SPATIAL DATA AVAILABILITY AND GIS MODEL USED TO ASSESS ECOLOGICAL CONNECTIVITY

Deliverable T.1.2.1

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Acronyms

GIS	Geographic Information System
CSI	Continuum suitability Index
DEGURBA	Degree of Urbanisation
EC	Ecological Connectivity
EEA	European Environmental Agency
IUCN	International Union for Conservation of Nature
GISCO	Geographic Information System of the European commission
ha	Hectares

Acknowledgements

Thanks to Christian Rossi from the Swiss National Park for the explanations regarding the whole calculation of the Continuum Suitability Index and the analysis regarding Strategic Alpine Connectivity Areas.

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1 Framework and problem statement

The rich biodiversity in the Alps and Dinaric mountains are threatened by fragmentation and habitat loss. Additionally, current political and economic circumstances in the Balkan Peninsula are leading to transboundary barriers causing challenges for humans and for the general landscape connectivity of the area.

The main intervention objective of the DinAlpConnect project is to strengthen transnational and sectoral cooperation to improve ecological connectivity (EC) throughout the Dinaric Mountains, connecting them with the Alps. It aims to enabling long term protection of biodiversity taking into account also the current climatic crisis.

A generalized approach, methodology, and investigation based on GIS technologies on the state of ecological connectivity at the Alpine/Dinaric conjunction and of the Dinaric mountains at macro-regional level is still missing. Thus, the present analysis seeks to define the general landscape permeability, to identify the physical barriers to ecological connectivity and to locate the main hotspots, including specific wildlife's core areas, corridors, least-cost paths, and stepping-stones. A more in-depth analysis of EC will be done in the project's transboundary pilot regions to contribute to the strengthen of transboundary ecological, social and economic linkages between Natura2000 and protected areas' sites on both sides of the borders.

1.1 Project area

At the macroregional level the project area covers the whole national states of Albania, Bosnia & Herzegovina, Croatia, Montenegro, and Slovenia, as well as the north-eastern part of Italy as well as the central and western mainland of Greece. The Italian regions considered are Friuli-Venezia Giulia, Trentino – Alto Adige and Veneto. The Greek regions considered are Western Macedonia, Epirus and Central Greece at NUTS 2 level, as well as Aetolia-Acarnania (NUTS 3) in Western Greece.

Austria is not involved in the project as a partner, but it would be an artificial cut off of the mountain chain, if southern Austria would not be considered, because the Karawanks mountains are linking Slovenia to the Alpine arc. Therefore, also Carinthia, Styria and Eastern Tyrol are included in the macroregional model.

Within the project area, four transnational pilot regions located between Albania and Greece; Bosnia & Herzegovina and Croatia; Croatia and Slovenia; and Italy and Slovenia are considered for detailed regional investigations.

2 Choice and objectives of the model

2.1 Objectives

One of the objectives of the DinAlpConnect project is to define a GIS model that would enable the analysis of landscape permeability at macroregional level and of ecological connectivity (EC) in and between the four transboundary pilot regions.

The model approach is two-fold:

1 – Project area-wide approach: It aims at detecting the current state of the landscape permeability within the project area (North – South corridor), identifying the main barriers currently blocking its development and secureness.

2 – Pilot Area / local approach: It utilizes closer scale geo and land use data for the mapping of selected habitats like dry grassland, and of main core areas and dispersal routes for selected wildlife species. This approach will enable the identification of the main local physical and socioeconomic barriers for ecological connectivity in each Pilot Region and at transboundary level. In order to be efficient and provide a realistic view of the ecological network, the EC analysis will consider the different local ecological, social and economic needs:

1. Current presence and distribution of selected species or habitats
2. The development of linear infrastructures and of urban sprawl
3. The current state of local economic activities and their contribution to biodiversity conservation

The GIS model will perform analyses considering different factors regarding EC following four main steps:

1. Analysis of the current habitat permeability based on specific species-related or landscape factors.
2. Identification of core areas for a selected number of species
3. Identification of current and potential core areas, wildlife corridors, least-cost paths and stepping-stones
4. Identification of current and potential environmental and anthropogenic barriers to EC. The barriers could also be of social or economic nature.

The mapping identification of wildlife core areas, corridors and barriers, will stimulate the discussion with local stakeholders for concrete site-specific measures to enhance EC in their area, promoting local development together with biodiversity protection. The obtained results will support decision makers in the implementation of the green infrastructure concept with specific actions and/or to define the most appropriate agricultural and forestry measures to promote EC in their area.

On macro-regional level, the visualizations will support the development of the Strategy for EC in the Dinarides and in its connection with the Alps. On local level, the maps will support the development of recommendations for the mitigation of important barriers for priority habitat types and species and the enhancement of ecological networks at local and transboundary level (e.g. effects of grazing or infrastructure development on EC). The model is the basis for the analysis on improved EC in transboundary regions and the elaboration of their Pilot region action plans.

2.2 Comparison of existing GIS models and their technical adaptability to the project area

There are two main approaches that could be applied for conducting an analysis of ecological connectivity on the DinAlpConnect project area.

On one hand, functional connectivity describes landscapes from the point of view of the wildlife species that need to move inside of it. The different factors associated to a landscape are related to the biological and ethological needs of the species considered, and enables the definition of the potential dispersal movements, core areas and corridors for certain species. Functional connectivity is species-based and use existing data on the known movements of exemplars to confirm the results of the model, and to delineate additionally important connectivity areas. On the other hand, the structural connectivity analysis has more a holistic approach. The GIS model detect the general permeability of habitats and landscapes, based on physical features and arrangements of habitat patches, focussing on a sort of "super species". The models are prioritising areas of low degree of human disturbance, which are assumed to be permeable for species (Hilty et al. 2020).

According to Hilty et al. 2020, existing models can be categorised taking into account the:

- Type of habitat: Marine, freshwater and terrestrial
- Scale: continental, cross-oceanic, macro – regional, regional, local
- Presence and level of human disturbance

- Objectives: identify specific wildlife's daily, seasonal and dispersal movements; identify habitats and their long-term persistence and adaptation to climate change

The two-fold GIS models in DinAlpConnect concentrate on terrestrial habitats on a macroregional scale and on specific habitats and species on a pilot regions' scale. The decision to adopt this kind of strategy came from two previous projects on EC that enabled us to identify the bes approach for DinAlpConnect's needs.

The BioRegio Carpathians project highlighted that the functional connectivity approach is best used to investigate the potential connectivity of specific species at pilot sites' and at regional scale, but it revealed its limits when applied at macroregional and project area scale. (http://www.bioregio-carpathians.eu/home_bioregio.html)

The AlpBioNet2030 project did not concentrate on specific species, but analysed the Alpine general connectivity and barriers using the structural approach of the Continuum Suitability Index (CSI). Its mapping methodology showed that the CSI is suitable for a large- scale analysis. (https://www.alpine-space.eu/projects/alpbionet2030/en/home)

The models need to show potentials of adaptation to major disturbing and connecting elements. Therefore, smaller anthropogenic disturbing elements cannot be considered. The technical adaptability will be given by both approaches, considering the different scales and elements.

2.3 Analysis on different scales

2.3.1 Alp-Dinaric wide

As a basis for the project, we refer to the state of the art from the AlpBioNet2030 project. To enhance EC between the Alps and the Dinaric Mountains, the permeability of the landscape and of important habitats will be simulated to identify the main barriers and define the general permeability of the area. To achieve this, the Continuum Suitability Index (CSI) was used. The CSI is a combined suitability analysis of the landscape permeability and structural connectivity, covering a wide range of issues, such as biological, geographical, socio-economical and landscape ecological questions (ECONNECT, n.d.).

The CSI is composed by 5 indicators, that allow the covering of all the above-mentioned issues :

- Land use/Land cover (LAN): it defines the kind of use and cover of the soil, if suitable for the EC
- Population (POP): it describes the population pressure; the higher, the lower EC suitability
- Environment (ENV): It highlights the level of environmental protection of a specific site, making it suitable for EC
- Fragmentation (FRA): it describes the rate of fragmentation of a land, which tends to inhibit EC
- Topography (TOP): it describes the roughness of the land, which may increase/decrease the EC potential.

See chapter 4.1.

2.3.2 Project pilot regions

Each one of the four project pilot regions selected a specific topic and aim for the local and transboundary analysis of EC:

Albania – Greece:

- The management of permanent grasslands and its effects on ecological connectivity

Bosnia & Herzegovina – Croatia:

- Conservation measures for Eastern sub-Mediterranean dry grasslands (*Scorzoneratalia villosae*) (i.e. removal of overgrowth), and its link to conservation measures for Karst Viper (*Vipera ursinii croatika*) (i.e. maintenance of grasslands, grazing).

- Increase the knowledge, improve the habitat management and perform the analysis of use of landscape and effects of human barriers (physical, social, economic) for specific species:
    - Brown Bear (*Ursus arctos*)
    - Meadow viper (Vipera ursinii)

Croatia – Slovenia:

- Long term conservation of dry grasslands and their contribution to ecological connectivity. The pilot site will analyze the grassland habitat loss and on how to improve ecological connectivity in the remaining patches.
- Problem of agriculture abandonment and overgrowth with forests.

Italy – Slovenia:

- Implementation of the transboundary wildlife strategy for chamois (Rupicapra rupicapra) and alpine ibex (Capra ibex)
- Management of the transboundary forests aimed to enhance ecological connectivity and biodiversity, with special emphasis on western capercaillie (Tetrao urogallos)

3 Data collection and harmonisation

3.1 Data inventory macroregional model

Administrative units:

- Eurostat/GISCO 2016 for NUTS regions in Eu- Countries on all levels.
- Eurostat/GISCO DEGURBA 2018 for municipalities in the EU countries and Albania
- Geoadata.gov.gr for municipal boundaries of Greece.
- Digital Atlas of Bosnia and Herzegovina and design by Eurac Research for administrative boundaries in Bosnia & Herzegovina
- OpenSteetMap contributors 2020 for municipal boundaries of Montenegro

Land cover:

- Corine Land Cover 2018, Version 2020_20u1 (EEA 2020 b)
- OpenStreetMap Contributors for watercourses in Albania, and Montenegro
- Faculty of Natural Science, department of Geography Sarajevo (n.d.) for watercourses in Bosnia & Herzegovina
- European Global Map from Eurogeographics 2019 for watercourses in Eu member states.
- Motorways: see road and railway infrastructure.

