Programme co-funded by the European Union

REGIONAL GUIDING PRINCIPLE

PILOT REGION 1:

BAVARIAN FOREST-MÜHLVIERTEL-ŠUMAVA (DE/AT/CZ)

Deliverable D 4.3.1, 4.2.4

WP4 Pilot Actions

Activity 4.3 Development of regional ecological network and wetland restoration concepts

Introduction

For the development of the regional guiding principles for pilot region 1, this summary provides basic information on the status of biodiversity and nature conservation in an international context in chapter 1. The second part reveals the national background of the pilot area for Czech republic, Austria and Germany. The third part of consists of the methodology and the results of the connectivity (MSPA and Euclidean Distance) and functionality analysis (ecosystem services) based on the Broader Habitat Types (BHT) resulting from of the Sentinel-2 classification of the project region. Furthermore, the findings are discussed and conclusions for the implementation of ecological corridors in this part of the Green Belt are drawn. In Annex I examples for possible corridors to improve the connectivity are visualized.

Index

1. Background

1.1 International

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services published a comprehensive assessment of the status of biodiversity and ecosystem services in 2019. According to this document worldwide around 25% of species assessed are threatened, meaning about 1 million species face extinction. Land-use change is still the main driver for loss of biodiversity for terrestrial and freshwater ecosystems; however, the role of climate change is increasing. Climate change leads to changes in species distribution, phenology, population dynamics and ecosystem function (IPBES 2019).

The European Environment Agency underlines in its report of the state of the environment 2020 that worsening trends have not improved since 2015. Conserving European biodiversity and nature remains discouraging. Of the 13 specific policy objectives set for 2020 for biodiversity, only two are likely meet: designating marine and terrestrial protected areas. Looking ahead to 2030, if current trends continue, they will result in further deterioration of nature and continued pollution of air, water and soil (SOER 2020).

1.2 Czech Republic

Large parts of Pilot Region 1 in Czechia are covered by the National Park and Protected Landscape Area Šumava. There are smaller protected areas in so called gaps between Šumava and Novohradské hory – natural reserves. Natura 2000 covers some of these reserves and also Šumava, Novohradské hory.

Šumava

Protection status - category “National Park” according to the Nature and Landscape Protection Act No. 114/92 Coll. There exist a zonation of the NP which sets the protection conditions:

Zone I - strict natural, includes the most valuable and stable areas with natural ecosystems - primeval forest remnants, wetlands and bogs. The territory of zone I is left to natural development without human influence.

Zone II - controlled natural, includes the remaining majority of forest and other ecosystems with varying degrees of composition and condition of stands from the original, altered to heavily damaged and genetically inappropriate. The aim of all activities is to maintain the natural balance and gradually bring the existing ecosystems closer to natural communities.

Zone III - peripheral, includes areas significantly modified by man and concentrated buildings. The aim is to maintain and promote the use of this zone for permanent housing, services, agriculture, tourism and recreation, unless this is contrary to the mission of the national park.

Significant international protection:

- the status of the “Biosphere Reserve”. Since 1990, the Bohemian Forest has been included in the UNESCO list,

- Šumava peat bogs” as the most typical phenomenon of the Šumava nature protection since 1990 included in the list of the so-called Ramsar Convention on the Protection of Wetlands of International Importance.

- "Šumava" included in the "Red Book of Ecosystems" by the International Union for Conservation of Nature (IUCN)

NP according to international criteria IUCN (category II - national parks), NP Bavarian Forest since 1970, NP Šumava since 1991

UNESCO Biosphere Reserve, Bavarian Forest BR since 1981, Šumava BR since 1990

“Gaps”

The nature reserve is defined in Act No. 114/1992 Coll., on nature and landscape protection, as a smaller area of concentrated natural values with the representation of ecosystems typical and significant for the relevant geographical area. Natural monument is defined as a natural formation of smaller size, especially geological or geomorphological formation, a site of rare minerals or endangered species in fragments of ecosystems with regional ecological, scientific or aesthetic significance, even one which, in addition to nature, has been shaped by human activity.

Natura 2000 is a network of protected areas that all the European Union countries create on their territory according to uniform principles. The creation of the Natura 2000 network is imposed by the two most important EU nature conservation legislation: Council Directive 2009/147 / EC, on the conservation of wild birds (replaces Council Directive 79/409 / EEC), Council Directive 92/43 / EEC on the conservation of natural habitats and of wild fauna and flora.

The aim of Natura 2000 is to ensure the protection of animals, plants and habitat types that are most valuable, endangered, scarce or limited to a certain area from a European perspective.

The Natura 2000 network consists of two types of protected areas – Special Protected Areas and Sites of Community Importance (SCI).

There occur 3 SPAs in the Pilot Region 1: Šumava, Boletice, Novohradské hory.

1.3 Austria

In Austria, the nine federal states are responsible for nature and landscape protection. The regulations in the nature conservations laws determine the nature protection (designation of protected areas) and species (animal and plant protection). In some federal states, selected habitats, such as bogs or glaciers, are generally protected. Several protected area categories have been defined. Objectives and regulations of these categories may differ between the individual federal

states. Furthermore, some of the categories of protected areas are effective in all nine states, others only in a few states.

Protected areas and sites according to national categories in pilotregion 1

The category „Nature Reserve“ (Naturschutzgebiet) is one of the most important categories of nature respectively land protection in Austria. These are largely natural or near-natural areas that are characterized by the existence of high value habitats and / or the occurrence of rare or endangered animal and plant species.

The category „Landscape Protection Area“ (Landschaftsschutzgebiet) is the most widespread in Austria. These are areas with a high aesthetic or recreational value of the landscape. The primary protection purpose is the preservation of the landscape scenery for general public and tourism.

In contrast to the usually large-scale landscape protection areas, a „Protected Landscape Section“ (Geschützter Landschaftsteil) is a small-scale landscape section with a protection purpose based upon scientific reasons or to preserve the rarity, peculiarity or beauty of these sceneries.

There are two Protected Landscape Sections, 3 Landscape Protection Areas and 14 Nature reserves located in the the Austrian part of the pilot region 1.

Table 1: protected areas by Austrian national categories in the pilot region 1 Bayerischer Wald-Mühlviertel- Šumava (based upon CDDA 2019; EEA 2020)

Country	site name	designation type german	designation type english	Foundation Date
AT	Unterriedl	Geschützter Landschaftsteil	Protected Landscape Section	1984
AT	Welset Pühret	Geschützter Landschaftsteil	Protected Landscape Section	1987
AT	Kulturterrassen in Ödenkirchen	Landschaftsschutzgebiet	Landscape Protection Area	2002
AT	Roadlberg	Landschaftsschutzgebiet	Landscape Protection Area	1997
AT	Tal der Kleinen Gusen	Landschaftsschutzgebiet	Landscape Protection Area	2000
AT	Hangwälder im Tal der Großen Mühl	Naturschutzgebiet	Nature Reserve	1996
AT	Kammerschlager Flachmoorwiese	Naturschutzgebiet	Nature Reserve	1994
AT	Magerwiese Fuchsgraben	Naturschutzgebiet	Nature Reserve	2010
AT	Moor bei Vorderweißenbach	Naturschutzgebiet	Nature Reserve	2005
AT	Orchideenwiese in Freundorf	Naturschutzgebiet	Nature Reserve	1994
AT	Pesenbachtal	Naturschutzgebiet	Nature Reserve	1963
AT	Predigtstuhl	Naturschutzgebiet	Nature Reserve	2001
AT	Rannatal	Naturschutzgebiet	Nature Reserve	2002
AT	Schlossberg Neuhaus	Naturschutzgebiet	Nature Reserve	2004
AT	Stadlau	Naturschutzgebiet	Nature Reserve	2003
AT	Stadler-Wiese	Naturschutzgebiet	Nature Reserve	1997
AT	Tal der Kleinen Gusen	Naturschutzgebiet	Nature Reserve	2000
AT	Tal des Kleinen Kößlbaches	Naturschutzgebiet	Nature Reserve	1996
AT	Torfau	Naturschutzgebiet	Nature Reserve	2006

A „Natural Monument“ (Naturdenkmal) is a protected natural structure that should be preserved in the public interest based upon its scientific, historical or cultural significance or because of its peculiarity, beauty, rarity or its special character for the landscape. This can be for example individual trees or groups of trees, springs, avenues, parks, caves, rock formations or gorges.

