391	22.0	40.4	37.6
11	Fertilisation	363	7.4	33.9	58.7
12	forest planting	319	12.5	32.6	54.9
13	Trampling, overuse	310	17.4	50.0	32.6
14	air pollution	273	21.6	28.9	49.5
15	modification of cultivation practices	260	11.2	37.3	51.5
16	artificial planting	255	14.9	35.7	49.4
17	Cultivation	247	8.5	38.1	53.4
18	Communication networks	245	18.4	47.3	34.3
19	Landfill, land reclamation and drying out, general	212	8.5	34.0	57.5
20	Sand and gravel extraction	194	13.4	35.1	51.5
21	paths, tracks, cycling tracks	192	24.5	44.3	31.3
22	management of water levels	189	8.5	41.8	49.7
23	Agriculture and forestry activities not referred to above	183	22.4	33.9	43.7
24	Sport and leisure structures	175	11.4	49.7	38.9
25	removal of dead and dying trees	173	21.4	32.9	45.7
26	roads, motorways	169	20.7	40.2	39.1
27	Other natural processes	168	14.9	46.4	38.7
28	Discharges	168	11.9	38.1	50.0
29	walking, horse-riding and non-motorised vehicles	163	28.2	39.3	32.5
30	competition	158	14.6	39.9	45.6
31	Other pollution or human impacts/activities	157	17.2	53.5	29.3
32	Erosion	155	23.9	40.6	35.5
33	Outdoor sports and leisure activities	154	20.8	35.7	43.5
34	Dykes, embankments, artificial beaches, general	152	13.8	37.5	48.7
35	Other human induced changes in hydraulic conditions	151	10.6	48.3	41.1
36	quarries	143	38.5	34.3	27.3
37	forestry clearance	140	20.7	37.1	42.1
38	mountaineering, rock climbing, speleology	132	56.1	30.3	13.6
39	modifying structures of inland water courses	131	20.6	42.0	37.4
40	Canalisation	130	11.5	35.4	53.1
41	dispersed habitation	129	17.1	52.7	30.2
42	forest replanting	124	12.9	37.9	49.2
43	motorised vehicles	123	19.5	46.3	34.1
44	continuous urbanisation	123	9.8	38.2	52.0
45	Burning	119	16.8	37.8	45.4
46	drying out / accumulation of organic material	117	10.3	37.6	52.1
47	Drying out	113	7.1	39.8	53.1
48	infilling of ditches, dykes, ponds, pools, marshes or pits	106	17.0	34.9	48.1
49	Peat extraction	106	11.3	33.0	55.7
50	sea defense or coast protection works	103	19.4	47.6	33.0
51	nautical sports	102	18.6	40.2	41.2
52	Removal of sediments (mud...)	98	14.3	40.8	44.9
53	management of aquatic and bank vegetation for drainage purposes	97	21.6	43.3	35.1
54	damage by game species	97	24.7	36.1	39.2
55	Use of pesticides	94	8.5	21.3	70.2
56	Other leisure and tourism impacts not referred to above	93	25.8	49.5	24.7
57	Pollution	93	18.3	33.3	48.4