Population pressure:

- GEOSTAT population grid 2011 ($1km^2$)
- Eurostat/GISCO DEGURBA 2018 for population numbers of 2018 on municipal level.
- Agency for statistics Bosnia & Herzegovina and Republika Srpska Institute of Statistics for population on municipal level 2013 and 2018.
- Statistical office of Montenegro for population data on municipal level.
- Statistical Office of the Republic of Slovenia for population data 2018 on municipal level.

Protected areas:

- Protected areas for all countries with UICN categories from UNEP-WCMC and IUCN (2020)
- Bioportal Croatia for protected areas in Croatia http://www.bioportal.hr/servicest
- Slovenian Environment Agency for protected areas in Slovenia
- Slovenian Forest Service for protected forests in Slovenia
- National Geoportal of Italy for protected areas in Italy

- Agency for Nature and Environmental Protection of Montenegro for List of protected areas in Montenegro
- Slovenian Forest Service for shapefiles of Emerald Network in Montenegro
- Protected areas of Bosnia and Herzegovina from the data repository of Cener21

Road and rail infrastructure:

- European Global Map from Eurogeographics 2019
- OpenStreetMap.org & geofabric.de 2020 for roads and railways in Albania, and Montenegro
- OpenStreetMap.org & geofabric.de 2020 for railways in Bosnia & Herzegovina
- Data repository of Cener21 for roads in Bosnia & Herzegovina

Topography:

- European Digital Elevation Model (EU-DEM), version 1.1 of the EEA 2020

3.2 Spatial harmonization and data processing

Coordinate system:

All geographic data were projected to the coordinate system ETRS 89 LAEA (EPSG 3035) to have a common spatial reference. The reference system is commonly used by the Eurostat and the European Environmental Agency for the provision of European – wide datasets, e.g. for administrative boundaries, land use or protected areas. This was necessary to conduct geoprocessing operations.

Harmonisation of the cell size:

The aim is to create a dataset with cell sizes of 100x100m, based on the Corine Land Cover dataset.

- Land use: 100 x 100 m
- Topography 25 x 25 m
- Population 1x1 km
- Protected areas: 100 x 100 m
- Fragmentation: 1x1km

Harmonisation of protected areas:

Starting point was the World database of protected areas (WDPA). The spatial data were downloaded by country. They were projected to the ETRS 89 LAEA coordinate system, merged by country and clipped by the project area, to exclude protected areas outside the area of interest. This database was completed by the Natura2000 (EEA 2019) and the Nationally designated areas (CDDA) dataset (EEA 2020a) for each country. This generated the basis for the comprehensive collection of protected areas for each country.

The collection of national and regional datasets for protected areas completed the international datasets (WDPA, CDDA, Natura2000):

- For Greece, the WDPA contains exactly the same number of protected areas as the CDDA dataset (http://mapsportal.ypen.gr/maps/683/view), and Natura 2000 sites of the official NATURA 2000 dataset. In addition, UNESCO sites and Ramsar sites are present. It can be assumed, that protected sites are fully collected in the WDPA.

- For Albania, the WDPA contains all protected sites of the "Document on strategic policies for the Protection of Biodiversity in Albania" (Albanian Ministry of environment 2015).
- For Montenegro, the WDPA represented the basic dataset, but it had to be completed by national datasets. Some very small natural monuments were neglected in the data collection.
- For Bosnia & Herzegovina, the WDPA dataset had to be combined with the CDDA dataset and datasets from the repository of project partner Cener21.
- For Croatia and Slovenia, we were able to access data from national offices or Bio portals.
- For Italy, the WDPA was considered as basic dataset. It was completed by the "official list of protected areas" (EUAP) and the Ramsar sites, downloaded from the National Geoportal of Italy for protected areas.

For protected areas in Slovenia, point- data were buffered with 50meters.

Regional protection designation through regional spatial plans were not considered, because these data were not available as harmonised datasets in shapefile format in most of the countries. Also, regarding the regional protection status, mostly it is purely declarative, as the spatial plan of a region does not enforce the protection in any particular way.

Fragmentation:

For the Fragmentation Indicator (FRA), the roads and railroads of the EuroGlobalMap (Eurogeographics, 2019), OpenStreet Map, and Cener21 were used. From the Open Street map dataset, the first 4 levels of roads were selected: motorways, primary roads and trunks, secondary roads and tertiary roads, as well as the trunks of each of these categories. This corresponds to the selection of the EEA 2016 dataset on landscape fragmentation and effective mesh density by major and medium anthropogenic fragmenting elements.

A few roads between Croatia and Slovenia, between Croatia and Bosnia & Herzegovina and between Kosovo and Albania did not match at the national borders. Also, mountain roads in the area of the Dolomites were not closed. These had to be connected by hand, using the World Street Map from ArcGIS as basemap.

Population pressure:

To create a detailed dataset for the population pressure indicator, we used the GEOSTAT Population grid 2011 as basis and updated it with municipal data from the DEGURBA 2018 dataset and from statistical offices of Slovenia, Bosnia & Herzegovina and Montenegro.

The collection of population numbers from 2018 created some data harmonisation problems:

- In Montenegro, the municipality Tuzi exists since 2018 because it had separated from the municipality Podgorica and the first population data were official reported for the year 2019. Therefore, the percentual part of 2019 was recalculated to the year 2018 to gain a theoretical population number for further steps.
- In Bosnia & Herzegovina, the latest population data on municipal level are from the population census of 2013. Fortunately, population data for municipalities of the Republica Srpska, which covers nearly half of the total area of Bosnia & Herzegovina, were available for the year 2018 (Republic of Srpska Institute of Statistics, 2019).

The update of the population figures from 2011 to 2018 in the 1x1km GRID cells was carried out on the assumption that the population has a natural growth. Migration cannot be represented of course. From 2011 to 2018, only 1.65% of the grid cells had a change of more than +/- 100 inhabitants. Some strong changes in GRID cells are due to incorrect boundary lines in the DEGURBA dataset. Only 18.2 % (21.494) GRID cells of the year 2018 fall into a category higher than 2 inh./ha, which is the threshold for a lower connectivity indicator value than 10 (highest connectivity). For 2011, this would have been 21.784 GRID cells.

It can be said that with the update of the dataset from 2011 to 2018, some minor population changes were revealed and included in the analysis.

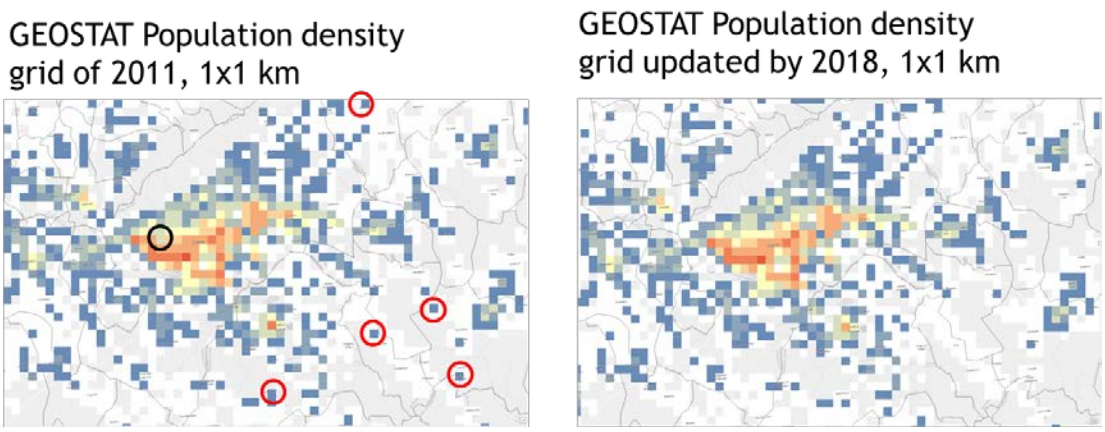


Figure 1: GEOSTAT population density grid of 2011 and updated grid of 2018

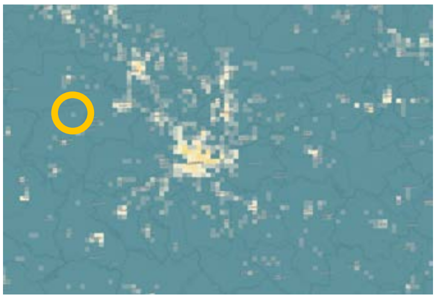


Figure 2: Population density around Ljubljana highlighting low population density cells in the surroundings

Figure 3: 1 × 1 km grid cell of low population density in the surroundings of Ljubljana

Land use and Topography:

Land use and topography data were available as already harmonised datasets, covering the whole DinAlpConnect project area. No data processing for harmonisation was required.

3.3 Data inventory pilot sites

Italy – Slovenia:

Pilot region Boundary:

- Repository of the Slovenian Forest Service for Triglav Hunting Management Area, part of the Gorenjska Hunting Management Area and Tarvisiano Hunting District.