In the Austrian part of the region 1, 68 Natural Monuments are documented, mainly old individual trees of e.g. *Taxus baccata*, *Tilia ssp.* or *Acer pseudoplatanaus* and some old alleys.

Protected areas and sites according to international directives in pilotregion 1

The Habitats Directive ensures the conservation of a wide range of rare, threatened or endemic animal and plant species. Adopted in 1992, the Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora aims to promote the maintenance of biodiversity, taking account of economic, social, cultural and regional requirements. It forms the cornerstone of Europe's nature conservation policy with the Birds Directive and establishes the EU wide Natura 2000 ecological network of protected areas, safeguarded against potentially damaging developments. According to the Birds and Habitat Directives, three site types of Natura 2000 protected areas can be differentiated whether the site is a Site under the Birds Directive (type A) or under the Habitat Directive (type B) or under both regulations (type C). In case that a protected area under Habitat and Birds Directive overlap, but are not identical, the sites are treated as separate.

In the Austria, 11 Natura 2000 sites are completly or partially located in the pilot region 1. Though, protected areas Oberes Donautal (site type A) and Oberes Donau- und Aschachtal (site type B) overlap at a large extend.

Table 2: protected areas according Habitat and Bird Directive in the pilot region 1 Bayerischer Wald-Mühlviertel- Šumava (status end 2019); site type A – Birds Directive; site type B- Habitat Directive; site type C - Birds and Habitat Directive

EU CODE	Name	ha	TYP
AT3112000	Oberes Donautal	924	A
AT3124000	Wiesengebiete im Freiwald	2404	A
AT3108000	Tal der Kleinen Gusen	347	B
AT3120000	Waldaist und Naarn	3835	B
AT3121000	Böhmerwald und Mühltäler	9348	B
AT3122000	Oberes Donau- und Aschachtal	7118	B
AT3125000	Rannatal	225	B
AT3127000	Eferdinger Becken	1342	B
AT3129000	Wiesengebiete im Mühlviertel	574	B
AT3149000	Amesschlag	28	B
AT3115000	Maltsch	353	C

Protected species and habitats in these Natura 2000 sites are listed in the following section.

AT3112000

- Species: *Alcedo atthis, Bonasa bonasia, Bubo bubo, Ciconia nigra, Dryocopus martius, Falco peregrinus, Haliaeetus albicilla, Lanius collurio, Pernis apivorus, Picus canus*

AT3124000

- Species: *Anthus pratensis, Coturnix coturnix, Crex crex, Gallinago gallinago, Lanius collurio, Locustella naevia, Lullula arborea, Miliaria calandra, Saxicola rubetra, Sylvia nisoria, Tetrao tetrix tetrix*

AT3108000

- Habitats: 6430, 6510, 6520, 9110, 9170, 91E0
- Species: *Barbastella barbastellus, Bombina variegata, Euplagia quadripunctaria, Lampetra planeri, Lucanus cervus, Lutra lutra, Maculinea nausithous, Ophiogomphus cecilia, Phengaris teleius*

AT3120000

- Habitats: 3130, 3150, 3260, 6230, 6510, 6520, 7110, 7120, 7140, 8230, 9110, 9130, 9170, 9180, 91D0, 91E0, 9410
- Speces: *Bombina variegata, Cottus gobio, Euplagia quadripunctaria, Lutra lutra, Maculinea nausithous, Margaritifera margaritifera, Myotis bechsteinii, Myotis myotis, Ophiogomphus cecilia, Phengaris teleius, Triturus cristatus*

AT3121000

- Habitats: 3130, 3150, 3260, 4070, 6230, 6410, 6430, 6510, 6520, 7110, 7120, 7140, 8150, 8220, 9110, 9130, 9140, 9180, 91D0, 91E0, 9410
- Species: *Austropotamobius torrentium, Barbastella barbastellus, Bombina variegata, Canis lupus, Carabus menetriesi pacholei, Castor fiber, Cottus gobio, Gentianella bohemica, Lampetra planeri, Lutra lutra, Lynx lynx, Margaritifera margaritifera, Myotis bechsteinii, Myotis myotis, Ophiogomphus cecilia*

AT3122000

- Habitats: 3150, 3260, 6430, 6510, 8150, 8220, 8230, 9110, 9130, 9170, 9180, 91E0, 9410
- Species: *Aspius aspius, Barbastella barbastellus, Barbus meridionalis, Bombina variegata, Carabus (variolosus) nodulosus, Castor fiber, Cottus gobio, Euplagia quadripunctaria, Gymnocephalus baloni, Gymnocephalus schraetzer, Hucho hucho, Lucanus cervus, Lutra lutra, Lynx lynx, Maculinea nausithous, Myotis emarginatus, Myotis myotis, Pelecus cultratus, Phengaris teleius, Romanogobio vladykovi, Rutilus meidingeri, Rutilus virgo, Triturus cristatus, Zingel streber, Zingel zinge*l

AT3125000

- Habitats: 8150, 8220, 9110, 9130, 9170, 9180, 91E0
- Species: *Barbastella barbastellus, Bombina variegata, Cottus gobio, Euplagia quadripunctaria, Lutra lutra, Myotis myotis*

AT3127000

- Habitats: 3150, 6210, 6510, 91E0, 91F0
- Species: *Aspius aspius, Barbastella barbastellus, Castor fiber, Cottus gobio, Cucujus cinnaberinus, Eudontomyzon mariae, Gymnocephalus baloni, Gymnocephalus schraetzer, Lutra lutra, Misgurnus fossilis, Myotis emarginatus, Osmoderma eremita, Rhodeus amarus, Romanogobio uranoscopus, Romanogobio vladykovi, Rutilus meidingeri, Rutilus virgo, Sabanejewia balcanica, Triturus cristatus, Unio crassus, Zingel streber, Zingel zingel*

AT3129000

- Habitats: 3150, 3260, 6230, 6510, 6520, 7120, 7140, 9110, 91D0
- Species: *Gentianella bohemica*

AT3149000

- Habitats: 3260, 6230, 6520

AT3115000

- Habiatats: 3150, 3260, 6230, 6430, 6510, 6520, 7140, 9110, 9130, 9180, 91E0, 9410
- Species: *Aegolius funereus, Alcedo atthis, Anas crecca, Anthus pratensis, Bombina variegata, Bonasa bonasia, Bubo bubo, Ciconia ciconia, Ciconia nigra, Circus aeruginosus, Circus cyaneus, Columba oenas, Cottus gobio, Crex crex, Dryocopus martius, Emberiza schoeniclus, Falco subbuteo, Gallinago gallinago, Glaucidium passerinum, Lampetra planeri, Lanius collurio, Lanius excubitor, Locustella fluviatilis, Locustella naevia, Lutra lutra, Lynx lynx, Margaritifera margaritifera, Milvus milvus, Ophiogomphus cecilia, Pernis apivorus, Picus canus, Saxicola rubetra, Scolopax rusticola, Streptopelia turtur, Sylvia communis, Tetrao tetrix tetrix, Tringa glareola, Tringa ochropus*

1.4 Germany

The National Park “Bayerischer Wald” is the core of protected areas in the German part of Pilot Region 1. It forms a larger area of highly protected land. The rest of the German part of Pilot Region 1 consists of narrow and smaller areas, protected under Natura 2000. They mainly serve as biodiversity hotspots within the Pilot Region. These already existing Natura 2000 hot spots can serve as a first basic matrix to strengthen the connection of protected areas towards Czechia and Austria and towards protected areas farther from the border in Germany.