58	skiing complex	93	46.2	38.7	15.1
59	acidification	91	4.4	34.1	61.5
60	Industrial or commercial areas	86	1.2	34.9	64.0
61	soil pollution	84	9.5	36.9	53.6
62	Restructuring agricultural land holding	83	7.2	26.5	66.3
63	stock feeding	80	7.5	11.3	81.3
64	discontinuous urbanisation	78	5.1	35.9	59.0
65	camping and caravans	78	19.2	39.7	41.0
66	Fish and Shellfish Aquaculture	74	8.1	35.1	56.8
67	reclamation of land from sea, estuary or marsh	74	9.5	67.6	23.0
68	disposal of household waste	73	12.3	46.6	41.1
69	Silting up	72	18.1	30.6	51.4
70	Leisure fishing	70	10.0	31.4	58.6
71	Taking / Removal of flora, general	66	18.2	47.0	34.8
72	Interspecific floral relations	66	30.3	47.0	22.7
73	Shipping	66	22.7	30.3	47.0
74	Hunting, fishing or collecting activities not referred to above	65	9.2	46.2	44.6
75	fire (natural)	64	40.6	43.8	15.6
76	Dumping, depositing of dredged deposits	58	19.0	34.5	46.6
77	collapse of terrain, landslide	55	30.9	41.8	27.3
78	Professional fishing	54	7.4	50.0	42.6
79	removal of beach materials	54	13.0	48.1	38.9
80	other patterns of habitation	54	18.5	42.6	38.9
81	port areas	52	15.4	44.2	40.4
82	removal of forest undergthreatth	50	8.0	38.0	54.0
83	disposal of inert materials	50	14.0	46.0	40.0
84	golf course	50	8.0	16.0	76.0
85	mowing / cutting	48	12.5	37.5	50.0
86	other forms or mixed forms of interspecific floral competition	43	4.7	18.6	76.7
87	Flooding	42	9.5	35.7	54.8
88	Vandalism	42	23.8	50.0	26.2
89	Mining and extraction activities not referred to above	41	22.0	36.6	41.5
90	Animal breeding	38	18.4	39.5	42.1
91	forest exploitation without replanting	38	15.8	44.7	39.5
92	Other urbanisation, industrial and similar activities	37	18.9	51.4	29.7
93	antagonism arising from introduction of species	37	16.2	35.1	48.6
94	other outdoor sports and leisure activities	36	41.7	38.9	19.4
95	Other discharges	36	8.3	69.4	22.2
96	Military manouvres	36	13.9	27.8	58.3
97	storm, cyclone	36	27.8	50.0	22.2
98	Improved access to site	35	11.4	62.9	25.7
99	mechanical removal of peat	35	8.6	31.4	60.0
100	Mines	34	50.0	38.2	11.8
101	pillaging of floristic stations	34	14.7	47.1	38.2
102	introduction of disease	33	6.1	66.7	27.3
103	disposal of industrial waste	33	24.2	51.5	24.2
104	Irrigation	31	6.5	41.9	51.6
105	modification of marine currents	31	9.7	35.5	54.8
106	trawling	30	6.7	40.0	53.3
107	skiing, off-piste	29	37.9	37.9	24.1
108	electricity lines	29	13.8	41.4	44.8
109	Agricultural structures	27	29.6	48.1	22.2
110	inundation	26	15.4	46.2	38.5
111	hand cutting of peat	26	3.8	38.5	57.7
112	Energy transport	25	8.0	52.0	40.0
113	removal of hedges and copses	25	4.0	32.0	64.0
114	Hunting	25	0.0	36.0	64.0
115	other forms or mixed forms of pollution	24	25.0	20.8	54.2
116	railway lines, TGV	24	25.0	20.8	54.2
117	open cast mining	22	68.2	13.6	18.2
118	other sport / leisure complexes	22	13.6	50.0	36.4
119	Taking / Removal of fauna, general	20	10.0	45.0	45.0
120	other forms or mixed forms of interspecific faunal competition	20	15.0	25.0	60.0
121	other communication networks	20	15.0	35.0	50.0
122	airport	19	5.3	57.9	36.8
123	bridge, viaduct	19	15.8	57.9	26.3
124	polderisation	18	0.0	22.2	77.8

125	Submersion	18	22.2	33.3	44.4
126	Natural catastrophes	17	11.8	52.9	35.3
127	bait digging	16	6.3	25.0	68.8
128	Storage of materials	16	0.0	31.3	68.8
129	sports pitch	14	0.0	7.1	92.9
130	avalanche	13	38.5	46.2	15.4
131	pipe lines	13	0.0	23.1	76.9
132	other industrial / commercial areas	12	0.0	50.0	50.0
133	lack of pollinating agents	12	0.0	66.7	33.3
134	genetic pollution	11	9.1	45.5	45.5
135	Interspecific faunal relations	11	9.1	27.3	63.6
136	fixed location fishing	10	0.0	40.0	60.0
137	Salt works	10	0.0	20.0	80.0
138	factory	10	0.0	40.0	60.0
139	drift-net fishing	8	0.0	25.0	75.0
140	collection (insects, reptiles, amphibians.....)	7	14.3	57.1	28.6
141	gliding, delta plane, paragliding, ballooning	7	14.3	57.1	28.6
142	industrial stockage	7	0.0	42.9	57.1
143	other forms of taking fauna	7	0.0	71.4	28.6
144	circuit, track	6	16.7	0.0	83.3
145	Interpretative centres	6	16.7	83.3	0.0
146	Exploration and extraction of oil or gas	5	0.0	0.0	100.0
147	Other forms of transportation and communication	5	40.0	60.0	0.0
148	other natural catastrophes	5	60.0	20.0	20.0
149	parasitism	5	20.0	20.0	60.0
150	trapping, poisoning, poaching	5	20.0	40.0	40.0
151	aerodrome, heliport	4	0.0	50.0	50.0
152	other forms of energy transport	4	25.0	75.0	0.0
153	tidal wave	4	0.0	25.0	75.0
154	tunnel	4	50.0	25.0	25.0
155	attraction park	3	0.0	66.7	33.3
156	earthquake	3	66.7	33.3	0.0
157	Noise nuisance	2	0.0	0.0	100.0
158	antagonism with domestic animals	2	0.0	0.0	100.0
159	competition (example: gull/tern)	2	50.0	50.0	0.0
160	stadium	2	50.0	0.0	50.0
161	hippodrome	1	0.0	0.0	100.0
162	taking from nest (falcons)	1	0.0	0.0	100.0
163	volcanic activity	1	100.0	0.0	0.0