Land cover:

- Corine Land Cover 2018, Version 2020_20u1 (EEA 2020 b)
- Slovenian Ministry of Agriculture, Forestry and Food (2021)
- ISPRA & Regione autonoma Friuli Venezia Giulia (2021)

Settlements and technical infrastructure:

- Surveying and Mapping Authority of the Republic of Slovenia, (2021a). Building cadaster Slovenia
- Regione Friuli-Venezia Giulia (2021) – Regional infrastructure for territorial and environmental data

Elevation and slope:

- European Digital Elevation Model (EU-DEM), version 1.1 of the EEA 2020

Transport infrastructure:

- Surveying and Mapping Authority of the Republic of Slovenia, (2021b). Consolidated cadastre of public infrastructure (2021) for road infrastructure and mountain footpaths in Slovenia
- Slovenia Forest Service (2021) Vector map of forest roads.
- Regione Friuli-Venezia Giulia (2021) - Regional infrastructure for territorial and environmental data

Slovenia – Croatia

Habitat map for grassland patches:

- Habitat map of Croatia (NKS 2016): Bardi A, et al. (2016)
- Aerial image: Geoportal Croatia (2021)
- Habitat map of Slovenia: Institute of the Republic of Slovenia for Nature Conservation, (2018)
- Land cover data for Slovenia: Slovenian Ministry for agriculture, forestry and food (2021)

Livestock change:

- Croatian Ministry of Agriculture (2021)
- Nikolić T. (2021) for municipal boundaries in Croatia
- Agricultural Institute of Slovenia, (2021). Central Cattle Database.

Population change:

- Eurostat/ GISCO (2021): Population numbers at municipality level for 2011 and 2020.
- Croatian Bureau of statistics (2021)
- Nikolić T. (2021). For municipal boundaries in Croatia

Change in number of farms:

- For 2010, SURS (Statistical office of Slovenia)
- For 2019, Administration of the Republic of Slovenia for Food Safety, Veterinary Medicine and Plant Protection
- Croatian Ministry of Agriculture (2021)

Water availability:

- Repository of Nautre Park Učka for ponds in nature park Učka (sent by request)
- Antonić O. et al. (2005) for ponds in municipalities of nature park Učka
- HGI-CGS (2021) for springs and water courses in municipalities of nature park Učka
- Slovenian Ministry for agriculture, forestry and food (2021)
- Institute of the Republic of Slovenia for Nature Conservation (2021). Water ponds in Primorska, revealed from the 1001 kal INTERREG IIIA Slovenia-Italy project (2000-2006). Sent on request.

Settlements and roads:

- OSM (2020) for settlements in Croatia and Slovenia
- Geofabrik (2021) for roads in Croatia
- Surveying and mapping authority of the republic of Slovenia (2021c) for roads in Slovenia

Croatia – Bosnia & Herzegovina:

Habitat map for grassland patches:

- Habitat map of Croatia (NKS 2016): Bardi A, et al. (2016)
- Aerial image: Geoportal Croatia (2021)
- Habitat map for Bosnia: Federal Ministry of Environment and Tourism of the Federation Bosnia and Herzegovina (2016)
- EEA Copernicus Land Monitoring Service, (2020). Grassland Change (GRAC) 2015-2018.
- Corine Land Cover 2018, Version 2020_20u1 (EEA 2020 b)

Livestock change:

- Croatia: Croatian Ministry of Agriculture (2021)
- Bosnia: Institute for Statistics of Federation Bosnia and Herzegovina (2021)

Change in number of farms:

- Croatia: Croatian Ministry of Agriculture (2021)
- Bosnia: Federation Bosnia and Herzegovina Ministry of agriculture, water management and forestry (2021)

Water availability:

- Croatia: European Global Map from Eurogeographics 2019, OpenStreetmap Contributrs, Corine Land Cover 2018
- Bosnia: Federal Ministry of Environment and Tourism of the Federation Bosnia and Herzegovina (2016).

Settlements:

- EEA Copernicus Land Monitoring Service, (2019a). European Settlement Map

Roads:

- Open Street Map Contributors (2021)

Albania - Greece

Habitat map for grassland patches:

- EEA Copernicus Land Monitoring Service, (2020). Grassland Change (GRAC) 2015-2018.
- Corine Land Cover 2018, Version 2020_20u1 (EEA 2020 b)

Livestock change:

- Greek Statistical Agency (2021)
- Albania:
    - Ministry of Agriculture and Rural Development of Albania (2019)
    - INSTAT (2020)

Population change:

- Eurostat/ GISCO (2021): Population numbers at municipality level for 2011 and 2020.

Water availability:

- Albania: ASIG & Biona (2015-2017). Liqenet. Lumenj.
- Greece: Geodata.gov.gr (2015a). Hydrographic network.
  Geodata.gov.gr (2015b). Lakes of Greece.
- Open Street Map contributors (2020). For water surfaces, especially ponds.

Settlements:

- EEA Copernicus Land Monitoring Service, (2019a). European Settlement Map

Roads:

- Geofabrik (2021) & Open Street Map Contributors (2021)

4 Design of the GIS model

First, the CSI algorithm needs to be calculated to then assess the situation of ecological connectivity in the project area.

4.1 Calculation of the CSI indicator

As mentioned earlier, the CSI is composed of five indicators. For each indicator, an indicator value from 0 (lowest permeability) to 10 (highest permeability) is applied according to the landscape characteristic. 0 means totally unsuitable and 100 indicates the highest suitability for the EC.

The following weights are used to calculate the CSI:

$$CSI = \frac{2 * LAN + 2 * POP + ENV + FRA + TOP}{7}$$

The result for each analysis unit (100x100 meter) lies between 0 and 10. These units are further collected into three specific Strategic Alpine Connective Areas (SACA), which define three main areas for the assessment of ecological connectivity: those where EC already works (SACA 1); those where some interventions need to be done (SACA 2); and the areas which are barriers for EC (SACA 3) (AlpBioNet2030, n.d.).

4.1.1 Indicator values for Land use/ Land cover (LAN)

For the Land use Indicator, we use the CORINE Land cover, having 100 m resolution. In the table 1 below, the land cover classes are listed with the given indicator value for EC, which was provided after experts' opinion during the ALPBIONET2030 project. The land use indicator is representing how suitable to EC the respective form of land use are, with a score between 0 (*worst*)-10 (*best*). Land use indicator values from 0 to 5 represent artificial areas with low permeability, values from 6 to 10 represent natural areas with higher permeability.

Coniferous forests:

In a meta-analysis conducted in 2010, Paillet et al. showed that species diversity in managed forests was significantly lower than in unmanaged forests. It was decided to evaluate coniferous forests with 7 instead with 6, like it was done in the AlpBioNet2030 project, because it was confirmed by forest engineers within the project consortium, that most of the forests in the respective countries are natural. This also shows a study on primary forests in Europe, which was able to map about one-fifth of the 7.3 M ha of forest estimated to be “undisturbed by man” in Europe (Sabatini et al. 2018). The map is visible in appendix 1.

High altitude forests:

In forestry research, it has been demonstrated that an increase of elevation is diminishing rates of productivity in forestry. Slight declines in productivity were recorded up to 1.800m asl in the central Alps, but above this level, it declined very rapidly. Annual height increments of Norway spruce diminished strongly under 1.700m sea level (Oswald 1969 in Worrell 1987). Based on this, it was assumed that forests more than 1.700m asl are less suitable for forestry and thus more likely to be undisturbed by man. These forests were classified with an indicator value of 8 instead of 7. Such high-altitude forests are mostly presented in the Italian and Austrian Alps, but also in the Dinaric Alps of Montenegro, and the Albanian and Greek Pindus mountains.

Water courses:

Rivers are not very well represented in land use models, but in lowlands, rivers are constituting hot spots of biodiversity. Especially in east of Croatia, areas of high biodiversity are belonging to rivers, and they can represent important corridors.

To represent these missing structures, more detailed water courses were inserted in the land use indicator, with a buffer distance of 200m each side. Watercourses crossing settlement structures were excluded from the dataset.

Motorways:

Motorways are underrepresented in the Corine Land Cover dataset, but they represent a big barrier for many wildlife species. Therefore, each motorway was buffered with a disturbance distance of 150m and was added with a land use value of “0” to the land use dataset. Tunnels, bridges and elevated motorways were excluded from this dataset.

Table 1: Indicator values for Land use/Land cover

Land Cover Class	Indicator value (0 - 10)
1.1.1. Continuous urban fabric	0
1.1.2. Discontinuous urban fabric	0
1.2.1. Industrial or commercial units	0
1.2.2. Road and rail networks and associated land	0
1.2.3. Port areas	0
1.2.4. Airports	0
1.3.1. Mineral extraction sites	2
1.3.2. Dump sites	0
1.3.3. Construction sites	0
1.4.1. Green urban areas	2
1.4.2. Sport and leisure facilities	2
2.1.1. Non-irrigated arable land	4
2.1.2. Permanently irrigated land	2
2.1.3. Rice fields	4
2.2.1. Vineyards	4
2.2.2. Fruit trees and berry plantations	2
2.2.3. Olive groves	4
2.3.1. Pastures	5
2.4.1. Annual crops associated with permanent crops	4
2.4.2. Complex cultivation patterns	2
2.4.3. Land principally occupied by agriculture, with significant areas of natural vegetation	6
2.4.4. Agro-forestry areas	5
3.1.1. Broad-leaved forest	7
3.1.2. Coniferous forest	7
3.1.3. Mixed forest	7
3.2.1. Natural grasslands	8
3.2.2. Moors and heathland	10
3.2.3. Sclerophyllous vegetation	8
3.2.4. Transitional woodland-shrub	9
3.3.1. Beaches, dunes, sands	7
3.3.2. Bare rocks	7
3.3.3. Sparsely vegetated areas	8
3.3.4. Burnt areas	8
3.3.5. Glaciers and perpetual snow	7
4.1.1. Inland marshes	10
4.1.2. Peat bogs	10
4.2.1. Salt marshes	10
4.2.2. Salines	10
4.2.3. Intertidal flats	10
5.1.1. Water courses	9
5.1.2. Water bodies	9
5.2.1. Coastal lagoons	10
5.2.2. Estuaries	10
5.2.3. Sea and ocean	10

Source: Swiss National Park 2018 a

4.1.2 Indicator values for Population (POP)

For the population data, the Population density grid of 2011 (1x1 km) was used and updated with municipal data of 2018 from the DEGURBA dataset and national statistical offices (*see spatial harmonization and data processing chapter*). As population pressure is also affecting its surroundings, a Kernel Density was applied to the population density grid of 2018 calculated on 1x1 km and redistributed on 100x100m. The search radius of the Kernel density was set to 1.500 meters. In this way, a sort of disturbance buffer to the surroundings was applied, depending on the amount of population density. To combine the buffer layer and the original density layer, the maximum value between these two layers was calculated for each raster cell.