The existing Natura 2000 areas within the German part of Pilot Region 1 cover landscapes from mountain forests, peatbogs, rivers and open landscapes. This results also in a high diversity of protected land and endangered species, which are present.

The Natura 2000 sites on the German side of Pilot Region 1 are listed in the following section together with the respective Habitat Types and species.

- **Hochwald und Urwald am Dreisessel** (7248-302)
  - Habitat Types: 9410, 8220, 9110, 4070
  - Species: *Lynx lynx*

- **Bischofsreuter Waldhufen** (7148-301)
  - Habitat Types: 7120, 7140, 7150, 7110, 6520, 6230, 6410, 6430, 91D0, 9410, 9110, 4030, 3260
  - Species: *Lynx lynx, Lutra lutra, Maculinea nausithous, Maculinea teleius*

- **Borstgrasrasen und Bergwiesen Obergrainet-Gschwendet** (7248-371)
  - Habitat Types: 7140, 6520, 6230, 6410, 6430, 6510
  - Species: No Appendix Species listed

- **Ilz-Talsystem** (72486-371)
  - Habitat Types: 6520, 6230, 6410, 6430, 6510, 9180, 91D0, 9170, 8220, 8310, 9110, 9130, 5130, 6110, 3260,
  - Species: *Barbastella barbastellus, Lutra lutra, Lynx lynx, Myotis bechsteinii, Myotis myotis, Bombina variegata, Triturus ´cristatus, Glaucopsyche nausithous, Glaucopsyche teleius, Margaritifera margaritifera, Unio crassus*

- **Nationalpark Bayerischer Wald** (6946-301)
  - Habitat Types: 7120, 7140, 7230, 7110, 8110, 6520, 6230, 6410, 6430, 91D0, 9180, 8220, 9140, 9110, 9130, 4030, 4070, 3260, 3160
  - Species: *Barbastella barbastellus, Lutra lutra, Lynx lynx, Myotis bechsteinii, Myotis myotis, Leucorrhinia pectoralis, Maculinea nausithous, Dicranum viride*

- **Moore bei Finsterau und Philippsreuth** (7148-302)
  - Habitat Types: 7120, 7150, 7110, 6520, 6230, 6430, 91D0, 9410
  - Species: *Lutra lutra*

2. Description of Methodologies

Two approaches were applied for conducting the connectivity and functionality analyses. On the one hand, a software for digital image analysis was used to assess the connectivity of the broader habitat types of interest (broad-leaved and coniferous forests & dry and mesic grassland). On the other hand, the potential of all BHT for a wide range of ecosystem services was defined by expert-based evaluation.

2.1 Connectivity Analysis

In digital image analysis concepts of mathematical morphology are widely used (Soille, 2013) and form the foundation of GuidosToolbox (Graphical User Interface for the Description of image Objects and their Shapes). GuidosToolbox (Vogt & Riitters, 2017) is a free software collection by Peter Vogt (Joint Research Centre, European Commission) and offers a variety of modules targeted to investigate several spatial aspects of raster image objects, for example pattern, connectivity, cost, fragmentation, etc.

2.1.1 Morphological Spatial Pattern Analysis (MSPA)

The MSPA (Morphological Spatial Pattern Analysis) is a generic and universal pattern analysis framework provided by a custom sequence of morphological operators (Soille & Vogt, 2008).

MSPA performs a segmentation on a binary image to identify and localise mutually exclusive morphometric feature classes describing the shape, connectivity and spatial arrangement of image objects by mapping and classifying them into categories (Vogt et al., 2017). The MSPA module automatically detects geometry and connectivity of the image components. Therefore, the foreground area of a raster based binary image is partitioned into seven MSPA classes: Core, Islet, Perforation, Edge, Loop, Bridge and Branch.

In terms of the assessment of the connectivity of BHT of interest, MSPA uses a series of image processing routines to identify hubs, links (corridors), and other features after reclassifying the raster land-cover map into foreground (forests or grassland) and background (all other classes) (Vogt et al., 2007).

The category of core is equivalent to hub, and bridge is synonymous to link (corridor). First the MSPA processing identifies the category core, which is based on the connectivity rule used to define neighbours and the value used to define edge width (Soille and Vogt, 2008).

In the basic settings of MSPA connectivity can be set to either four (cardinal directions only) or eight neighbours. The minimum size of core and the number of pixels classified as core is affected by the settings of the edge width. By increasing the edge width, the minimum size of core increases and thereby reduces the number of pixels defined as core areas. The decrease of core areas that results from increasing edge width arise in gains for all other classes, not just edge. This way increasing the edge width can shift core to islet if the area of core is small and core to bridge if the area of core is narrow. (Wickham et. al. 2010)

In the application of MSPA in DaRe to Connect we used eight-neighbour connectivity and an edge width value of two (2) corresponding an effective pixel size of 10 metres for this analysis.

The input data is the raster (grid) map of the Sentinel-2 BHT classification of WP3 Activity 3.1 of the pilot region. The input map must contain the two data classes Foreground (BHT of interest) and Background (other BHT).

2.1.2 Euclidean Distance

To measure the degree of intactness, shape and spatial arrangement of patches on a given binary map, the analysis methodology of Euclidean Distance offers a practical and effective method of implementation. The module of Euclidean Distance analysis scheme is also available in GuidosToolbox and uses the same input data as the MSPA described above.

This application creates maps of objects of interest showing the Euclidean distance map inside and outside those objects. To illustrate the influence zones of each object and to derive the pairwise proximity between neighboring image objects this type of analysis may be further pursued. For the establishment of cost-efficient reconnecting pathways in restoration planning proximity may be used to locate close encounters of existing objects. (Vogt et al., 2017)

In terms of the connectivity of BHT of interest the generated distance maps provide spatially explicit information allowing for highlighting hotspots of highly fragmented areas or those dominated by well-established networks of forests or grassland. The spatial information of these distance maps may be of high importance for monitoring, planning and risk assessment.

Additionally, the simple, yet intuitive analysis scheme is easy to communicate and can be related to a variety of spatial planning measures by illustrating the degree of fragmentation or intactness and allowing direct comparisons with results among the pilot regions.

2.2 Functionality Analysis

2.2.1 Ecosystem Services (ESS) and Landscape Services (LSS)

To create a sound matrix of ecosystem service capacities for the broader habitat types along the Green Belt in the Danube Region, an existing matrix for the whole of Europe by Stoll et al. (2015) was used as template. It then was assigned to the definitions of Landscape Services by de Groot et al. (2002, 2006 and 2010) and revised by the experts of each project partner.

