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APPLICATION OF THE CZ-GLOBIO MODEL IN BESKYDY PROTECTED LANDSCAPE AREA

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ABSTRACT

Spatially oriented simulation models have not yet been applied to the territory of Beskydy Protected Landscape Area (PLA) to assess the state of biodiversity at a local scale. The CZ-GLOBIO model, which is adapted to the conditions of the Czech Republic, was used as a tool to assess habitat degradation using four selected drivers. The aim of the article is to apply the CZ-GLOBIO model for biodiversity status assessment in Beskydy PLA at the biotope level using detailed habitat data. The result of the application of the model is the evaluation of the state of biodiversity and the risk of its degradation using the Mean Species Abundance (MSA) index. Values are obtained for each segment as well as the average value for the entire territory. The results of biodiversity modelling are available by five maps and five tables with output Mean Species Abundance (MSA) values. Understanding the spatial distribution of the resulting MSA values contributes to the landscape-level habitat assessment of Beskydy PLA. This can serve as a basis for further policy decisions in the environmental field.

Keywords: biodiversity, CZ-GLOBIO, Mean Species Abundance, landscape modelling, Beskydy Protected Landscape Area

INTRODUCTION

Biodiversity means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems (CBD, 2021). Biodiversity therefore has a significant impact on the functioning of the complex ecosystems that make up the environment, thus itneeds to be protected and ecosystems need to be maintained or restored (Švecová *et al.*, 2007). However, biodiversity is declining rapidly due to a range of anthropogenic impacts (World Wildlife Fund, 2021).

Many different organisations are trying to reduce the intensity and negative impacts of anthropogenic impacts on nature globally. Yet over the last few decades, the intensity of anthropogenic influence has been increasing, causing significant and undesirable changes in biodiversity and ecosystems around the world.

The persistent changes can be registered, quantified and assessed to some extent by using geoinformation technologies and models designed to simulate and predict processes or phenomena in the context of potential biodiversity loss or the selection of unprotected ecologically valuable areas for protection. The quantitative environmental impact assessment models, which are contemporarily being developed aim to exactly inform decision-makers, especially state experts in the field of environmental protection (Pechanec *et al*., 2016), and thus effectively support policy decisions on global human impacts on biodiversity to maintain generally sustainable development on Earth. This involves working with geographic data in a Geographic Information Systems (GIS) environment. GIS offers a range of extensive spatial analytical tools and capabilities that can be used to navigate and find relationships between individual spatial phenomena or objects and thus understand them better. GIS offers efficient, fast and high-quality processing of geographic data from many different data sources and can analytically evaluate them. They find applications in both public administration and the private sector, for example in the protection of ecologically valuable areas, restoration of disturbed landscapes or weather simulation in meteorology.

The Global biodiversity model for policy support (GLOBIO) has been used globally on all continents (Alkemade *et al*., 2009). In 2009, Rob Alkemade and the research team applied GLOBIO model version 3.0 to the entire world. They account for land use intensity, harvesting, nitrogen deposition and climate change took into. A predicting scenario has been created at the global level, covering nine world regions for the period 2010–2050. For land use they performed an extensive meta-analysis and showed that MSA gradually decreases with land-use intensity increase. Moderate growth in the human population, the economy and increased agricultural productivity remain the assumptions. The authors took into account shifts of biomes, which are also used in the Millennium Ecosystem Assessment to mimic the effect of climate change on species. In a case study, Schipper *et al*. (2017) assess the state of biodiversity in Mexico using the GLOBIO model. Mexico is generally known for its high biodiversity and good quality geographic data (Schipper *et al*., 2017). The team of researchers has been assessed the loss of naturalness in the study area based on the average values of MSA (Mean Species Abundance) weighted by area (land use change and infrastructure development). The lower the MSA value reached, the greater the loss of habitat for biodiversity. Conversely, the higher the MSA values, the more habitat is natural for biodiversity, i.e. no loss.

The model has also been applied at a local scale but this adequate regional data is required, which causes difficulties to use in Central Europe. For this reason, the model has been used only exceptionally in Central Europe. In the Czech Republic, most of the input data is regional, therefore the same driver as used in the GLOBIO 3 model can be used. The adaptation and use of the GLOBIO model to local conditions in the Czech Republic has been addressed by Vilém Pechanec *et al*. (2016). The study area has been the Dřevnice river basin. The model has been suitably adapted to conditions at local and regional scales. The result of the work is the Czech adaptation of the GLOBIO model version. 3.6 referred to as CZ-GLOBIO. Stržínek (2018) applied the CZ-GLOBIO model on the territory of the Czech Republic, both at regional and local scales. He used all five drivers to achieve the resulting MSA_{TOT} index. Kaňková (2013) dealt with the modification of MSA indicators for use in the conditions of the Czech Republic at a regional scale. She used the drivers of land use change, infrastructure development and landscape fragmentation rates for the whole territory of the Czech Republic in a GIS environment to assess biodiversity degradation.

The study aims to apply the CZ-GLOBIO model at a local scale in Beskydy PLA to assess the degree of habitat degradation by four key drivers using current data. The emphasis is on the results of the CZ-GLOBIO biodiversity status modelling, which are interpreted through maps and tables with MSA output values.

MATERIALS AND METHODS

Study area

The model was applied to the territory of Protected Landscape Area, which is situated in the highlands of the Outer Western Carpathians and occupies almost the entire territory of the Moravian-Silesian Beskydy Mountains, a substantial part of the Vsetín Hills and the Moravian part of the Javorníky Mountains, forming the border with Slovakia. It was officially proclaimed on 5 March 1973. With an area of 1 160 km^2, it is the largest protected landscape area in the Czech Republic. The reasons for the designation of Beskydy PLA were its exceptional natural values, especially the remnants of natural forests with rare Carpathian fauna and flora, species-rich meadows and pastures and unique surface and underground pseudo-karst phenomena. The Beskydy landscape has a significant, ecological, biological, cultural and scenic value that arose via the interaction of people and nature over time. The importance of the protected landscape area is underlined by the designation of 59 nature reserves and nature monuments. As part of the development of the European Natura 2000 protected areas system, the entire landscape declared area was proposed as a Site of Community Importance and also two Special Protection Areas for bird protection were established within the area – Beskydy and Horní Vsacko.