In the table below, the classification scheme is shown, to which the population density was reclassified.

Table 2: Indicator values for population density

INHABITANTS PER HA	INDICATOR VALUE
≤ 2	10
2 - 5	9
5 - 9	8
9 - 16	7
16 - 26	6
26 - 43	5
43 - 67	4
67 - 106	3
106 - 172	2
172 - 300	1
> 300	0

Source: Swiss National Park 2018 b

4.1.3 Indicator values for Environment (ENV)

For the Environmental protection Indicator (ENV) the following data was used: World Database on Protected Areas WDPA (UNEP-WPMC, 2017), nationally designated areas (CDDA), Natura 2000 sites, National databases like Bioportal Croatia, National Geoportal of Italy, Slovenian Environment Agency and the repository of Cener21.

A classification scheme according to the legal protection status was the basis for the definition of indicator values.

Table 3: General classification scheme for Environment

LEGAL PROTECTION STATUS	INDICATOR VALUE (0 - 10)
Strict conservation status, no economic use	10
Protected areas with strictly regulated economic use	9
Protected areas with legal restraints	6 or 7
Protected areas where the management serves the sustainable development of natural ecosystems	5
Protected areas without legal restraints	5
No protection	0

Source: Swiss National Park 2018 c

According to this classification scheme, project partner experts of each country defined an indicator value for different protected areas by expert evaluation. For Italy, Austria and Slovenia, the indicator values of AlpBioNet2030 were adapted also to the DinAlpConnect model, to guarantee the best possible comparability between the two models.

In cases of overlapping of protected sites, the most restrictive one is considered for the definition of the indicator value. This was operationalised in Arc GIS, during the conversion of the polygon data to raster data by indicating the indicator values as priority field. In this way, the indicator value determines which feature should take preference over another feature that falls over a cell. The feature with the largest positive indicator value is always selected for conversion (Arc GIS software).

Table 4: Indicator values for protected areas in Italy, Austria, and Slovenia

Country	Type of protected area	IUCN category	Indicator Value
Italy	Other Protected Natural Regional Areas (Monumento naturale)	IV	7
	Regional/Provincial Nature Park Regional/Provincial Nature Park	V IV	6 7
	National Park		9
	Ramsar site		7
	Natural Marine Reserve and Natural Protected Marine Area		7
	Regional/Provincial Nature Reserve Regional/Provincial Nature Reserve	IV Ia	7 10
	State Nature Reserve State Nature Reserve	Ia IV	10 7
	Natura 2000 (Habitat & Bird) Specially Protected Areas of Mediterranean Importance (Barcelona Convention)		7 8
	World Heritage Site		6
Austria	Biosphere Park	V	5
	Landscape Protection Area (Landschaftsschutzgebiet)	V	5
	National Park	II	9
	Nature Park (Naturpark)	V	5
	Nature Reserve (Naturschutzgebiet)	IV	7
	Ramsar Site, Wetland of International Importance		5
	Site of Community Importance (Habitats Directive)		6
	Special Protection Area (Birds Directive)		6
Slovenia	Nature reserve, strict nature reserve, natural monument		10
	Triglav National Park Zone 1 and Zone 2		9
	Regional park		7
	Landscape park		7
	Triglav National Park, Zone 3		7
	Natura 2000		6
	Ecological important areas		5
	Forest reserves (category I)		10
	Forest reserves (category II)		9
	Protective forests		7

Table 5: Indicator values for protected areas in Croatia, Bosnia & Herzegovina, and Montenegro

Country	Type of protected area	IUCN category	Indicator value
Croatia	National park - Nacionalni park	II	9
	Special reserve - Posebni rezervat	IV	8
	Natural monument - Spomenik prirode	III	6
	Strict nature reserve - Strogi rezervat	Ia	10
	Park architecture Monument - Spomenik parkovne arhitekture	/	5
	Significant Landscape - Značajni krajobraz	V	6
	Regional park - Regionalni park	V	7
	Forest park - Park šuma	V	5
	Nature park - Park prirode	VI	8
	Natural Monuments - Point data	IV	6
	Important Plant Area		5
	Natura 2000 SCI area		6
	Natura 2000 SPA area		6
	Ramsar site		5
	UNESCO Geopark		5
	UNESCO Man and Biosphere site		5
	UNESCO World Heritage Site (Core Zone)		6
	UNESCO World Heritage Site (Buffer Zone)		5
Bosnia & Herzegovina	Strict Nature Reserve (SNR)	Ia	10
	Wilderness Area (WA) / Special Nature Reserve (SNR)	Ib	10
	National Park (NP)	II	9
	Nature Park	III	/
	Natural Monument or Feature (NM)	IIIb	5
	Habitat/Species Management Area (HMA/SMA)	IV	6
	Protected Landscape (PL)	Va	7
	Regional park	Vb	/
	Protected area with sustainable use of natural resources (PAWSU)	VI	5
	Ramsar site	Not protected	
Montenegro	Strict nature reserve	Ia	5
	National Park	II	7
	Natural Monument	III	7
	Nature Park (National)	V	5
	Nature Park (International)	V	5
	Landscape With Special Features	V	5
	Special Nature Reserve (International)		9

Table 6: Indicator values for protected areas in Albania and Greece

Country	Type of protected area	IUCN category	Ind. Value
Albania	National Park (Category Ii)	II	7
	National Park Lurë-Mali I Dejës		9
	National park Thethi		9
	Protected Landscape (Category V Iucn)	V	7
	Nature Monument (Category Iii Iucn)	III	5
	Nature Monument Pishe Poro		7
	Managed Nature Reserve (Category Iv Iucn)	IV	7
	World Heritage Site (natural or mixed)		5
	Ramsar Site, Wetland of International Importance		7
	Specially Protected Areas of Mediterranean Importance (Barcelona Convention)		7
	Resource Reserve (Category Vi)	VI	7
	Strict Nature Reserve (Category I)	I	10
Greece	Absolute Nature Reserve Area	Ia, II	10
	Absolute Nature Reserve Zone In National Park	Ia	10
	Aesthetic Forest	III	7
	Controlled Hunting Area	Not Assigned	5
	Core Zone In National (Woodland) Park	II	10
	Game Breeding Station	Not Assigned	5
	National (Woodland) Park - Peripheral Zone	VI	5
	National Marine Park	VI	9
	National Park	VI	9
	National Park - Peripheral Zone	VI / not assigned	5
	Natural Monuments And Landmarks (Protected As Strict Nature Reserve)	Ia, III	10
	Nature Reserve Area	IV, V, VI	9
	Nature Reserve Area - Peripheral Zone	V	5
	Nature Reserve Zone In National Marine Park	Ia, II	9
	Nature Reserve Zone In National Park	II, IV, VI	9
	Other Protected Areas	III,IV, VI	5
	Ramsar Site, Wetland of International Importance	Not Reported	9
	Site of Community Importance (Habitats Directive)	Not Reported	6
	Special Protection Area (Birds Directive)	Not Reported	6
	UNESCO-MAB Biosphere Reserve	Not Applicable	9
	Wildlife Refugee	IV	7
	World Heritage Site (natural or mixed)	Not Applicable	9

For Croatia, the IUCN categories in the following types of protected areas were updated.

National parks:	IUCN category was changed to II. The former category III refers primarily to smaller areas that are more geomorphologically and culturally oriented in protection
Special reserve:	Category Ib is related to unaltered natural areas, and the special reserve is intended for the preservation of natural values and / or endangered habitats, which is more in line with category IV. Category V refers to larger areas of cultural landscapes shaped by anthropogenic influence.
Natural monuments:	IUCN category was changed from category IV to III. Category III is more geomorphologically and culturally oriented (related to the protection of natural elements of space), while category IV is focused on biological values (protection of species or habitats).
Parks:	The IUCN categorization does not cover areas or features created solely by anthropogenic influence
Significant landscape:	Category was changed from IV to V. The focus of category VI is the protection of ecosystems and ecological processes through the sustainable use of natural resources and covers mainly areas with natural elements. On the other hand, category V includes the protection of altered landscapes, where the goal is to preserve such landscapes and their value for biodiversity (essentially this category includes less "natural" areas.
Forest parks:	The forest park is intended for rest and recreation and may include planted forests (which are anthropogenically conditioned ecosystems). Therefore, category V was selected, which mainly refers to the modified ecosystems and their maintenance in that form.
Nature Park:	In category II, the exploitation of natural resources is generally not allowed, while in category VI it is, if it is sustainable and enables the protection of existing ecosystems.

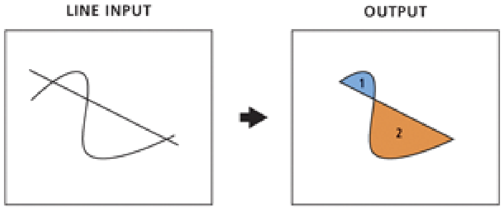
4.1.4 Indicator values for Fragmentation (FRA)

For the calculation of the effective mesh density, two input datasets were created: A dataset of fragmented patch areas (Ai) and a dataset of a 1x1 km grid.

1) Fragmented patch areas:
   The following human infrastructure were considered as fragmenting elements: Motorways, railways and roads, as well as built-up areas.
   For the selection of fragmenting railways and roads, it was assumed, that tunnels shorter than 1km have a fragmenting effect, while for motorways this value was set to 4km (Swiss National Park 2018 d). Therefore, tunnels of roads and railways with a length of more than 1km and of motorways with a length of more than 4km were eliminated. Motorways were given a higher value than other roads and railways. Therefore, a buffer of 1,5km was created on each side of the motorways and treated as built up area.
   For built- up areas, the following Corine Land Cover classes were considered, similar to the methodology of the EEA 2019:
   - 1.1. continuous urban fabric, discontinuous urban fabric
   - 1.2. industrial and commercial units, port areas and airports, (without 1.2.2 road and rail networks and associated land)
   - 1.3. mineral extraction sites, dump sites and construction sites
   - 1.4.2. sport and leisure facilities
   - 4.2.2. salines

   Coastlines were treated as fragmenting elements, but to overcome the border effect of the inland boundaries of the project area, fragmenting elements within 50km from the boundary of the bordering countries Switzerland, Austria, Hungary, Serbia, Kosovo and North Macedonia were considered.
   To design and calculate the fragmented areas (Ai), the polylines of roads and railways were merged and transformed to polygons. Then, the buffer of motorways and the built-up areas were erased from the polygons.