By the definition of the Millennium Ecosystem Assessment (MEA) “ecosystem services” comprise various benefits for human beings provided by ecosystems. They can be divided into four categories:

- Provision services (e.g. food, fresh water)
- Regulating services (e.g. climate regulation, pollination)
- Cultural services (e.g. recreation, education)
- Supporting services (e.g. soil formation, photosynthesis)

Thus, these ecosystem services not only sustain fundamental human needs but also have a high economic value. (MEA, 2005; TEEB, 2010)

In order to understand and quantify these complex socio-ecological systems and develop models of ecosystem services, assessment matrices are a common tool in this research field (Burkhard et al., 2009, 2012; Stoll et al., 2015).

For the evaluation methodology of the project, the matrix of Stoll et al. (2015) was used. It assigns a value from 0 (no capacity) to 5 (very high capacity) to each CORINE land cover class or BHT, respectively, to indicate their capacity for every ecosystem service.

In comparison to ecosystem services, landscape services take spatial patterns, which result from human and natural processes, as well as the social dimension more into account (Vallés-Planells et al. 2014). This makes the broader concept of landscape services better applicable and thus it is commonly used in landscape planning. Therefore, the ecosystem services of Stoll et al. were matched to the corresponding terms of de Groot et al. (Figure 1).

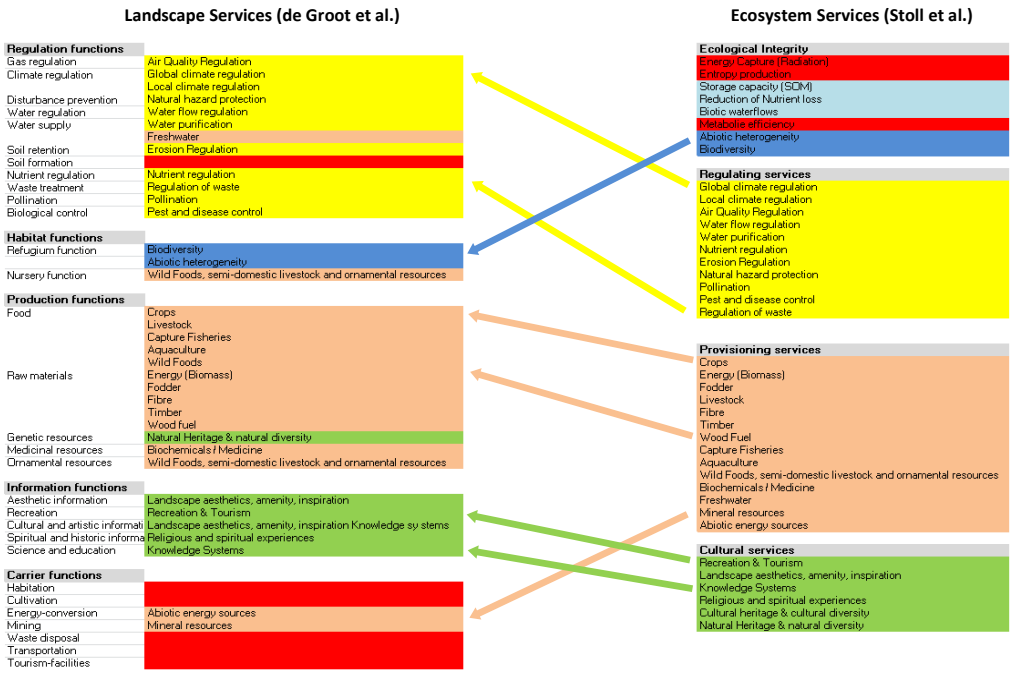

Figure 1: Assignment of the ecosystem services (Stoll et al., 2015) to the corresponding Landscape services (de Groot et al. 2002, 2006, 2010).

As a result, we can see the Europe-wide matrix with the new terminology below (Figure 2), which serves as a basis for the further analysis of the ecosystem services within the Danube region.

Figure 2: Translated ESS matrix with 1320 values based on Stoll et al. (2015). Green – very high capacity of ESS, red – no capacity of ESS.

Expert Review

Subsequently, the matrix was discussed in a first round of expert-based revision by the project partners in a group discussion in the course of the workshop at the project partner-meeting in Kubova Huť (CZ). After the initial review round in order to adapt the values to the characteristics of each project region, the mean values for each capacity score were calculated. The resulting table was once again sent out for discussion to come to a joint consensus (Figure 3). Eventually, the outliers, namely values that varied by more than ±2 from the original score, were analyzed and the final value was calculated.

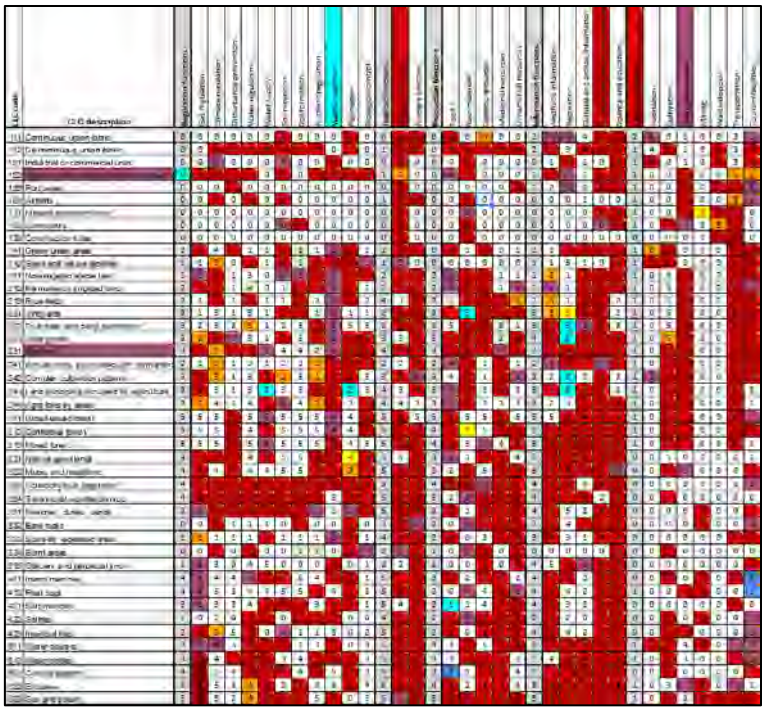

Figure 3: Working process of finding an expert-based consensus of ecological values of land cover classes for the Danube Region. The colors are marking comments from different project partners.

Final ESS-Matrix

By linking the final ESS-Matrix to the broader habitat types using CORINE land cover classes as reference, the BHT could be assigned to the landscape services and ultimately to the consequential total function value (Figure 4).