Geomorphologically, the territory of Beskydy PLA is part of the Outer Western Carpathians. The highest point is the peak of Lysá hora (1324 m above sea level), while the lowest point is at the level of river Rožnovská Bečva near village Zubří (350 m above sea level). The main European watershed runs east-west through the centre of the PLA. The streams north of the line, belong to the Oder River basin and subsequently to the Baltic Sea basin. The streams south of this line, belong to the Danube basin and the Black Sea basin. The climatic conditions of the Beskydy Mountains are influenced by their location in the central part of Europe. There is a clash between oceanic and continental climate influences. According to the climatic classification of the Czech Republic, the Beskydy region belongs to the category of cold regions. Only a small part belongs to the category of moderately warm areas (Vondráková *et al*., 2013). Land use is mainly natural and is protected against activities that could reduce its aesthetic and natural values. Forests (especially beech-fir forests) cover about 71 % of the whole territory. Minor parts are covered by non-forest habitats (meadows, pastures, wetlands). Anthropogenic interventions in the landscape, in particular the location and approval of buildings, can only be implemented concerning preserving the overall landscape characters and significant landscape elements, particularly protected areas and cultural landmarks.

Data

Table 1 summarizes the input data used in the application of the CZ-GLOBIO model in Beskydy PLA. The aim was to use current data. The data were processed in the ArcGIS Pro interface using geoprocessing tools for spatial analysis (Identity, Spatial Join, Buffer, Clip, etc.). The input datasets Data200 (produced by the Czech land surveying and cadastral office) and ArcČR 500 ver.3.3 (prouced by ArcData Praha) have a declared absolute accuracy of up to 100 m (according of official metadata). Analysis of ArcČR 500 proved that the relative positional accuracy to the position in the Basic geographic database is within a 99 % probability of 150 m. Given a mean Basic geographic database positional error of 5-30 m, the absolute positional error of ArcČR 500 in 3.3 is estimated to be within 200 m (ARCDATA PRAHA, 2021). To obtain MSA values that reflect the state of biodiversity in the Beskydy PLA, have been used current data from the Detailed Combined Layer (DCL). This is an entirely unique product, which in a detailed scale (M 1:10 0000), captures the specifics of the Czech landscape and distinguishes 152 types of habitats. The data capture both natural and degraded and non-natural habitats. The dataset uniformly covers the entire Czech Republic. With this data, we can very well describe the real biodiversity in the entire area of interest, not just the occurrence/absence of a few selected species. The layer was created in cooperation between Global Change Research Centre (CzechGlobe) and our department within the framework of long-term collaboration IMALBES (http://www.imalbes.cz).

Table 1: Usage data for calculating individual drivers

NAME	PRODUCER	OBJECT	TOPICALITY	DETAILED SCALE	INDICATORS OF MSA
OpenStreetMap	Geofabrik	Roads; railways	2020	1 : 10 000	MSA_F; MSA_I
Structure and population in the municipalities	Czech Statistical Office	Population in municipalities	2020	–	MSA_I
Detailed combined layer	Global Change Research Centre	Land use at habitat level	2019	1 : 10 000	MSA_{LU}; MSA_N; MSA_I; MSA_F
Expert nitrogen measurement	Global Change Research Centre	Nitrogen critical load exceedance	2018	500 × 500 m	MSA_N
ArcČR 500 v 3.3	ARCDATA PRAGUE, s.r.o.	Obce	2016	1 : 500 000	MSA_I
Large Specially Protected Areas	NCA CR	Borders of the Beskydy PLA	2020	1 : 10 000	MSA_{LU}; MSA_N; MSA_I; MSA_F
Knowledge base for inferring the response of individual habitats to stressful issues	Global Change Research Centre	Habitat sensitivity values	2020	–	MSA_{LU}

Legend: MSA_{LU}—MSA of land use change; MSA_I—MSA of Infrastructure development; MSA_F—MSA of Landscape fragmentation; MSA_N—MSA of Atmospheric nitrogen deposition.

Model GLOBIO

The Global biodiversity model for policy support (GLOBIO) is a model developed by the PBL Netherlands Environmental Assessment Agency in collaboration with various partners to inform and support policymakers by quantifying the global human impacts on biodiversity and ecosystems. Official GLOBIO website is https://www.globio.info.

The model is based on simple cause-effect relationships between selected drivers and biodiversity impacts. That is, there is a principle of mutual causality between drivers and the state of biodiversity. The pressure of individual drivers on biodiversity was determined based on scientific studies on the occurrence of selected species of plants and animals (Alkemade *et al.,* 2009). The core of the system lies in the selection of individual drivers and the calculation procedure. The model works with environmental drivers that represent pressures or the previously mentioned impact on biodiversity. Pechanec *et al*. (2021) state impact–response relationship is derived from a database of observations of species responses to change. The database contains separate measures of the indicator MSA (Mean Species Abundance) about different measures of pressures or drivers. Items in the database are derived from studies in the peer-reviewed literature, reported as a time course of change in a single event or as a response in parallel events under different pressures. GLOBIO works with five drivers in its calculations that negatively affect biodiversity and reduce MSA values:

1. MSA of Land use change (MSA_{LU})
2. MSA of Infrastructure development (MSA_{I})
3. MSA of Landscape fragmentation (MSA_{F})
4. MSA of Climate change (MSA_{CC})
5. MSA of Atmospheric nitrogen deposition (MSA_{N})

MSA expresses the mean abundance of native species in disturbed conditions relative to their abundance in undisturbed environments. MSA values are quantified based on a synthesis of empirical monitoring data of species in disturbed environments compared to an undisturbed reference situation, as reported in a comparative study (Alkemade *et al*., 2009). It reaches values ranging from zero to one, where sites with a value of one signify a high degree of diversity expressed by the full number of authentic species and vice versa. The MSA value takes on a range of 0 -1. A value of 1 means 100 % fulfillment of naturalness (no habitat degradation, no negative driver impact). Values close to 0 represent non-natural biotopes or biotopes where the influence of the driver is strong (negative), and the original saturation of species (naturalness) is low (Alkemade *et al*., 2009).