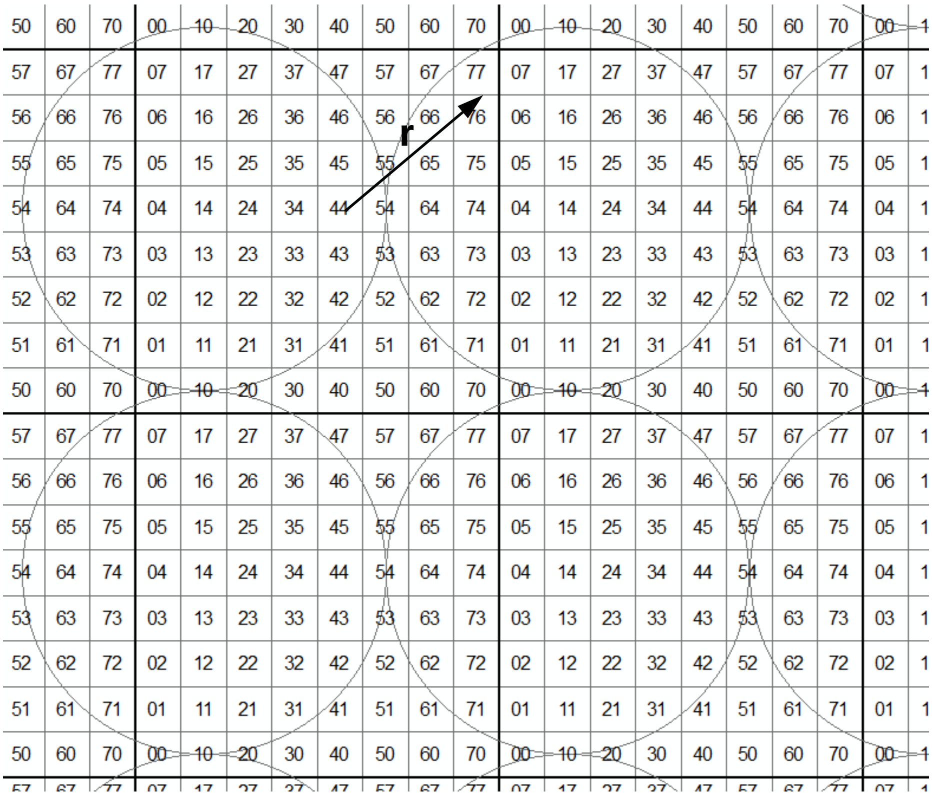
Figure 4: The Feature to Polygon function



Source: Arc GIS software, Feature in Polygon.

2) The 1x1 km grid cell was created by the "Create fishnet" function in ArcGIS. With a second grid of 8x8 km, it was possible to assign an ID to the 1x1 km grid, which identifies the position of each 1x1 km grid cell within an 8x8 km grid cell (00, 01, 02 … 07, 10, 11,12 … 77). This made it possible to calculate circles with a radius of 3,999 km for each 1x1 km grid cell that don't touch each other and iterate the calculations of the effective mesh density through the 64 positions. The following example shows the circles for grid cells no.14.

Figure 5: 1x1 km grid cells within 8x8 km grid cells with circles no. 14, r=3.999m

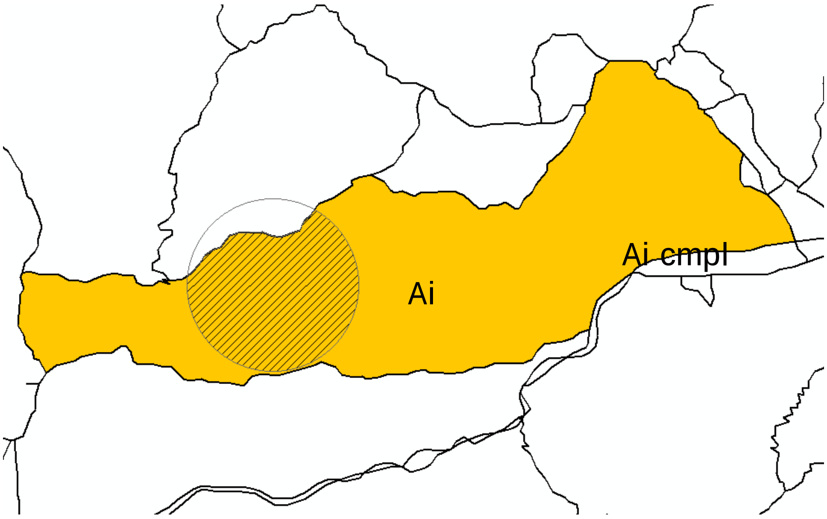


For each 1x1 km grid cell, the effective mesh size (meff) was calculated for the surrounding 50,24 km² (Swiss National Park 2018 d). This means that for each grid cell, a circle with a radius of 3,999 km was created from its centroids. Then, the fragmented areas for each circle (Ai) were created. The Ai² was calculated by the multiplication of the fragmented patch area of the circle (Ai) and complete fragmented patch area (Ai cmpl) to reduce the boundary problem (Moser et al. 2007).

Calculation of the effective mesh size:

$$m_{eff.} = \frac{1}{A_{tot.}} \sum_{i=1}^{n} {A_i}^2$$

Figure 6: Example for the calculation of Ai²



Calculation of the effective mesh size, reducing the boundary problem according to the procedure of cross- boundary connections (CBC):

$$m_{eff.}{}^{CBC} = \frac{1}{A_{tot.}} \sum_{i=1}^{n} (A_i \times A_{i\,cmpl})$$

(Moser et al. 2007)

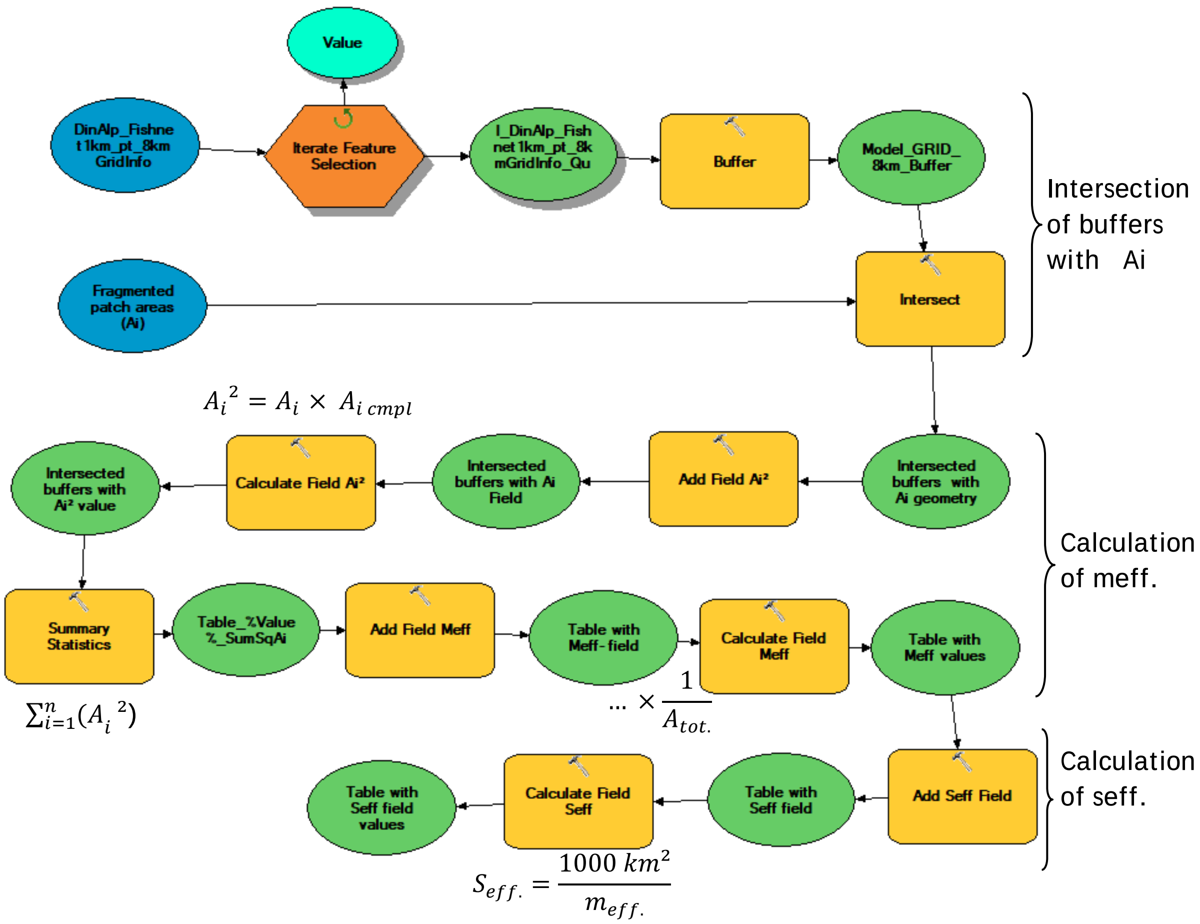
$m_{eff.}{}^{CBC}$	Effective mesh size with cross boundary connections
A_i ...	Fragmented patch area
$A_{i\,cmpl}$ ...	Complete fragmented patch area
$A_{tot.}$ ...	Total Area of the reporting unit

For the categorisation of the indicator value, the effective mesh density was used, which is directly derived from the effective mesh size.

$$S_{eff.}{}^{CBC} = \frac{1000\ km^2}{m_{eff.}}$$

The following programme developed in the Arc GIS Model Builder shows the calculation of the Effective mesh density for each 1x1 km grid cell.