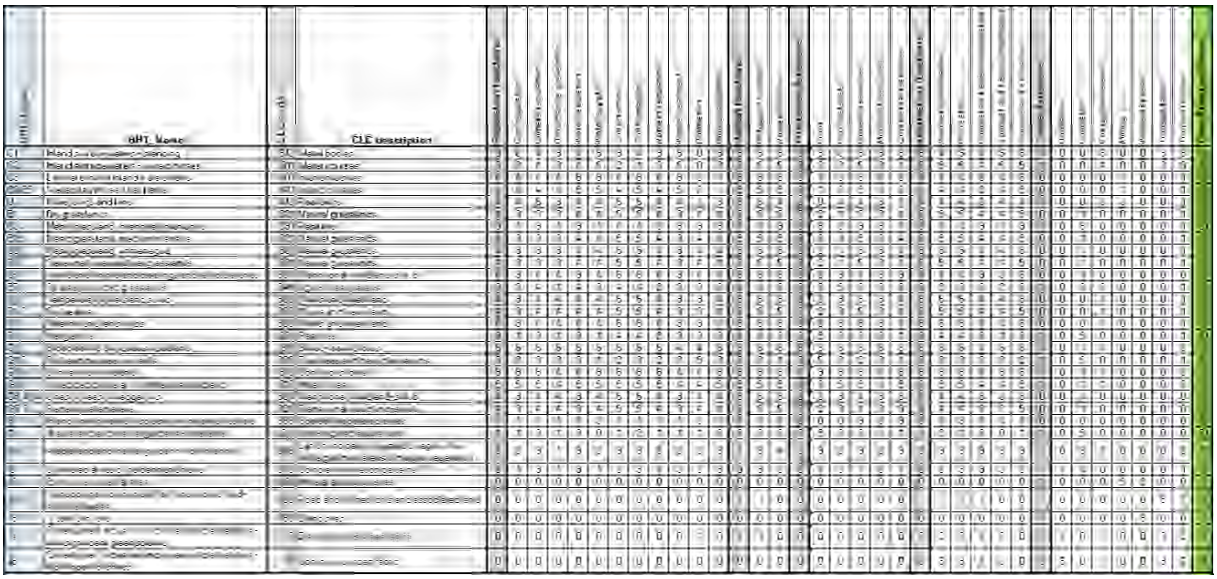

Figure 4: The final, reviewed ecosystem services-matrix, assigned to the corresponding broader habitat types via CORINE land cover codes.

3. Results

Using the Sentinel-2 classification of broader habitat types (Figure 5) as reference, further analyses on the connectivity, with a focus on different broader habitat types of interest within the pilot region, and on the functionality for all BHT of the studied area of the Bavarian Forest (DE), the Mühlviertel (AT) and Šumava (CZ) were conducted. But also, the map of BHT itself gives a good first glance of the landscape's composition and consequentially favorable areas for linking the existent protected areas.

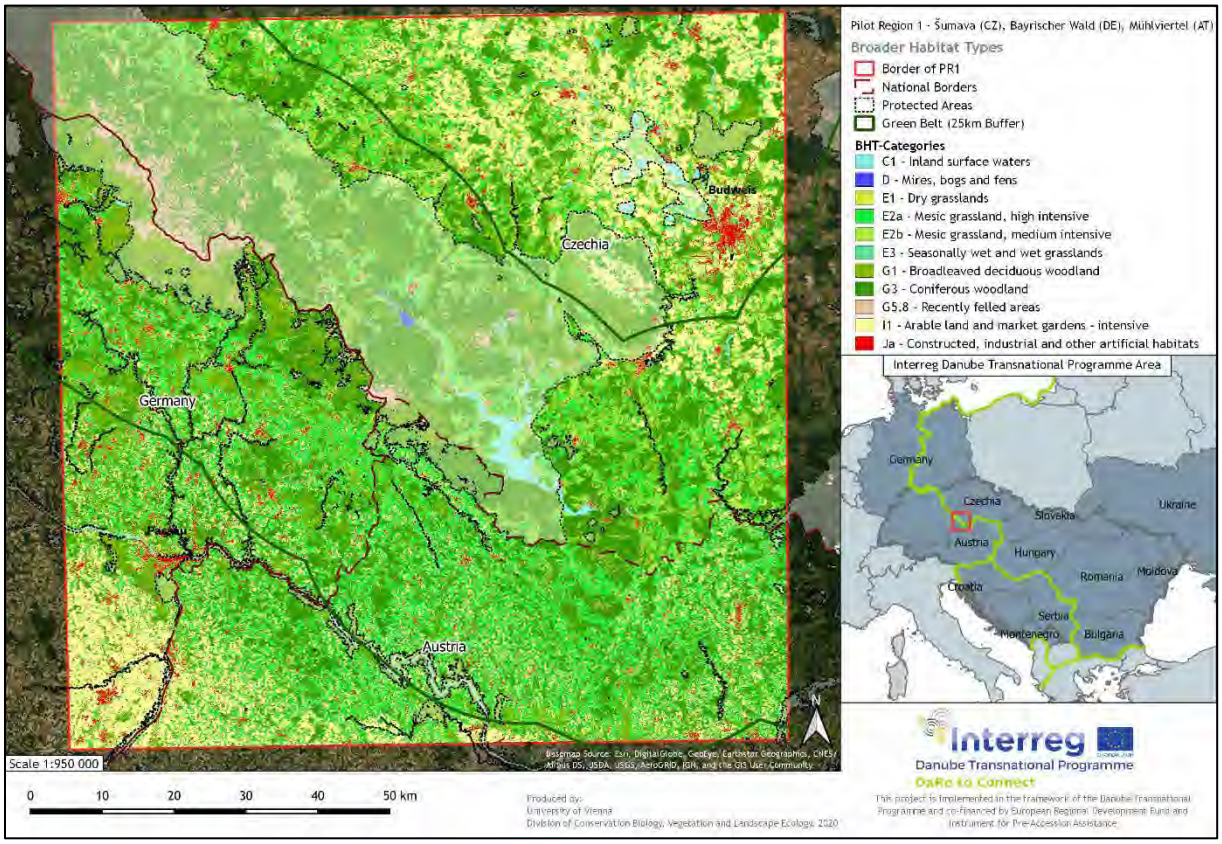

Figure 5: The map of the broader habitat types classification using the Sentinel-2 data of pilot region 1 „Bavarian Forest-Mühlviertel-Šumava (DE/AT/CZ)".

As we can see in Figure 5, the core area of protected areas of Pilot Region 1 in the Czech part is the National Park and Landscape Protected Area Šumava and its adjoining protected areas. It stretches along the Czech-German and Czech-Austrian borders, with total length approximately 100 km. The area is also covered by Natura 2000 sites (Special Protected Area, Special Area of Conservation Šumava). The most typical landscape structure is montane woodland with peatbogs. The core area of Šumava consists of bog woodland, montane spruce forests, active raised bogs. Beach forests (with high proportion of spruce and fir) and managed spruce forests dominate in lower altitudes. Forests in Šumava were influenced by windfalls and bark-beetle gradation in last years which resulted in large-scale break-up in the tree layer. If not managed by foresters, the habitat recovers quickly by itself. But still, large areas of forests were managed (clearings, peeling of dead wood).

Primary forest-less small patches are found across Šumava. Most typical are raised bogs, but we can find also glacial lakes with cirques, rocks, screes. Many raised bogs were drained of water in past and they are restored today.

Czech Šumava is also typical with many areas of abandoned villages. They are covered partly by pioneer birch forests and partly by degraded meadows not managed for long period. Some plots of precious secondary forest-fewer areas are managed by grazing or mowing. Near recent settlement the management of meadows occurs frequently, sometimes in quite an intensive way.

Southeastern part of the Pilot Region 1 is already outside from Šumava. It is dominated by cultural landscape with only some patches of small scale protected areas (small sites Rašelinšitě Kapličky, Pláničský rybník-Bobovec, Čertova stěna – Luč, linear structures along the rivers Vltava-Rožmberk-Větřní, Horní Malše). They form fragmented and isolated network, functioning - in terms of the MSPA - as Islets, Branches, Loops, Bridges and Perforations.