The Detailed Combined Layer (DCL) of habitats from 2018 was used for the area of interest. This layer contains data on 152 habitat types across the country (Pechanec *et al*., 2021). Of the five drivers originally proposed, four were used: (i) Land use change (MSA_{LU}), (ii) Infrastructure development (MSA_{I}), (iii) Landscape fragmentation (MSA_{F}), (iv) Atmospheric nitrogen deposition (MSA_{N}).

The resulting indicator representing the average species abundance and biodiversity degradation in analyzed areas is the MSA total index (denoted MSA_{TOT}). The total MSA value is an overlay of all available MSA indicators (Alkemade *et al*., 2009). According to Alkemade et al., it is a simple product of values. By adapting the model to Czech conditions - CZ-GLOBIO, the MSA indicator in this study was determined based on habitat naturalness, and accordingly, it was more appropriate to use the central limit theorem equation in arithmetic space to calculate the MSA_{TOT} indicator (Pechanec *et al*., 2021): the MSA_{TOT} indicator by equation (Pechanec *et al*., 2021):

$$MSA_{TOT} = \frac{\sqrt{MSA_{LU}{}^2 + MSA_F{}^2 + MSA_I{}^2 + MSA_N{}^2}}{\sqrt{4}} \qquad (1)$$

MSA_{TOT} – result indicator of MSA, total value
MSA_{LU} – driver of Land use change
MSA_F – driver of Landscape fragmentation
MSA_I – driver of Infrastructure development
MSA_N – driver of Atmospheric nitrogen deposition

Detailed characteristics of individual MSA indicators of the CZ-GLOBIO model

MSA of Land Use Change (MSALU)

Data on the quality of natural, near-natural alien and non-natural habitats were used to calculate MSALU based on their representativeness and preservation status, While representativeness is defined as the extent to which the assessed habitat matches the description of the natural habitat type according to the Catalogue of Habitats of the Czech Republic (Chytrý *et al*., 2010) and preservation value assesses the conservation status of the habitat. For non-natural and natural alien habitats, values were directly assigned according to expert conversion tables. In contrast, values were assigned to natural and nature-near habitats based on a combination of representativeness and preservation coefficient values.

MSA of Landscape fragmentation (MSAF)

Landscape fragmentation is the breakdown of a complex landscape into individual segments. The influence of road and rail networks or built-up areas on the preservation of the naturalness of the landscape must be taken into account. It is well known that traffic routes have several negative effects on biodiversity. Not only do they create a barrier between nature on both sides, i.e. fragmentation, but they also contribute to air pollution, disturbance of naturalness, and traffic accidents (Bennet, 2017). The different segments of the geometry of the envelope layers of roads and electrified railways were assigned MSAF values based on their surface area using internal expert tables (Van Rooij, 2008).

MSA of Infrastructure Development (MSAI)

Segments of non-natural character are considered to be infrastructure elements. These include buildings, concrete areas, roads, parking lots, etc. Proximity to the nearest roads, land use types and density of settlements as infrastructure factors negatively affect the MSA (Alkemade *et al*., 2009). The MSA becomes low in the vicinity of road elements. However, as distance increases, the MSA value increases simultaneously up to places where roads have no impact (MSA = 1). The aspect of distance from human presence or action was taken into account by creating buffers for roads for distances of: 0.15 – 0.25 – 0.3 – 0.45 – 0.5 – 0.75 – 0.9 – 1 – 1.35 – 1.5 – 2.25 – 3 – 4.5 – 5 – 6 – 7.5 – 10 – 15 km (Van Rooij,2008). The population density in the municipalities was calculated as the ratio of the number of inhabitants to the area of the territory [km²].

MSA of Atmospheric Nitrogen Deposition (MSAN)

The effect of nitrogen deposition was derived from critical load values for major ecosystems using a soil map and ecosystem sensitivity to nitrogen inputs. Data from expert measurements provided in a 500 × 500 m grid include nitrogen deposition values (primary data of CzechGlobe)). The critical load value is value when the buffering capacity of the area is exceeded, and nitrogen begins to have a negative effect on its surroundings. (for more info see Alkemade *et al*., 2009). The empirical value of the critical nitrogen load was calculated as the ratio between the number of ground vegetation species in the nitrogen-treated habitat and the number of species in the control habitat (Bobbink *et al*., 2004). The critical load value was evaluated for non-natural and natural habitats according to Bobbink (2004) and Zapletal *et al*. (2014). For natural habitats, critical load values were calculated for long-term steady-state conditions according to UBA (2004) and assessed by Zapletal *et al*. (2014).

The nitrogen exceedance (NE) value for each habitat was calculated using Equations 2 and 3.

$$NE = ND - CL \qquad (2)$$

$$MSA_N = 1 - ln(NE + 1) \qquad (3)$$

NE – nitrogen deposit impact
ND – nitrogen deposits
CL – critical load
MSA_N – driver of atmospheric nitrogen deposition

MSA – Mean Species Abundance – (MSATOT)

The MSA total index (denoted MSATOT) is an indicator representing the mean species abundance and biodiversity degradation in analyzed areas. The calculation is based on an estimate of the abundance of individual species under a specific pressure compared to their abundance under primary vegetation conditions.

In ArcGIS Pro software, the individual driver layers were merged into a single layer (Identity tool), which entered into the calculation of MSATOT values via mathematical relationship (1). Subsequently, the quantitative MSA values were assigned appropriately to each segment and finally, the single-number MSA values of each driver were calculated as the average values of MSA weighted by area.

The driver climate change was not calculated in this study because, at the time of the study, sufficiently detailed climate data derived from the CMIP6 model was unavailable. With current knowledge, the data from available models of the CMIP5 version is no longer appropriate to use (Fick & Hijmans, 2017).