Figure 7: Program for the calculation of effective mesh density (Seff)



The table below shows the classifications with the corresponding indicator values. It is aligned to the classification in the AlpBioNet 2030 project, but the thresholds for indicator values 1-7 were slightly changed, according to the geometric interval classification of the effective mesh density, considering only values between 0 and 100.

Table 7: Indicator values for Fragmentation

S_{EFF} NUMBER OF MESHES PER 1000 KM² (S_{EFF})	Indicator Value (0 - 10)
< 0,5	10
0,5 – 1	9
1 - 2	8
2 - 4	7
4 – 7	6
7 – 12	5
12 – 20	4
20 – 35	3
35 – 60	2
60 – 100	1
> 100	0

Source: Based on Swiss National Park 2018 d

4.1.5 Indicator values for Topography (TOP)

For the Topography Indicator (TOP), the European Digital Elevation Model (EU-DEM), version 1.1 of the EEA 2020 was used. The dataset has a spatial resolution of 25 m. To determine the topography value, the following formal was applied:

$$TOP = 0{,}5 * value_{altitude} + 0{,}5 * value_{slope}$$

The table below shows the Altitude and Slope classifications with the corresponding indicator values:

Table 8: Indicator values for Topography

ALTITUDE (m a.s.l.)	INDICATOR VALUE (0 - 10)		SLOPE (°)	INDICATOR VALUE (0 - 10)
- 1500	10		≤ 30°	10
1500 – 1675	9		30 – 40°	7
1675 – 1850	8		40 - 45°	5
1850 – 2025	7		> 45°	3
2025 – 2200	6			
2200 – 2375	5			
2375 – 2550	4			
2550 – 2725	3			
2725 – 2900	2			
> 2900	1			

Source: Swiss National Park 2018 e

4.2 Models for pilot sites

4.2.1 Species - based models

- Ibex
- Chamois
- Western capercaillie

The following methodology derives mainly from the BioRegio Carpathians project (Favilli et al. 2013).

Factor classes: Topography (slope and elevation), Land cover, Human presence (distance to settlements), Species' ecology (distance to roads, size of core areas). According to each species considered, each factor has a different weight inside of the model.

Calculation of pixels' values with a geometric mean:

$$\prod_{i=1}^{n}(S_i^{Wi})$$

Π = multiply n habitat factor classes (i)

S = scores of factor classes (S_i)

W = habitat factors weight (W_i)

(Favilli et al. 2013)

To assign a suitability score to each class within each factor, we use a fixed scale between 0 (no suitability) and 100 (maximum suitability), having in mind the following biological interpretation:

- 100: best habitat, highest survival, and reproductive success
- 50: sub-optimal habitat, food availability and passage
- 25: occasional use and passage
- 0: avoided/barrier

(ibid.)

Table 9: Land cover (1)

Land use (carta della natura FVG)	Ibex	Cham.	Tetrao	ID	Land use (Raba)	Ibex	Cham.	Tetrao
22.1-Fresh waters (lakes)	25	25	10	7000	Water bodies	25	25	10
24.1-River courses (waters of major rivers)	25	25	10	4220	Other water logged areas	25	25	10
				4210	Reeds	0	0	0
24.221-Sub-alpine and mountain greens with herbaceous vegetation	100	100	10					
31.42-Subalpine heaths with Rhododendron and Vaccinium	80	80	10	1500	"Belts of trees and bushes"	10	25	75
31.52-Exalpine pine forests of the Central-Eastern Alps	25	25	10	1410	Re-growth on old farmland	5	100	75
31.611-Ontanete with Alnus viridis of the Alps	80	80	20					
31.81-Middle European shrublands of rich soils	20	20	20					
34.75-Eastern sub-Mediterranean dry meadows	50	50	20					
35.11-Nardus stricta	70	70	20					
36.31-Mountain and sub-alpine scrublands and related communities	80	80	20					
36.413-Pastures with Carex austroalpina	80	80	20	1800	Grass meadows (over 80 % of area) with forest trees	80	80	75
36.433-Pastures with Carex firma	100	100	20					
36.5-Alpine and subalpine fertilised pastures	80	80	20	1300	Permanent meadow	80	80	20
38.2-Mowed and fertilised meadows	25	25	20					
41.11-Central European acidophilic beech forests	25	50	60					
41.13-Neutrophilous and mesophilous beech forests of the Alps	25	50	70					
41.15-Subalpine beech forests of the Alps	40	60	80					
41.16-Thermal calcifile beech forests of the Alps	25	50	60		Forest	According to forest stand map		
41.41-Mixed forests of ravines and escarpments	25	40	25					
41.59-Oak forests of northern Italy	25	25	25					
41.81-Ostrya carpinifolia woodlands	25	40	25					
41.9-Chestnut woods	10	25	10					

Table 10: Land cover (2)

Land use (carta della natura FVG)	Ibex	Cham.	Tetrao	ID	Land use (Raba)	Ibex	Cham.	Tetrao
42.12-Calcifile ash forests of the Alps and central-northern Apennines	40	50	80					
42.13-Acidophilous beech forests of the Alps and central-northern Apennines	40	50	80	2000	Forest	According to forest stand map		
42.1B-Native coniferous afforestation	40	50	50					
42.21-Subalpine spruce forests	60	70	100					
42.221-Mountain acidophilous scrubland: Dominant plant species: Picea abies	60	70	100					
42.222-Montane calciferous spruce forests. Dominant plant species: Picea abies	60	70	100					
42.322-Laric woods (Laricetum deciduae) as woodland formations or as subalpine heaths and woodland meadows	70	80	60					
42.611-Alpine black pine forests	70	70	40					
44.11-Pre-Alpine willow thickets. Dominant plant species: Salix eleagnos, Salix purpurea, Salix incana, Salix triandra	25	25	10					
44.13-Willow galleries. Dominant species: Salix alba	25	25	10					
54.4-Acid swamp	20	20	20	4100	Swamp	20	20	20
61.11-Alpine siliceous glaciers	90	90	10	5000	Dry areas with special vegetation cover	100	90	10
61.22-Alpine basichiaions of the alpine and nival plain	100	90	10					
61.23-Alpine basal belts of the highland and subalpine plains	100	100	10					
62.15-Basic rocks of the central-eastern Alps	100	100	10	6000	Barren land without grasses	100	80	10
62.21-Middle European mountain siliceous rocks	100	100	10					
63-Glaciers and permanently snow-covered areas	60	50	10					

Table 11: Land cover (3)

Land use (carta della natura FVG)	Ibex	Cham.	Tetrao	ID	Land use (Raba)	Ibex	Cham.	Tetrao
82.3-Extensive farming and complex farming systems	10	10	0	1240	Other agricultural plantations	10	10	0
				1180	Fields with permanent plants (nurseries, asparagus, etc.)	10	10	0
82.3-Extensive farming and complex farming systems	10	10	0	1222	Extensive orchard or meadow orchard	10	10	0
83.21-Vineyards	10	10	0	1211	Vineyard	10	10	0
				1221	Intensive orchard	10	10	0
				1100	Fields	10	10	0
				1600	Agricultural area under preparation	0	0	0
83.31-Coniferous plantations	25	25	25	1420	Forest plantation	25	25	25
83.324-Robiniums	20	20	10					
85.1-Large parks	20	20	20					
86.1-City centres	0	0	0	3000	Urban and built up areas, roads	0	0	0
86.3-Active industrial sites	0	0	0	1190	Greenhouse	0	0	0
86.41-Caves	15	15	0					

The basis for assigning values for forests in Slovenia was a forest stand map. The first input was the share of conifers in the wood stock (below 75%, 75 to 95% and above 95%), the second input was a stand crown density (dense, normal, loose and with gaps), and the third input was developmental stages / forest structure (11 groups). The values were assigned for other forestlands (Pinus mugo stands, electric transmission lines and enclosures for wild animals). These input values were multiplied and then reduced according to forest habitat types (forest associations).

Chamois (Rupicapra rupicapra)

Land cover (Weight: 45%)

Table see above

Table 12: Slope (Weight: 20%)

Classes	Scores (% suitability)
Bottom-gentle 0-30°	50
Steep 30-60°	100
Ridge top 60-90°	50

Table 13: Distance to human settlements (Weight: 10%)

Classes	Scores (% suitability)
0-100 m	0
100-500 m	50
> 500 m	100

Table 14: Elevation (Weight: 15%)

Classes (m a.s.l.)	Scores (% suitability)
0-500	20
500-1000	50
1000-1500	60
1500-2000	100
2000-2500	50
>2500	10

Table 15: Distance to roads (Weight: 5%)

Classes	Scores (% suitability)
0-50 m	10
50-200 m	25
>200 m	100

Table 16: Distance to motorways weight: 5%

Classes	Scores (% suitability)
0-200 m	0
>200 m	100

Selection of core areas:

- Habitat Suitability > 75
- Area > 500 ha
- Including smaller areas where census data confirm presence
- Including areas with distance <200m to big core areas (>500 ha)

Alpine Ibex (Capra ibex)

Land cover (Weight: 45%)

Table see above

Table 17:Slope (Weight: 20%)

Classes	Scores (% suitability)
Bottom-gentle 0-30°	50
Steep 30-60°	70
Ridge top 60-90°	100

Table 18:Distance to human settlements (Weight: 10%)

Classes	Scores (% suitability)
0-100 m	25
100-500 m	50
> 500	100

Table 19:Elevation (Weight: 15%)

Classes (m a.s.l.)	Scores (% suitability)
0-500	10
500-1000	25
1000-1500	50
1500-2000	100
2000-2500	90
>2500	80

Table 20:Distance to roads (Weight: 5%)

Classes	Scores (% suitability)
0-50 m	10
50-200 m	25
>200 m	100

Table 21:Distance to motorways weight: 5% (Ibex)