The basis of the protected areas and therefore cores in the Austrian part of the pilot area “Bavarian Forest-Mühlviertel-Šumava” is mainly represented by an agglomerated, compound area consisting mostly of the Natura2000 area “Böhmerwald und Mühltäler” as well as the three protected areas at state level “Orchideenwiese in Freundorf”, “Stadlau” and “Torfau” adjacent to the Czech Šumava National Park and Landscape protected area.

Starting with the Eastern end of the Czech protected areas of Šumava National Park the area of the Green Belt is characterized by the absence of any nature reserve for about 30 kilometres to the Natura2000 areas of „Wiesengebiete im Freiwald“ and „Maltsch“ in the East of the pilot area near the Austrian-Czech border.

Lateral bridges in form of protected areas to the nearest Natura2000 areas „Oberes Donau- und Aschachtal“, „Rannatal“, „Leitenbach“ and „Eferdinger Becken“ and the adjoining protected areas at state level in the South of the pilot area do not exist.

In terms of landscape types, these various greater compounds of protected areas differ strongly in composition and structure. While the border region adjoining to the Czech Republic in the North is characterized by closed woodland, like in the Natura2000 area “Böhmerwald und Mühltäler”, the grassland landscapes of the Natura2000 areas of „Wiesengebiete im Freiwald“ and „Maltsch“ primarily consist of semi-open and open habitats. The different characteristics of these landscapes and their respective composition lead to particular challenges in the relinking habitat corridors in the pilot area.

The network of protected areas on the German part of the Pilot Area is divided into a western and an eastern part with major differences in their structure. Differences in landscape types are mainly regarding a differing level of land-use. Main features are different types of forests (e.g. spruce forests, montane spruce forests) open and semi-open habitats and wetlands.

The northern part is dominated by the “Nationalpark Bayerischer Wald” an area protected on national-level. Different types of spruce forests of nationally uniqueness are characterizing the area. The National Park is directly neighboring the Czech National Park Šumava, and is part of the core-protected-area of the Pilot Region.

The western part of the German side of the Pilot Region is characterized by a more fragmented status of protected areas. From the eastern border of the National Park Bayerischer Wald to the border triangle there is no core area in the MSPA. The Natura 2000 areas “Ilz Talsystem”, “Bischofsreuter Waldhufen” and “Hochwald und Urwald am Dreisessel” form a rather fragmented and isolated network of protected areas.

3.1 Connectivity Analysis

3.1.1 Morphological Spatial Pattern Analysis (MSPA)

Since it is the foremost goal of DaRe to Connect to establish new corridors among these protected areas, its is expedient to analyse the connectivity of BHTs that are essential for the migration and interaction of a variety of species in a matrix of an often intensively used and fragmented cultural landscape. Thus, the MSPA was conducted for two in pilot region 1 most important scenarios: firstly, broad-leaved and coniferous forests and, secondly, dry and mesic grassland.

Broad-leaved and coniferous forests

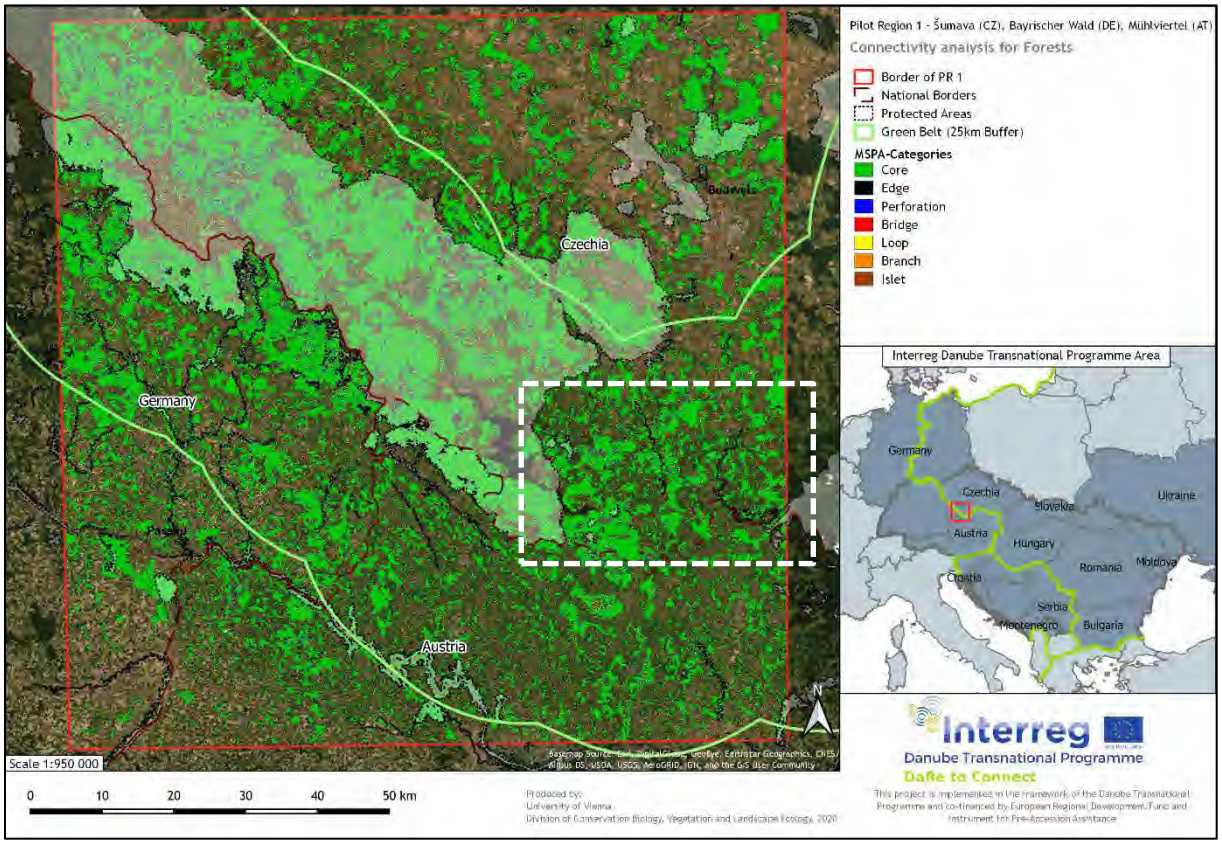

Figure 6: The map of the MSPA classes showing (possible) connections within the network of broad-leaved and coniferous forest areas of pilot region 1 „Bavarian Forest-Mühlviertel-Šumava (DE/AT/CZ)”.

In Figure 6 it can be seen, that, generally, within the 25km buffer of the Green Belt the core areas of forested BHTs are much bigger and more abundant than on the surrounding area. Also, a large part of the protected areas show a high coverage of woodland. In between the conservation sites, the patches of forests get to a great extent smaller and more scattered, since the anthropogenic use of the non-protected areas is significantly higher.

As already described above, the next large Natura 2000 site in the East of the protected areas around the National Park Šumava are the “Maltsch” (AT) and “Horní Malše” (CZ) along the Austrian-Czech border, with some small sites in the 20-30 km gap. Besides that, there are also unprotected forest patches of partly remarkable size but also a lot of very small and fragmented ones. There exist bridges or at least some islets and branches through small structures like hedges or field shrubs between some of them. But, especially on the Austria site and also in Czechia, intensively used land (pastures, meadows and arable land) often separates the residual forests (almost) completely, leaving very little space for species.