Table S2. Regression results. Regression coefficients and model diagnostics based on univariate multinomial regression with conservation status as dependent variable (equation 1).

Regression coefficient	Estimate	Standard error	Wald statistic	Significance level
% Artificial land use				
$\beta_{1,U1}$	-0.255	0.0999	6.5	0.01
$\beta_{2,U1}$	0.145	0.0207	49.0	<0.01
$\beta_{1,U2}$	-0.625	0.1044	35.9	<0.01
$\beta_{2,U2}$	0.198	0.0208	91.2	<0.01
% Arable land use				
$\beta_{1,U1}$	0.022	0.0835	0.1	0.79
$\beta_{2,U1}$	0.023	0.0045	27.6	<0.01
$\beta_{1,U2}$	-0.586	0.0932	39.5	<0.01
$\beta_{2,U2}$	0.051	0.0045	129.8	<0.01
% Pasture				
$\beta_{1,U1}$	0.086	0.0811	1.1	0.29
$\beta_{2,U1}$	0.041	0.0093	19.5	<0.01
$\beta_{1,U2}$	-0.210	0.0846	6.2	0.01
$\beta_{2,U2}$	0.068	0.0091	55.6	<0.01
% Green infrastructure (nodes)				
$\beta_{1,U1}$	1.047	0.1095	91.4	<0.01
$\beta_{2,U1}$	-0.016	0.0020	64.8	<0.01
$\beta_{1,U2}$	1.392	0.1090	163.0	<0.01
$\beta_{2,U2}$	-0.030	0.0023	172.2	<0.01
% Natura2000 coverage				
$\beta_{1,U1}$	1.114	0.1146	94.4	<0.01
$\beta_{2,U1}$	-0.027	0.0034	64.8	<0.01
$\beta_{1,U2}$	1.738	0.1241	196.2	<0.01
$\beta_{2,U2}$	-0.061	0.0046	177.8	<0.01
Nitrogen deposition				
$\beta_{1,U1}$	0.375	0.1346	7.8	0.01
$\beta_{2,U1}$	0.000	0.0002	0.1	0.75
$\beta_{1,U2}$	-0.064	0.1400	0.2	0.65
$\beta_{2,U2}$	0.001	0.0002	6.7	0.01
Road density				
$\beta_{1,U1}$	-0.114	0.1053	1.2	0.28
$\beta_{2,U1}$	0.424	0.0837	25.7	<0.01
$\beta_{1,U2}$	-0.482	0.1092	19.5	<0.01
$\beta_{2,U2}$	0.652	0.0833	61.2	<0.01
Fertilizer input				
$\beta_{1,U1}$	-0.010	0.1046	0.0	0.93
$\beta_{2,U1}$	0.006	0.0015	15.8	<0.01
$\beta_{1,U2}$	-0.792	0.1149	47.5	<0.01
$\beta_{2,U2}$	0.015	0.0015	106.6	<0.01

Table S2. Continued.