RESULTS

The result of the application of the CZ-GLOBIO model at a local scale in the territory of Beskydy PLA are the calculated MSA values of four key factors that reflect the loss of naturalness of biodiversity at the biotope level. The total MSA value (MSA_{TOT}) was obtained by calculating (eq. 1) the spatial overlap of all four driver layers with the MSA values – (i) Land use change (MSA_{LU}), (ii)Infrastructure development (MSA_I), (iii)Landscape fragmentation (MSA_F), (iv)Atmospheric nitrogen deposition (MSA_N). The MSA values of the sub-drivers and the resulting MSA_{TOT} indicator are presented in two ways. First, the average MSA value of each driver and MSA_{TOT} is presented, which was calculated as an average values of MSA weighted by area representing the areas in which each habitat type is found in Beskydy PLA (Table 2). Second, calculations of the average MSA value of each driver were performed. Thirdly, MSA values were classified into five categories ranging from zero to one for a better overview of the impact of each driver on native biodiversity, with each category differing from each other by an MSA value of 0.2. In general, there is an inverse relationship, i.e. the intensity of habitat degradation increases as the MSA value decreases (Tables 3, 4, 5, 6, 7).

Table 2: MSA values of spatially weighted layer averages for Beskydy PLA

AVERAGE VALUES OF MSA WEIGHTED BY AREA	
MSA_{LU}	0.54
MSA_F	0.7
MSA_I	0.69
MSA_N	0.74
MSA_{TOT}	0.7

The largest manifestation of degradation in Beskydy PLA is proved by driver of Landscape fragmentation (MSA_F), which has an average value equal to 0.217. In contrast, the driver of Atmospheric nitrogen deposition (MSA_N) proves the smallest manifestation of degradation (0.752). The average values of MSA_{TOT} weighted by area corresponds to 0.7. The MSA_{LU} indicator, which characterizes the current habitat naturalness, only reaches a value of 0.54 (a value of 1 represents the original state of habitat diversity). The remaining indicators reached higher MSA values – for Infrastructure development (0.69), Landscape fragmentation (0.7) and Atmospheric nitrogen deposition (0.74).

Table 3: Calculated habitat degradation values (MSA_{LU})

HABITAT DEGRADATION (MSA_{LU})				
Interval	**Category**	**Segments**	**Area [m²]**	**Representation [%]**
(0;0.2⟩	Lower	9 892	1 673,586	4,78
(0.2;0.4⟩	Higher	12 847	3 981,447	11,38
(0.4;0.6⟩	Medium	15 398	7 242,832	20,69
(0.6;0.8⟩	Lower	10 127	7 371,029	21,06
(0.8;1⟩	Low	16 352	14 731,856	42,09
Total		**64 616**	**35 000,750**	**100**

Table 4: Calculated habitat degradation values (MSAN)

HABITAT DEGRADATION (MSA_N)				
Interval	**Category**	**Segments**	**Area [m²]**	**Representation [%]**
(0;0.2⟩	Lower	3 427	531.766	0.64
(0.2;0.4⟩	Higher	16 291	4 745.399	5.75
(0.4;0.6⟩	Medium	12 715	6 498.121	7.88
(0.6;0.8⟩	Lower	16 020	11 074.723	13.43
(0.8;1⟩	Low	61 175	59 624.615	72.29
Total		**109 628**	**82 474.624**	**100**

Table 5: Calculated habitat degradation values (MSA_I)

HABITAT DEGRADATION (MSA_I)				
Interval	**Category**	**Segments**	**Area [m²]**	**Representation [%]**
(0;0.2⟩	Lower	15 668	47 606 273.976	3.97
(0.2;0.4⟩	Higher	0	0	0
(0.4;0.6⟩	Medium	41 551	323 396 373.134	26.97
(0.6;0.8⟩	Lower	35 758	491 057 847.082	40.96
(0.8;1⟩	Low	14 870	336 917 800.904	28.10
Total		**107 847**	**1 198 978 295.096**	**100**

Table 6: Calculated habitat degradation values (MSA_F)

HABITAT DEGRADATION (MSA_F)				
Interval	**Category**	**Segments**	**Area [m²]**	**Representation [%]**
(0;0.2⟩	Lower	8 038	48 119 029.671	4.01
(0.2;0.4⟩	Higher	18 296	305 791 328.197	25.50
(0.4;0.6⟩	Medium	156	113 136 924.841	9.43
(0.6;0.8⟩	Lower	75	113 145 430.929	9.43
(0.8;1⟩	Low	57	619 174 402.477	51.63
Total		**26 622**	**1 199 367 116.115**	**100**

Infrastructure development associated with landscape fragmentation has reduced the biodiversity of many habitats, especially native and introduced shrub vegetation along roadsides, which are affected by regular clearing and new roads. The road and rail network also reduces the quality of natural habitats by spreading weeds and invasive plants (Šerá, 2008).

Table 7: Calculated habitat degradation values (MSA_{TOT})

HABITAT DEGRADATION (MSA_{TOT})				
Interval	**Category**	**Segments**	**Area [m²]**	**Representation [%]**
(0;0.2⟩	Lower	17 777	28 097 796.414	2.34
(0.2;0.4⟩	Higher	12 658	21 505 163.921	1.79
(0.4;0.6⟩	Medium	29 303	133 879 489.731	11.17
(0.6;0.8⟩	Lower	94 370	794 042 076.175	66.23
(0.8;1⟩	Low	32 648	221 364 771.163	18.46
Total		**186 756**	**1 198 889 297.406**	**100**

In terms of the representation of MSA indicators divided into five intervals, the MSATOT value has a representation of 4.13 % in the interval from 0 to 0.4. On the contrary, the MSALU, MSAN and MSAF indicators have a higher representation in the same interval (16.16 %, 6.39 % and 29.51 %, respectively). The MSALU and MSAF indicators have a higher representation (16.16 % and 29.51 %) in the MSA 0 to 0.4 interval compared to the MSAN (6.39 %) and MSAI (3.97 %) indicators (Table 5). The highest values of individual MSA indicators were found in mountainous areas, hilly parts of the Beskydy PLA and partly in border areas of the state. These high values of MSA indicators were mainly related to the occurrence of small-area special protected areas. The lowest values of MSA of all factors were found mainly in the intravilas of villages, as well as in the vicinity of roads and railways and in areas of arable land (Figures 1 to 2). The spatial distribution of all resulting MSA values of the sub-drivers in the territory of the Beskydy Protected Landscape Area is expressed in maps (Figures 1 to 5).