Looking at the Southern and Southwestern part of the pilot region, the Natura 2000 sites of the Danube and its accompanying tributaries stand out. The target here would be their increased connection with the large forest areas of the NP Bavarian Forest, NP Šumava and the Böhmerwald.
In this case, there is a better network of present protected areas than in the Eastern part, since the tributaries of the Danube reach closer to the core area of pilot region 1. These protected sites along rivers and streams (e.g. “Ilz-Talsystem” (DE), “Erlau“ (DE) and “Böhmerwald und Mühltäler (AT)“, which function particularly as corridors, often consist of forests. But again, the landscape matrix is characterized by the influence of agricultural usage. So, these forests corridors are by far not consistent and get at narrowed down to very thin bridges or even interrupted by intensively used grass- and farmland or urban area.

In the West of the pilot region 1, next to the Bavarian Forest, the Natura 2000 site “Oberlauf des Regens und Nebenbäche” connects well with the national park and its adjoining, mainly coherent forests.

Dry and mesic grassland

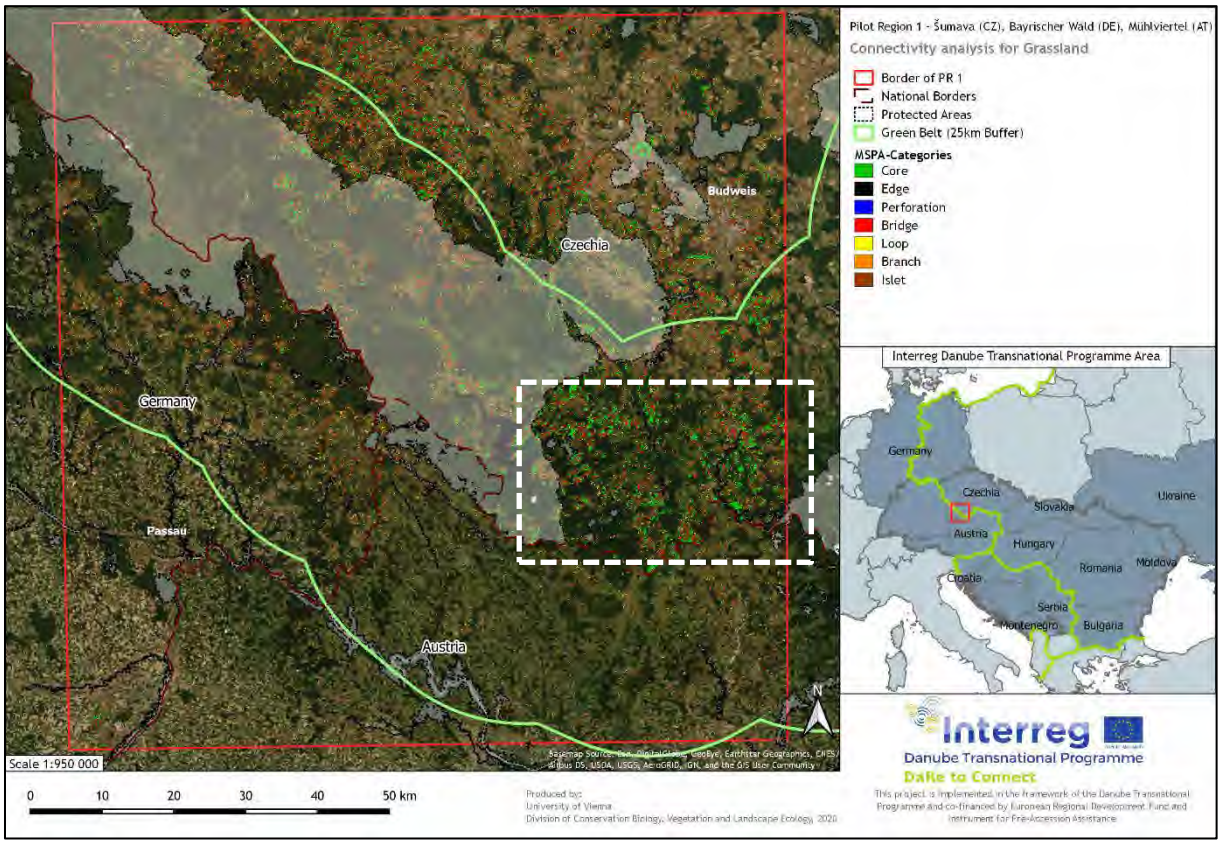

Figure 7: The map of the MSPA classes showing (possible) connections within the network of dry and mesic grassland areas of pilot region 1 „Bavarian Forest-Mühlviertel-Šumava (DE/AT/CZ)".

The MSPA result for the dry and mesic grassland shows a much more modest picture of the connectivity. Since the proportion of the dry grassland habitats are restricted to very small areas within the Šumava National Park, in the map below (Figure 7) mainly mesic grassland with medium intensive use are depicted.

Obviously, the situation in the German and Austrian parts of the pilot region are extremely scarce in terms of extensive grassland patches due to the much higher percentage of intensive land use. Thus, the present status of the network for natural grassland is not favorable. But, Natura 2000 sites like "Borstgrasrasen und Bergwiesen Obergrainet-Gschwendet", "Wiesengebiete im Freiwald" and "Wiesengebiete im Mühlviertel" are not only surrounded by arable land, it is also bordering more intensive grassland areas, that constitute a potential improvement of the connectivity of these corridor gaps.

On the Czech side, on the other hand, is a much bigger and better-connected network of mesic grassland types. Mostly within the Green Belt, between NP Šumava and the Natura 2000 sites along the Maltsch/Malše and in the North of the National Park reaching beyond the Green Belt into the landscape around Natura 2000 site "Českobudějovické rybníky" and further in the west of Budweis.

To summarize both analyses one can see already a first very important gap between two Natura2000 in the very east of pilot region 1. This gap is visualized as a white dotted line in Figure 8 and Figure 9.

Detailed examples of highly important gaps/links and possible ideas for corridors have been collected in section 6 and will be further discussed with relevant national stakeholders.

3.1.2 Euclidean Distance

Analyzing the result of the measurement of Euclidean Distance the protected areas on the Austrian part of the pilot region the highlighted links and reconnecting pathways suggest potential connection opportunities.