Classes	**Scores (% suitability)**
0-200 m	0
>200 m	100

Selection of core habitats:

- Habitat Suitability > 60
- Area > 500 ha (according to census data)

Western capercaillie (Tetrao urogallus)

Land cover (Weight: 40%)

Table see above

Table 22:Slope (Weight: 20%)

Classes	Scores (% suitability)
Bottom-gentle 0-30°	100
Steep 30-60°	40
Ridge top 60-90°	0

Table 23:Distance to human settlements (Weight: 10%)

Classes	Scores (% suitability)
0-100 m	10
100-500 m	25
500-1000 m	80
> 1000 m	100

Table 24:Elevation (Weight: 15%)

Classes (m a.s.l.)	Scores (% suitability)
0-500	0
500-1000	20
1000-1500	100
1500-2000	70
2000-2500	10
>2500	10

Table 25:Distance to roads (Weight: 8%)

Classes	Scores (% suitability)
0-50 m	0
50-200 m	10
200-1.000 m	50
>1.000 m	100

Table 26:Distance to motorways weight: 7% (Western capercaillie)

Classes	Scores (% suitability)
0-500 m	0
500- 1.000 m	50
> 1.000 m	100

Selection of core areas:

- Habitat Suitability > 60
- Areas > 250 ha, based on following information:
  - presence data confirm smallest area >250 ha
  - 80% of all suitable areas within patches >250ha
  - Bollmann et al. confirmed 2013 high number of occupied suitable patches >250 ha and a low number of occupied patches in smaller areas

To define a habitat suitability, the obtained pixel values are divided in four suitability classes:

- Suitability > 60 – 100% = Appropriate for an optimal habitat, core areas, highest survival and reproductive success (CORE AREAS) (in some cases, we selected 75% as threshold to avoid too many core areas to be displayed and to facilitate the calculation of the least-cost paths)
- Suitability > 50 - < 60% = Sub-optimal habitat, food availability, passage sites (low resistance areas – optimal for least-cost paths), stepping stones
- Suitability > 25 - < 50% = Occasional habitat
- Suitability > 0 - < 25% = Minor barrier
- Suitability 0 = Avoided, non-habitat (Barrier)

4.2.2 Models for grassland preservation and restoration

The models for the preservation and restoration of permanent grassland and dry grassland are developed for the three following pilot sites:

- **Slovenia – Croatia:** Kras - Učka & Ćićarija
- **Croatia – Bosnia & Herzegovina:** Lisac – Una
- **Albania – Greece:** Kolonjë, Përmet – Northern Pindus

While forests and water courses are representing the hot spots of biodiversity, human settlements and artificial infrastructure of a certain dimension may represent the most important barriers.

Grasslands are in between these two categories and represent seminatural habitats, usually in between ecological conservation areas. Because of these characteristics, grassland has a big influence on connectivity and is important for wildlife. Grasslands are extensively used human-made habitats, where biodiversity is kept under human control. Due to the crescent agriculture abandonment, grasslands grow without any control, with the subsequent shrinking of natural habitats, and ending in being a potential barrier for same species. The overgrazing of the remaining grasslands increases the land competition between livestock and wildlife species. Therefore, it is important to know the situation of grassland in each of the pilot sites and define the most appropriate interventions in agricultural activities like gazing.

The eastern Sub-Mediterranean dry grassland is a target habitat type in need of a favourable conservation status, according to Art. 6 of the Habitat directive, therefore, it needs the selection of the best actions to preserve it.

According to expert judgement, a favourable status is based on the habitat's representativity, relative surface in respect to the national territory, degree of conservation of its structure and function, as well as its restoration possibilities.

The added value provided by the use of the GIS model, is that by analysing the current structure of dry grassland habitats in the pilot regions, the structure of the population and cattle in the area, the terrain, water availability and the presence of settlements, we can identify the best grasslands' areas for preservation of the ecological connectivity in the Pilot region. This approach will enable the conservation of grassland's biological diversity and ecological connectivity in the long term.

The following steps were conducted in the single pilot sites:

1. The identification of the status of dry grassland habitat to gain a map for grassland restoration.
2. Spatial suitability analysis of grassland preservation with Multi- Criteria Evaluation (MCE)
3. Combination of status of dry grassland and suitability analysis

The analysis of the status of dry grassland habitat was conducted with slightly different methods, according to the data availability in the pilot sites:

- **In Slovenia**, the identification is based on the land use map, considering the category "Permanent grassland" for dry grassland. The category "Agricultural land, growing with forest trees" was also included in dry grassland, because these areas are grazed or mowed at least once per year. It is "An area overgrown with grass, on which individual forest trees or shrubs grow and are regularly, at least once a year, grazed or mowed. The cover of grasslands is at least 80%, and the cover of tree canopies or bushes is less than 75%." (Ministrstvo za kmetijstvo, gozdarstvo in prehrano 2013).
  "Agricultural land in overgrowth" and "trees and shrubs" were considered as "overgrowing grassland".
- **In Croatia**, the grassland analysis started from the habitat map of 2016, filtering grassland categories.
  The Map of non-forest terrestrial habitats of Republic of Croatia (Bardi et al. 2016) was used, from which all polygons in the Pilot region with dominantly grassland habitats were selected. These are mainly polygons that have a code starting with the letter 'C' in column NKS1. Then the selection continued for areas, which are dominated by dry grassland habitats that form Natura 2000 habitat Eastern sub-mediteranean dry grasslands (Scorzoneratalia villosae). These are polygons that have codes C352 and C353 in the column NKS1. Permanent infrastructure elements like roads, railroads, settlements, as well as permanent agricultural areas were removed from the grassland areas, using a digital ortho-photo form 2018 (DGU 2021). Patches that had a size less than 0,4ha were also removed from the grassland – dataset.
  Based on this selection, the habitat map was actualised by the aerial image of 2021. This was done by overlapping the two datasets and interpreting the aerial image by hand. Using this method, it was possible to identify

"grasslands", "grassland in transition" and already overgrown grassland, which was defined as "Woodland" and excluded from the further analysis:

- Grasslands (1) – no or a small amount of woody vegetation is visible in the polygon which is dominated by grasses (open habitats);
- Transition (2) – polygons that are in between classes (1) and (3) are classified as transition polygons. It is a very broad category that covers areas with a variable degree of openness in respect to the woody vegetation);
- Woodland (3) – a dense cover of woody vegetation is present in the polygon or the polygon is dominated by trees with a sparse understory (closed habitats).

The analysis was finalised by a field work, confirming the three classes.

- **In the pilot regions Albania - Greece and Croatia - Bosnia & Herzegovina,** the model was based on Corine Land Cover Status Maps from the years 2000 and 2018.
  Firstly, the Corine Land cover classifications were redefined by two different grassland classification and one forest classification.

Classification 1: Grassland

231, Pastures
321, Natural grasslands
322, Moors and heathland
333 Sparsely vegetated areas (presence of herbaceous vegetation)
211 Non-irrigated arable land (Presence of areas with sown grass for silage or hay production)
242 Complex cultivation patterns (Presence of parcels of permanent grassland like pastures, meadows)
243 Land principally occupied by agriculture, with significant areas of natural vegetation (presence of parcels of pasture)
244 Agro– Forestry areas (this classification is not present in the pilot region)

Classification 2: Overgrowing grassland categories

323, Sclerophyllous vegetation
324, Transitional woodland-shrub

Classification 3: Forest categories

311, Broad leaved forests
312, Coniferous forests
313, Mixed forests

In a second step, the changes of the three defined categories were analysed.

Definition **of grassland changes:**

1) Unchanged Grassland = Grassland (1) in 2000 and Grassland (1) in 2018
2) Overgrowing grassland = Grassland (1) in 2000 and overgrowing grassland (2) in 2018
3) Overgrown grassland with forests= Grassland (1) in 2000 and forests (3) in 2018
4) Areas in phase of overgrazing = overgrowing grassland (2) in 2000 and Grassland in 2018 (1)
5) Strong overgrazing = forests (3) in 2000 and Grassland (1) in 2018
6) Possible overgrazed areas = Grassland (1) in 2000 and Bare rocks (CLC 332) in 2018

The spatial suitability analysis for grassland preservation with Multi- Criteria Evaluation (MCE) was conducted by the following method:

1. Selection of indicators and criteria (distance [km], number of livestock [n], change of population [%] etc.)
2. Standardization of criteria (0-100)
3. Definition of weights for each criterion (rating)
4. Application of an algorithm: geometric mean and overlay – function

$$\prod_{i=1}^{n} (S_i^{W_i})$$

The selection of the criteria was based on the following indicators:

- Relevance for Ecological connectivity:
  - Size of grassland patches as an indicator for habitat suitability
- Socioeconomic factors/ drivers:
  - Livestock change
  - population change or change in number of farms
- Suitability for farming:
  - Water availability by distances to water sources like rivers, springs and ponds
  - Distances to settlements as an approximation to distance to farms
  - Accessibility: distances to roads

Table 27: Selected criteria and measurement units for the grassland models

Criteria	Measurement unit
Size of grassland patches	Hectares [ha]
Livestock change	+/- numbers of livestock
Population change	+/- % of population numbers
Change in numbers of farms	+/- % of farms
Distance to water courses, ponds, springs	[m]
Distance to settlements	[m]
Distance to roads	[m]

The standardization of criteria was conducted by an expert evaluation and referring to literature.

Size of grassland patches:
To harmonize the datasets for grassland patches, patches which were divided by a road smaller than 14m were dissolved by a buffer with 7m.