The results of the study show that the spatially weighted average value of the MSATOT index in the Beskydy PLA is still high (0.7). However, low MSALU values (0.9) indicate a significant reduction in biodiversity compared to the original natural habitats, which is also confirmed by Pechanec *et al*. (2016, 2021). On the basis of our research (study of "Care plans of PLA" and spatial planning documents in the region) it can be claimed, that a frequent cause of biodiversity degradation in the Beskydy PLA is land conversion in the context of agriculture and furthermore urbanization (expansion of housing developments). To reduce biodiversity loss at the habitat level, it is necessary to effectively protect natural and near-natural habitats, consider sustainable use of arable land and establish forest plantations on degraded soils (Alkemade *et al*.,2009).

Fig. 1: Spatial distribution of habitats with resulting MSA_{LU} values

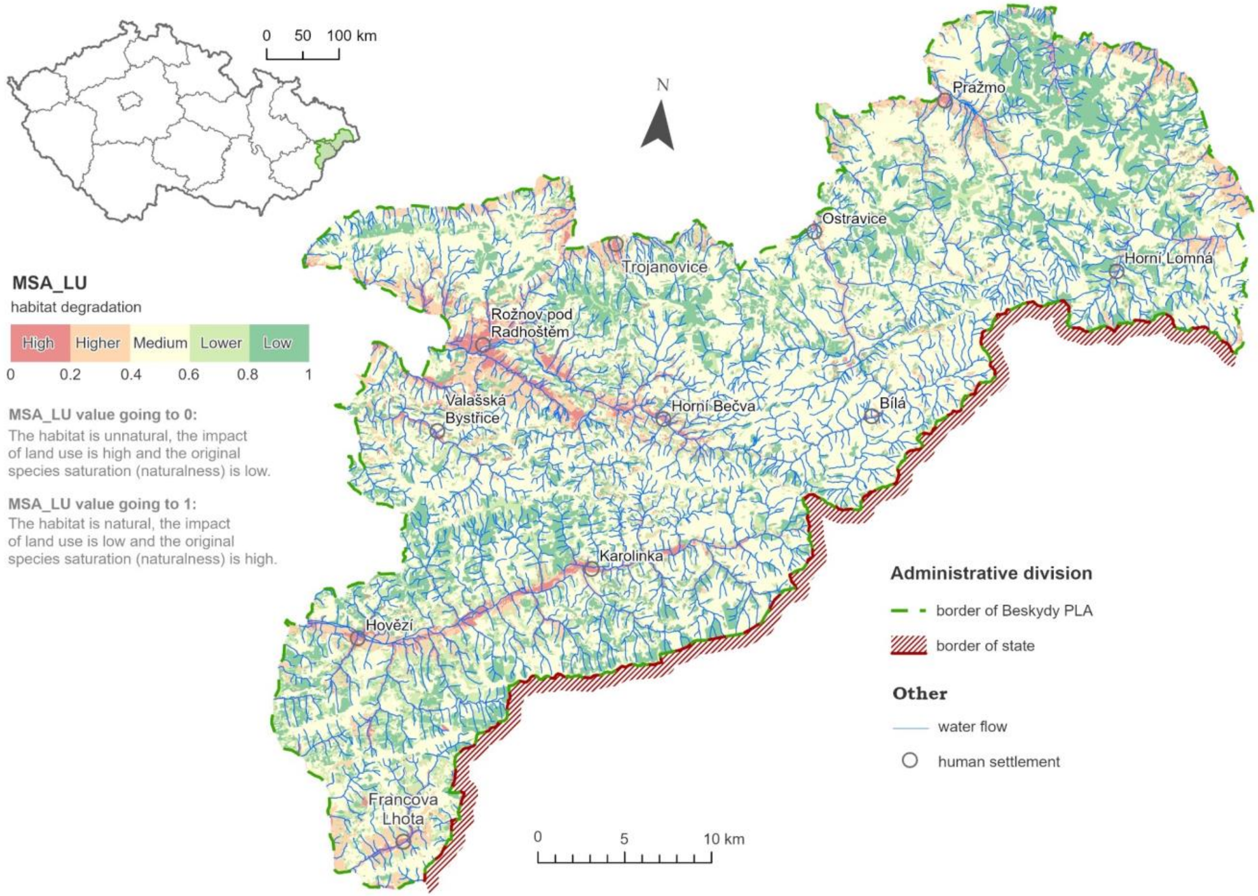


Fig. 2: Spatial distribution of habitats with resulting MSA_N values

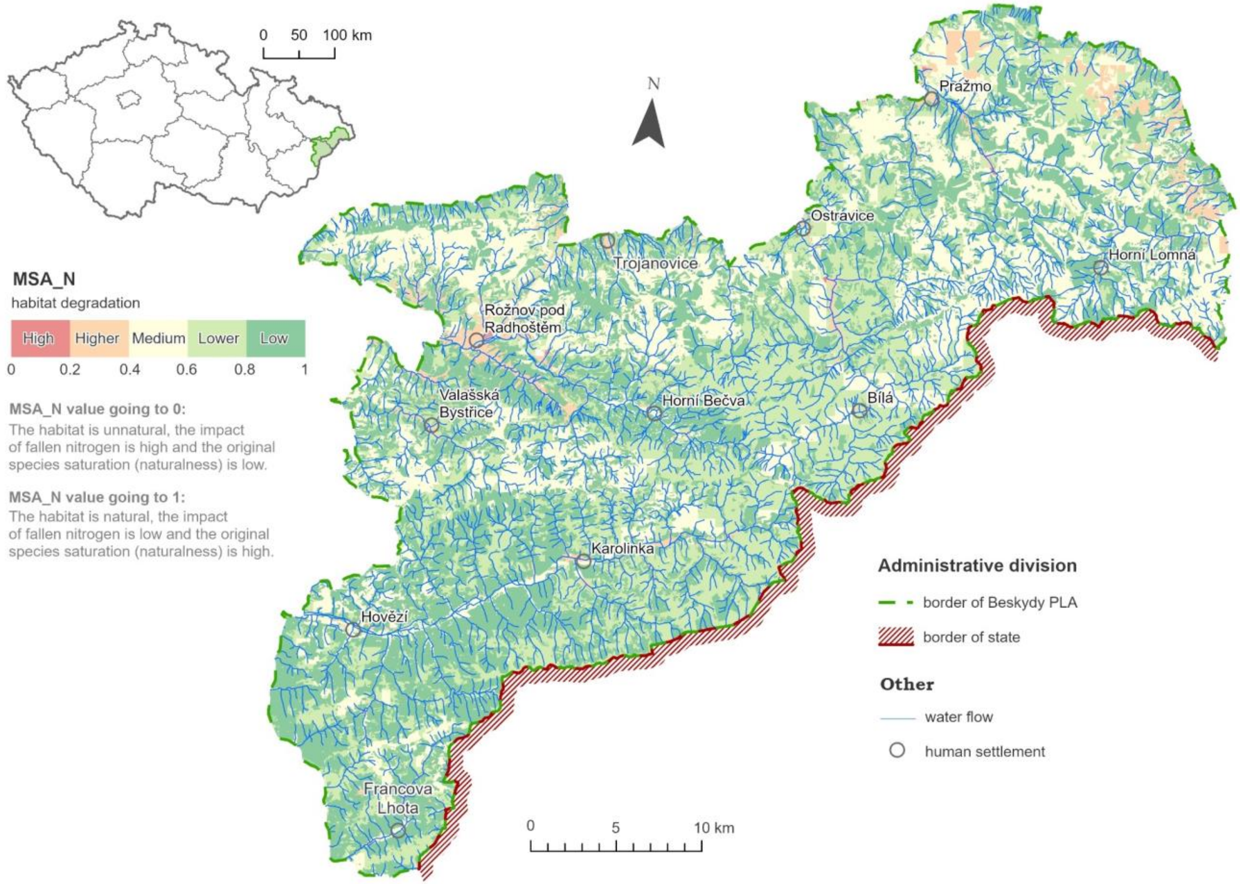


Fig. 3: Spatial distribution of habitats with resulting MSA$_I$ values

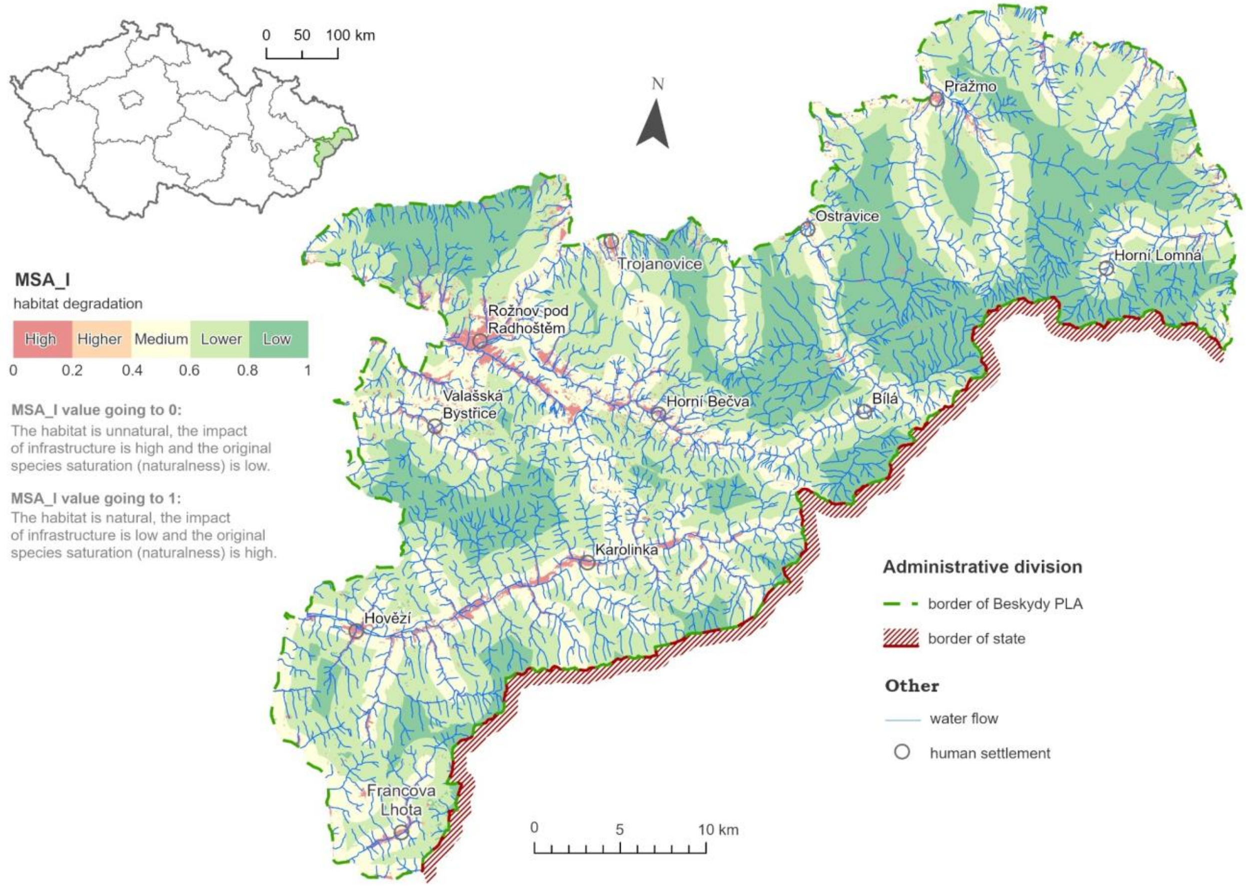


Fig. 4: Spatial distribution of habitats with resulting MSA_F values

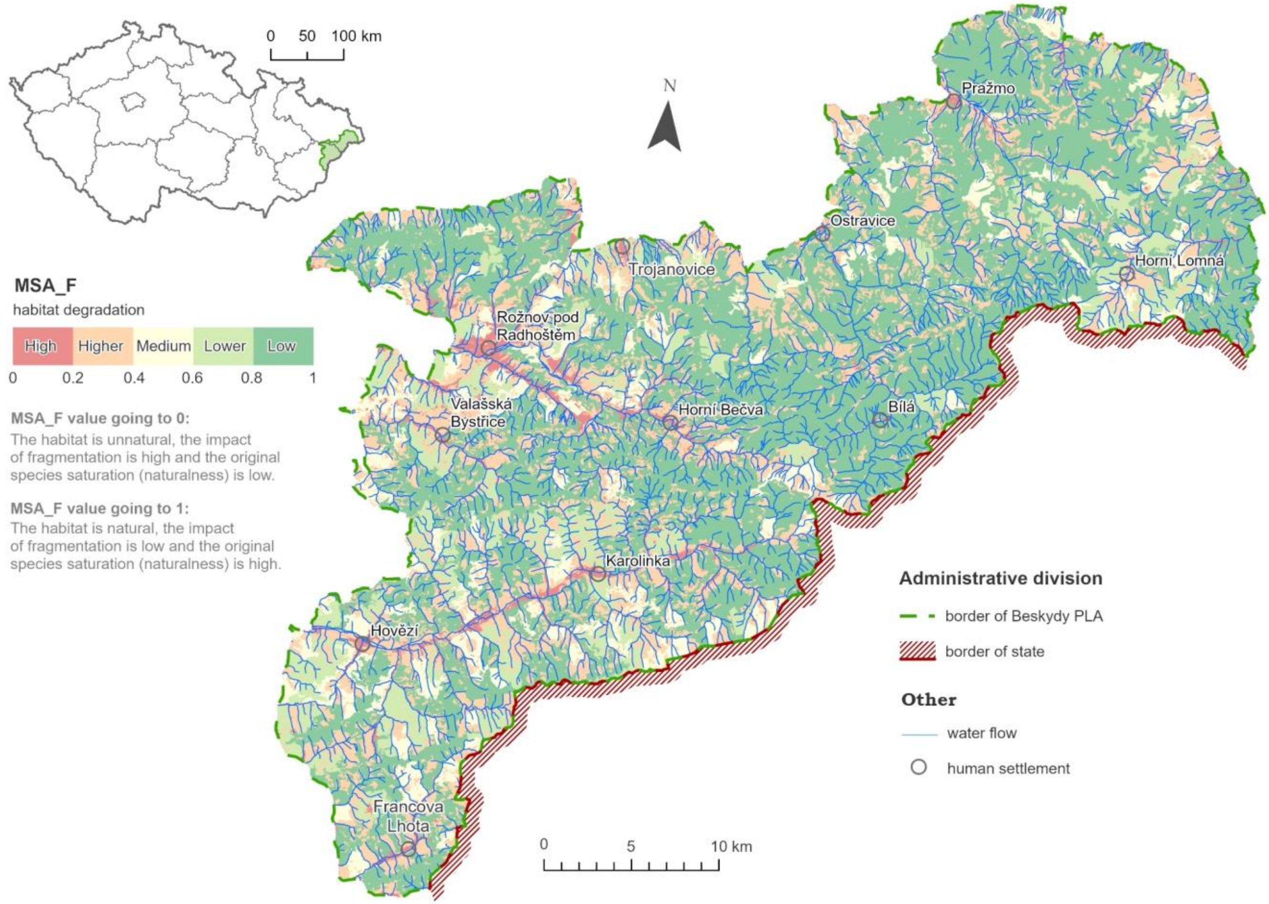
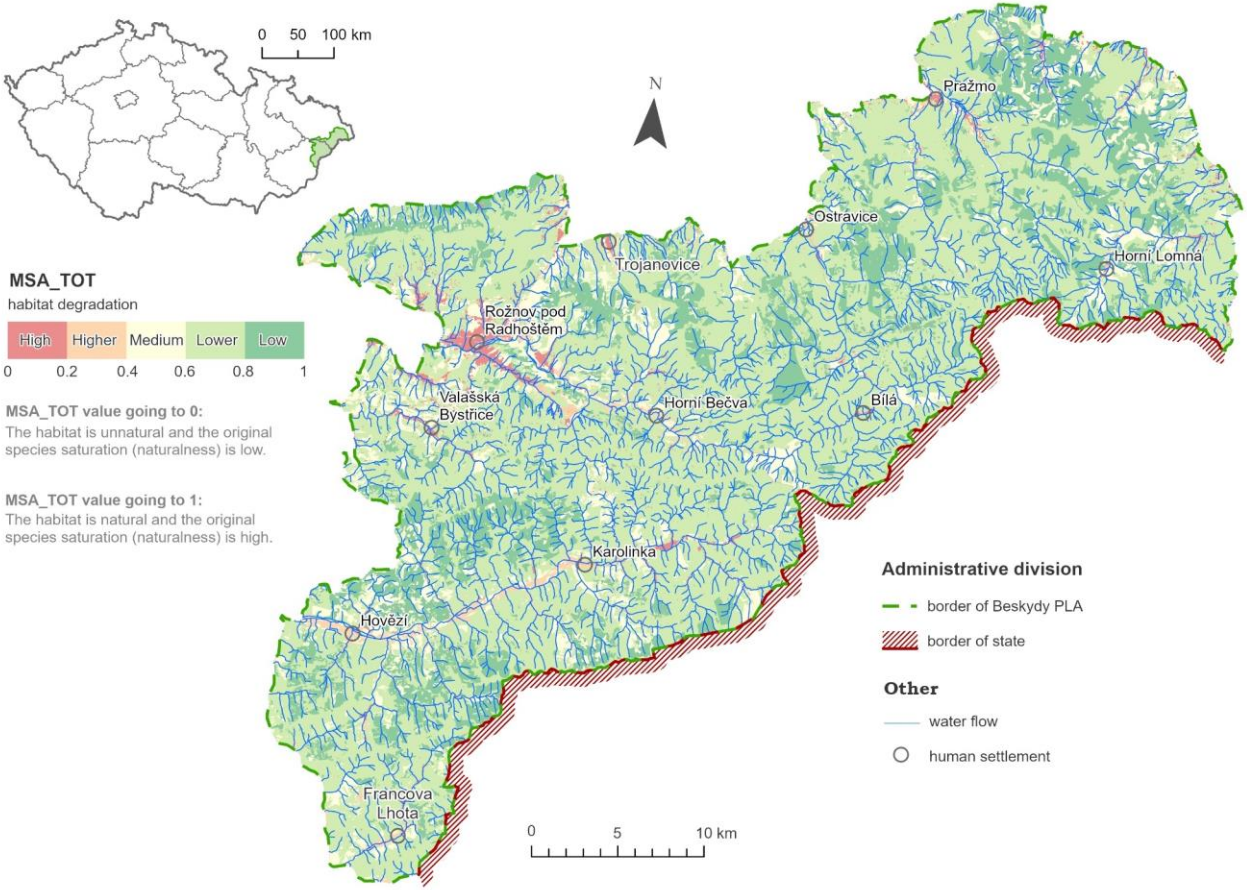