Regression coefficient	Estimate	Standard error	Wald statistic	Significance level
Exceedance of the critical load for nitrogen				
$\beta_{1,U1}$	0.138	0.1063	1.7	0.19
$\beta_{2,U1}$	0.001	0.0004	4.7	0.03
$\beta_{1,U2}$	-0.270	0.1124	5.8	0.02
$\beta_{2,U2}$	0.002	0.0004	30.7	<0.01
Modification of hydrographic functioning				
$\beta_{1,U1}$	0.540	0.0822	43.2	<0.01
$\beta_{2,U1}$	0.314	0.0822	14.6	<0.01
$\beta_{1,U2}$	0.522	0.0817	40.9	<0.01
$\beta_{2,U2}$	0.422	0.0817	26.7	<0.01
Grazing				
$\beta_{1,U1}$	0.251	0.0760	10.9	<0.01
$\beta_{2,U1}$	-0.140	0.0760	3.4	0.07
$\beta_{1,U2}$	0.134	0.0790	2.9	0.09
$\beta_{2,U2}$	-0.205	0.0790	6.7	0.01
Abandonment of the pastoral system				
$\beta_{1,U1}$	0.420	0.0797	27.8	<0.01
$\beta_{2,U1}$	0.130	0.0797	2.6	0.10
$\beta_{1,U2}$	0.519	0.0761	46.5	<0.01
$\beta_{2,U2}$	0.492	0.0761	41.7	<0.01
Drainage				
$\beta_{1,U1}$	0.598	0.0892	45.0	<0.01
$\beta_{2,U1}$	0.372	0.0892	17.4	<0.01
$\beta_{1,U2}$	0.677	0.0864	61.3	<0.01
$\beta_{2,U2}$	0.684	0.0864	62.6	<0.01
Invasion of alien species				
$\beta_{1,U1}$	0.838	0.1177	50.7	<0.01
$\beta_{2,U1}$	0.619	0.1177	27.6	<0.01
$\beta_{1,U2}$	0.974	0.1141	73.0	<0.01
$\beta_{2,U2}$	0.983	0.1141	74.3	<0.01

Table S3. Regression results of model 1. Regression coefficients and model diagnostics based on a multivariate multinomial regression with conservation status as dependent variable.

Regression coefficient	Level of response	Estimate	Standard error	Wald statistic	Significance level
Intercept	U1	0.3210	0.1990	2.60	0.11
% Artificial land use	U1	0.0592	0.0215	7.61	0.01
% Arable land use	U1	0.0080	0.0058	1.92	0.17
% Pasture	U1	0.0174	0.0101	2.97	0.08
% Natura 2000 coverage	U1	-0.0190	0.0041	21.04	<0.01
Exceedance of the critical nitrogen loads	U1	0.0001	0.0004	0.08	0.77
Intercept	U2	-0.0183	0.2244	0.01	0.93
% Artificial land use	U2	0.0663	0.0217	9.37	<0.01
% Arable land use	U2	0.0313	0.0059	28.33	<0.01
% Pasture	U2	0.0386	0.0101	14.49	<0.01
% Natura 2000 coverage	U2	-0.0433	0.0055	61.23	<0.01
Exceedance of the critical nitrogen loads	U2	0.0005	0.0005	1.26	0.26

Table S4. Regression results of model 2. Regression coefficients and model diagnostics based on a multivariate multinomial regression with conservation status as dependent variable.

Regression coefficient	Level of response	Estimate	Standard error	Wald statistic	Significance level
Intercept	U1	1.2149	0.2728	19.83	<0.01
% Artificial land use	U1	0.0720	0.0231	9.70	<0.01
% Arable land use	U1	-0.0010	0.0061	0.03	0.87
% Pasture	U1	0.0088	0.0104	0.72	0.40
% Natura 2000 coverage	U1	-0.0192	0.0043	20.19	<0.01
Exceedance of the critical nitrogen loads	U1	0.0002	0.0004	0.14	0.71
Modification of hydrographic functioning	U1	0.1620	0.1090	2.21	0.14
Grazing	U1	-0.0228	0.0845	0.07	0.79
Abandonment of pastoral systems	U1	0.1652	0.0865	3.65	0.06
Drainage	U1	0.2180	0.1094	3.97	0.05
Invasion by a species	U1	0.5169	0.1292	16.00	<0.01
Intercept	U2	1.3147	0.2982	19.44	<0.01
% Artificial land use	U2	0.0885	0.0235	14.15	<0.01
% Arable land use	U2	0.0167	0.0063	7.03	0.01
% Pasture	U2	0.0254	0.0108	5.59	0.02
% Natura 2000 coverage	U2	-0.0421	0.0058	53.17	<0.01
Exceedance of the critical nitrogen loads	U2	0.0004	0.0005	0.64	0.42
Modification of hydrographic functioning	U2	0.0561	0.1171	0.23	0.63
Grazing	U2	-0.0524	0.0999	0.28	0.60
Abandonment of pastoral systems	U2	0.5125	0.0896	32.73	<0.01
Drainage	U2	0.5082	0.1129	20.27	<0.01
Invasion by a species	U2	0.7460	0.1313	32.28	<0.01

Table S5. Regression results of model 3. Regression coefficients and model diagnostics based on a multivariate multinomial regression with conservation status as dependent variable.