Table 28: Standardization of size of grassland patches

Size [ha]	Score
< 1 ha	10
1 - 2 ha	25
2 - 5 ha	50
5 - 10 ha	80
> 10 ha	100

Livestock change from 2010/2011 to 2019/2020:
The standardisation followed the classification of 5 categories of livestock change according to the natural breaks method.
A strong decrease of livestock means that agriculture cannot be maintained and therefore it was ranked with a low suitability for restoration. A certain number of livestock is supporting the dispersal of seeds and good for maintaining grassland habitats, while a high increase of livestock could indicate a high density of livestock, which competes wildlife (Nyhus 2016) and the areas tend to be overgrazed.
To consider cattle and small ruminants in one indicator, the numbers were transferred to Livestock Equivalent Units, where data of multiple livestock species were available. A factor of 1:5 was considered, which means that 1 cattle head needs 1 ha of pastures and the same is necessary for 5 sheep and goats.
For each pilot site, an individual classification was made.

Table 29: Example of the pilot site Kras – Ucka (SI-HR) for the standardization of livestock change

Change in number of animals [n]	Score
-342 - -90	10
-89 - 0	25
0- 90	50
91 - 180	100
181 - 614	75

Change in numbers of farms from 2010/2011 to 2019:
If data for the change in numbers of farms were not available, the indicator was replaced by population change from 2011 to 2020. The standardisation followed the classification of 5 categories of population change. Negative population change

was classified with a standardized score of 0-50, positive population change with scores 50- 100. For each pilot site, an individual classification was made.

Table 30: Example of the pilot site Kras – Ucka (SI-HR) for the standardization of change of farms

Change in number of farms [%]	Score
-79- -60 %	25
-59 - -45 %	35
-44 – 0 %	50
1 - 150 %	85
> 150 %	100

Distances to water courses, springs, ponds:

The effect of the airline distance from water on utilization by cattle was analysed by Patton (1971). He stated, that with the increase of air-line distance from water, the utilization of forage by cattke decreases. The maximum airline distance from water that cattle were found on a mountainous study area was around 1.000 to 1.200 m.

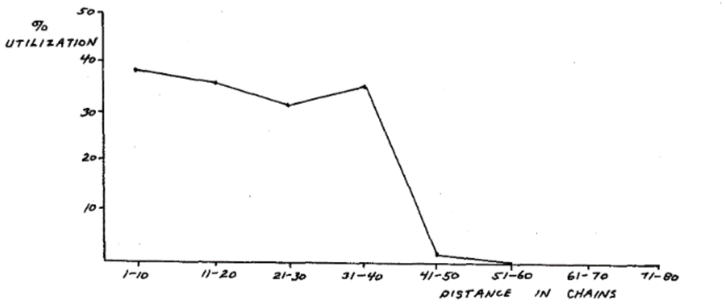


Fig. 9. The effect of distance from water to site on utilization.

Figure 8: the effect of distance from water to site on utilization

Source: (Patton 1991)

Table 31: Classification of distance to water

Distance to water [m]	Score
0 - 800	100
801 – 1.200	Fuzzy logic – linear decrease
1.201 – 2.000	20
> 2.000	5

Distances to settlements:

The proximity to settlements was considered as an approximation of distance to farms. It was ranked by assuming that within 1 km the risk of overgrazing is high. Distances between 1 and 2 km were assumed to have a high probability for the persistence of grassland over a long period. For higher distances, it was assumed, that grasslands are endangered of overgrowing by forests. Therefore, distances of more than 2 km gets lower scores.

Table 32: Classification of distance to settlements

Distance to settlements [m]	Score
0- 1.000	50 – 100 Fuzzy logic – linear decrease
1.000 – 2000	100
2.000 – 3.000	Fuzzy logic – linear decrease
3.000	10

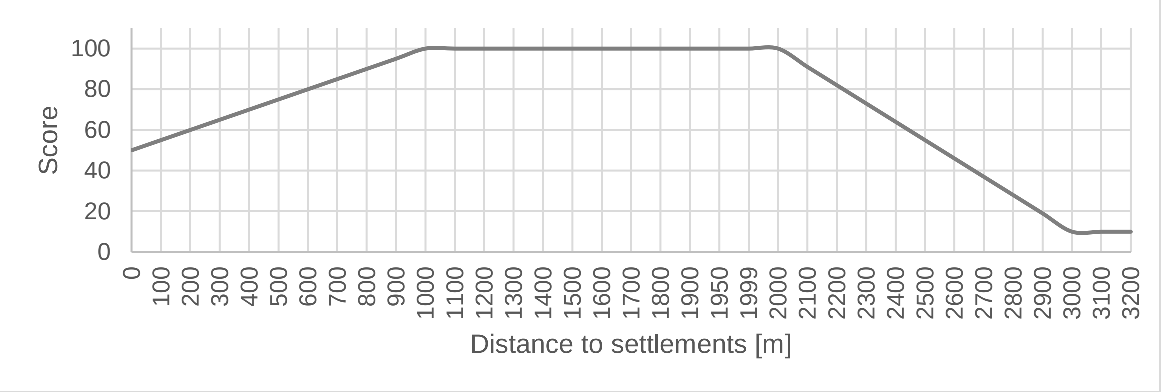


Figure 9: classification of distance to settlements

Distance to roads:

For roads, all roads were selected, from the datasets, which contribute to the accessibility of grassland. Motorways, trunk roads, express ways and tunnels were excluded from the dataset.

Table 33: Classification of distance to roads

Distance to roads [m]	Score
0 - 200	100
200 – 1.000	Fuzzy logic - linear decrease
> 1.000	10

Definition of weights:
The weights were defined by an evaluation of the importance of the indicators.

Table 34: Weights of indicators for grassland preservation

Criteria	Weighting	Expert evaluation
Size of grassland patches	33 %	The most important factor for connectivity are continuous grassland patches.
Livestock change	25 %	If grassland should be preserved, agriculture has to be maintained.
Change in numbers of farms Or population change	11 %	
Distance to water	15 %	Water availability is less important, because water can be provided through infrastructural investments.
Distance to settlements	8 %	These factors are less important, because the road network is dense and livestock can migrate.
Distance to roads	8 %	

The final step is the combination of the status of dry grassland and the suitability analysis. Grassland in phase of overgrowing was filtered from the grassland maps and the suitability for its preservation was visualized on these areas. The result shows grassland patches with a high priority to be restored for the preservation of grassland and its contribution to ecological connectivity.

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6 Appendix

Appendix 1: Primary forests in Europe

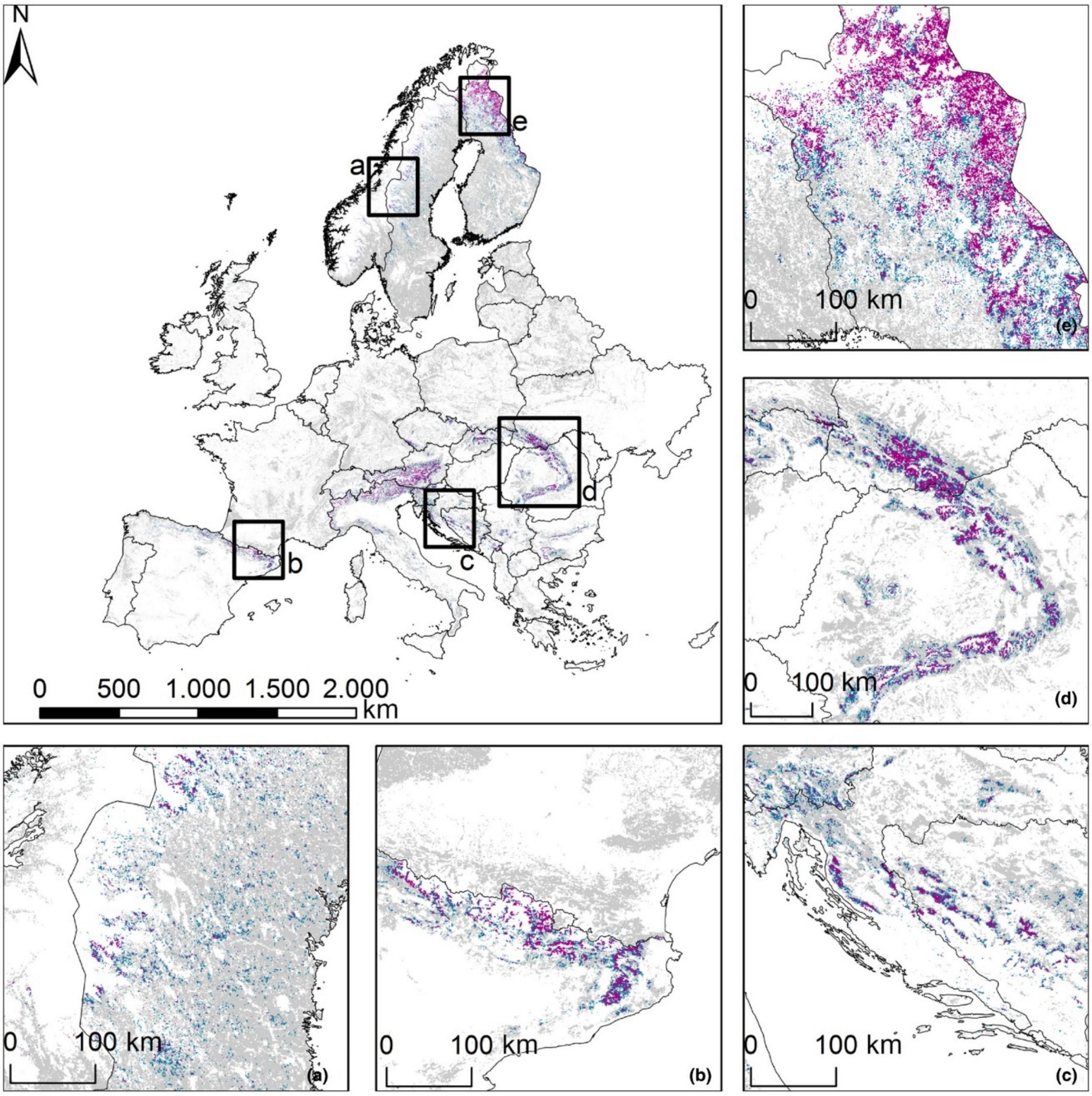

Figure 10: Areas with the highest likelihood of occurrence of primary forest in Europe at a 1 × 1 km resolution.