Fig. 5: Spatial distribution of habitats with resulting MSA_{TOT} values



DISCUSSION

The aim of the study was to assess the degradation of biodiversity at habitat level on a detailed scale in the Beskydy PLA using the CZ-GLOBIO model. The results of the distribution of calculated Mean Species Abundance (MSA) values of individual drivers assessing habitat degradation are expressed in map outputs (Figures 1 to 5).

This is the second application of the CZ-GLOBIO model at the local level for Czechia. The difference to the GLOBIO model is i) in the data used, ii) the way of describing biodiversity (original discovery data, here habitat map), and iii) modification of the algorithm for calculating the total MSA value. The study shows how to apply the model to actual conditions, which data are available and usable. The difference compared to the first study using the habitat map is the extent of the territory. It was carried out for the entire Czech Republic and included all landscape segments, including degraded ones (Pechanec *et al.*, 2021).

This study focused on one specific area with a special nature protection regime (PLA) in the Czech Republic. It clearly shows what results can be achieved in a long-term protected area. The study shows how a biotope map can be used to describe biodiversity. Most of the studies with the GLOBIO model were based on discovery (survey) data only. The biotope map reflects the heterogeneity of the landscape on a suitable scale and gives a continuous picture of diversity, making it easier to identify the externalities of the territory.

In fact, the current of MSA output values depends on the availability of input data sources. Therefore, the current of data is a significant aspect and has been considered in this study in the application of the model. Data granularity is another important aspect for an effective scenario. The population density data in the municipalities (1 January 2020) were input to calculate the values of the mean species abundance of drive, which reflects the state of habitat degradation in terms of the infrastructure of the area. For a more accurate analysis of habitat degradation, it would be more appropriate to use population data for more detailed (smaller areas) territorial units (e.g. cadastral areas or basic settlement units). Current population data for the 57 basic settlement units are so far only available for 1991 and 2001.

A better assessment through MSA can be achieved by using an environmental driver of Climate change, which has not been implemented here. The Climate change driver is different in nature from the other four drivers. This is because the available empirical evidence is limited to areas where these changes are already taking place (e.g. mountain forests). Where the ratio of species loss per biome is a function of air temperature. This model would be compared with the model used in IMAGE, which uses a linear regression curve to determine the relationship between temperature increase and the stability of areas within biomes. The coefficients for each region are estimated from the regression dependencies and correlation parameters of the two models (Alkemade *et al*., 2009). Pechanec (2021) reports that work is underway to develop a Climate change driver for the CZ-GLOBIO model using the EUROMOVE module. The impacts of climate change are more likely to affect habitats that are in extreme conditions, such as alpine grasslands, dry grasslands and peatlands. An increase in temperature for the same amount of precipitation will also have a negative impact on habitats already found in dry areas. At the same time, the change in climatic conditions may lead to an increased spread of alien and invasive species downstream of transport routes and watercourses. A more accurate prediction of the response of individual habitats to changes in climatic conditions needs to be made once the climate change factor is included in the CZ-GLOBIO model.

The habitat quality is a good proxy for biodiversity status, and land use data about habitat occurrences are easily available to the government (Kučera & Pojer, 2011). In the PLA context, in order to include the CZ-GLOBIO model in the decision-making processes of the state administration, we recommend applying the most up-to-date data on driver impacts, on the state of land use, and on natural habitat occurrences. Habitat mapping is regularly updated via surveillance following the Habitat Directive obligations by the Nature Conservation Agency of the Czech Republic (Lustyk et Oušková, 2006).

ArcGIS Pro software was used for the application of the CZ-GLOBIO model. Using this GIS, it is possible to process data at a detailed scale for the entire Czech Republic in a relatively short time – on the order of 10 h (Pechanec *et al.*, 2021). Due to the higher computational requirements of the CZ-GLOBIO model application, it is recommended to carefully consider the choice of appropriate computing technology.

CONCLUSION

The aim of the study was to apply the CZ-GLOBIO model at a local scale in the Beskydy PLA in order to assess the degree of habitat degradation by four key drivers with current data using the Combined layer of habitats. This is the second application of the CZ-GLOBIO model at a local scale for the Czech Republic (Stržínek, 2018). The application of the model consisted in calculating MSA values of partial drivers that result in the reduction of habitat naturalness. The individual MSA values (MSA_{LU}, MSA_{N}, MSA_{I}, MSA_{F}) were then used to calculate the resulting MSA_{TOT} index, which is an indicator of the resulting state of habitat degradation. The difference to the GLOBIO model is in principle in the calculation of MSA values.

Habitat quality is a valuable proxy indicator of biodiversity status. Land use data at the habitat level is readily available to the government (Kučera et Pojer, 2006). The results of CZ-GLOBIO modelling are a significant expert input used at guiding policy decisions on biodiversity conservation for Beskydy PLA. It is recommended to use the most current data on factor impacts, land use status and habitat occurrence in CZ-GLOBIO modelling. Habitat mapping is regularly updated locally through monitoring in relation to the obligations under the habitats directive by the Nature Conservation Agency of the Czech Republic (Lustyk et Oušková, 2006).

The usefulness of the study is closely linked to the issue of biodiversity loss and extinction of animal and plant species in the world in recent years. The study registers the fact that measured MSA values of habitat degradation are negatively related to anthropogenic activities in the territory of Beskydy PLA. This conclusion can be quantitatively drawn from the resulting MSA values of individual environmental drivers.

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STATEMENT

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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