Regression coefficient	Level of response	Estimate	Standard error	Wald statistic	Significance level
Intercept	U1	0.2260	0.2780	0.66	0.42
% Artificial land use	U1	0.0721	0.0227	10.10	<0.01
% Arable land use	U1	0.0071	0.0059	1.44	0.23
% Pasture	U1	0.0122	0.0102	1.44	0.23
% Natura 2000 coverage	U1	-0.0182	0.0042	18.61	<0.01
Exceedance of the critical nitrogen loads	U1	-0.0001	0.0004	0.07	0.80
Wetlands	U1	0.7552	0.2779	7.38	0.01
Sparse vegetated areas	U1	-0.2823	0.2303	1.50	0.22
Forests	U1	0.0290	0.2292	0.02	0.90
Grasslands	U1	0.5486	0.2506	4.79	0.03
Heathland and shrub	U1	0			
Intercept	U2	-0.2313	0.3193	0.52	0.47
% Artificial land use	U2	0.0802	0.0230	12.13	<0.01
% Arable land use	U2	0.0305	0.0061	25.21	<0.01
% Pasture	U2	0.0321	0.0104	9.60	<0.01
% Natura 2000 coverage	U2	-0.0437	0.0057	59.19	<0.01
Exceedance of the critical nitrogen loads	U2	0.0003	0.0005	0.44	0.51
Wetlands	U2	0.9065	0.3126	8.41	<0.01
Sparse vegetated areas	U2	-0.1499	0.2710	0.31	0.58
Forests	U2	-0.0801	0.2661	0.09	0.76
Grasslands	U2	1.0242	0.2805	13.33	<0.01
Heathland and shrub	U2	0			

Table S6. Model diagnostics. Correct classifications based the difference between observed and predicted frequencies of each assessment conclusions for models 1, 2 and 3.

		Predicted: FV	Predicted: U1	Predicted: U2	**Percentage correct classifications**
Model 1	Observed: FV	**185**	161	80	43.4
	Observed: U1	106	**249**	190	45.7
	Observed: U2	32	161	**318**	62.2
Model 2	Observed: FV	**231**	129	66	54.2
	Observed: U1	123	**242**	180	44.4
	Observed: U2	31	151	**329**	64.4
Model 3	Observed: FV	**208**	141	77	48.8
	Observed: U1	145	**213**	187	39.1
	Observed: U2	42	151	**318**	62.2

Supplement text: Mathematical solution of equation 1

This supplement describes the solution for the multinomial regression model, which is expressed as

$$\log\left(\frac{P(i)}{P(FV)}\right) = \beta_{1i} + \beta_{2i}x \qquad (1)$$

where P(i) is the probability of class membership in the categories U1 or U2, P(FV) is the probability of class membership in the reference category FV; x is the independent or predictor variable (e.g. the proportion of artificial land cover) and β_{1i} and β_{2i} are the regression coefficients. Solving equation (1) for P(FV), P(U1) and P(U3) requires solving a systems of the following three equations:

$$\frac{P(U1)}{P(FV)} = \exp\left[\beta_{1U1} + \beta_{2U2}x\right] \qquad (2)$$

$$\frac{P(U2)}{P(FV)} = \exp\left[\beta_{1U2} + \beta_{2U2}x\right] \qquad (3)$$

$$P(FV) + P(U1) + P(U2) = 1 \qquad (4)$$

The solutions for P(FV), P(U1) and P(U3) follows from substituting equations (2) and (3) into equations (4).

$$p(FV) = \frac{1}{1 + \exp\left[\beta_{1U1} + \beta_{2U2}x\right] + \exp\left[\beta_{1U2} + \beta_{2U2}x\right]} \qquad (5)$$

$$p(U1) = \frac{\exp\left[\beta_{1U1} + \beta_{2U2}x\right]}{1 + \exp\left[\beta_{1U1} + \beta_{2U2}x\right] + \exp\left[\beta_{1U2} + \beta_{2U2}x\right]} \qquad (6)$$

$$p(U2) = \frac{\exp\left[\beta_{1U2} + \beta_{2U2}x\right]}{1 + \exp\left[\beta_{1U1} + \beta_{2U2}x\right] + \exp\left[\beta_{1U2} + \beta_{2U2}x\right]} \qquad (7)$$

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Abstract

Under Article 17 of the Habitats Directive, Member States of the EU must submit information on how the Habitats Directive is being implemented every six years. For the reporting period 2001 to 2006, 25 Member States provided, for the first time, detailed assessments on the conservation status of each of the habitat types and species listed in the directive and found on their territory or different bio-geographical regions therein. This report presents a model based approach to assess how conservation status may change in the future. This approach is based on the available assessments and simulates the probability that a habitat assessment results in a favourable conservation status as a function of drivers of change.

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