Broad-leaved and coniferous forests

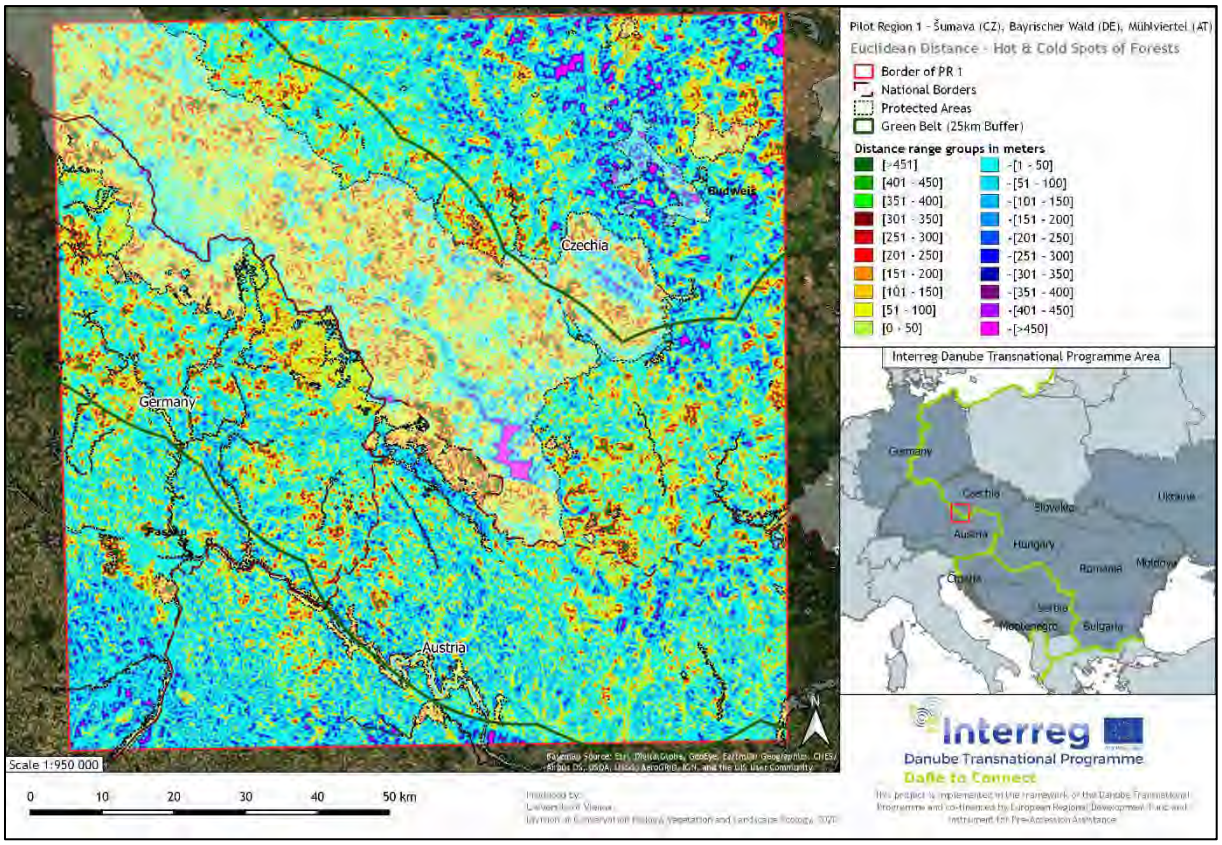

Figure 8: The map of the Euclidean Distances showing the hot and cold spots of broad-leaved and coniferous forest areas of pilot region 1 „Bavarian Forest-Mühlviertel-Šumava (DE/AT/CZ)".

Regarding the Euclidean Distance for forest habitat types (Figure 8), the dominance of the core area Šumava is clearly visible, showing many hot spots within the protected areas. There are some links with protected areas in the south eastern gap that point out the potential of networking to connect eventually with the nature sites of "Maltsch", "Horní Malšeand" and "Novohradské hory".

The implementation of lateral connections beyond the Green Belt to other national protected areas on the Czech side appear to be unsuitable due to the greater distances between those areas. As it can be seen, for example, at the intensively cultivated area around Budweis.

Potential connections between existing protected areas on the German side of the Pilot Region tend to be inbound towards the Green Belt and the existing core areas. Also, on the German side the

implementation of lateral connections to other national protected areas in the south and west appear to be unsuitable due to the greater distances between those areas.

Dry and mesic grassland

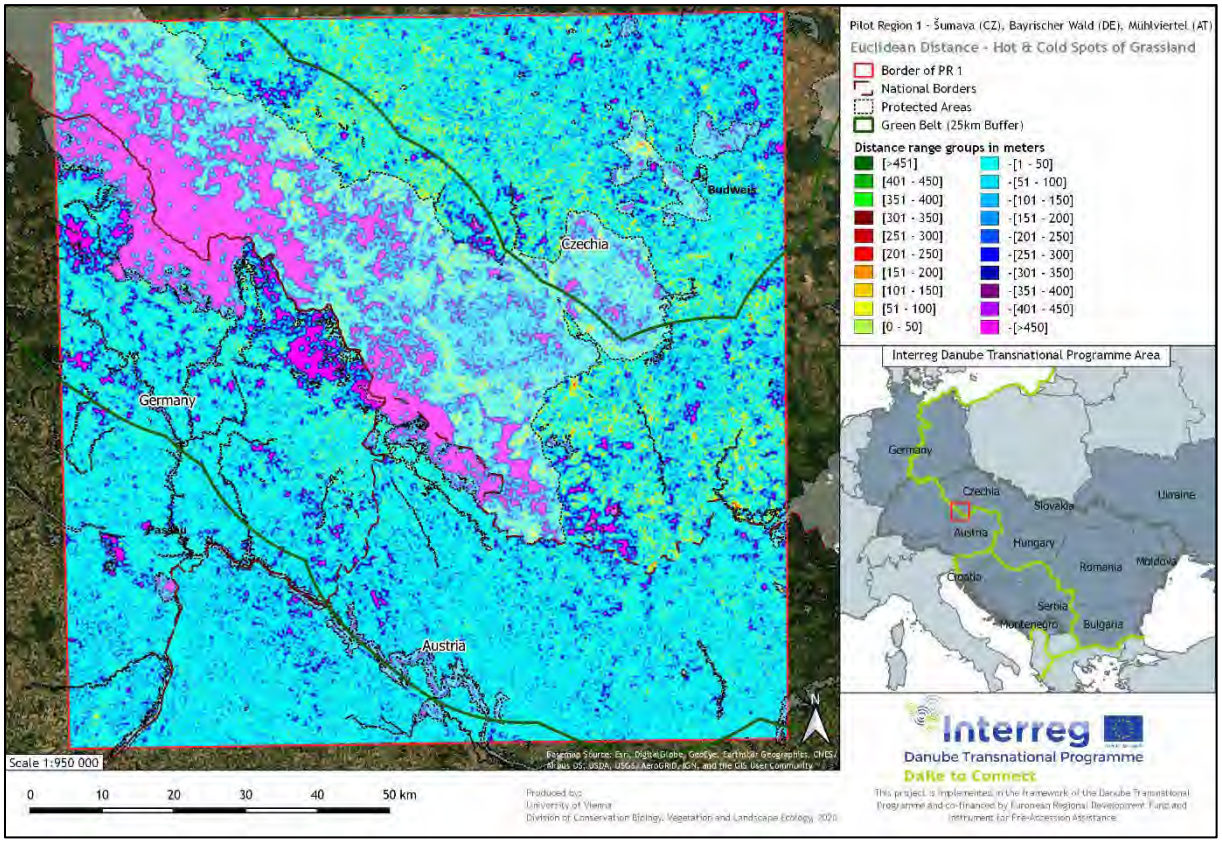

Figure 9: The map of the Euclidean Distances showing the hot and cold spots of dry and mesic grassland areas of pilot region 1 „Bavarian Forest-Mühlviertel-Šumava (DE/AT/CZ)".

The results for the mesic grassland (Figure 9) underpin the findings from the MSPA. Here, only bigger but still scattered Hot Spots of this BHT can be located on the Czech side, in the East and North of NP Šumava.

The German and Austrian parts show an evenly distributed, but small grassland Hot Spots. The concentration increases with the proximity to the core protected areas.

3.2 Functionality Analysis

This combined matrix allows it to display the broader habitat types' capacity of the 30 single ecosystem services, the five main services and the total function value within the project areas, also based on the classification of the Sentinel-2 data with a 10m resolution (WP3, Activity 3.1).
Using pilot region 1 as an example, the resulting maps of the ESS-analysis can be seen in the following chapters.

3.2.1 Main Services

The aggregation of the respective ESS to the mean values gives an overview of the five main services provided by the landscape along the 50km corridor and its surrounding area as follows.

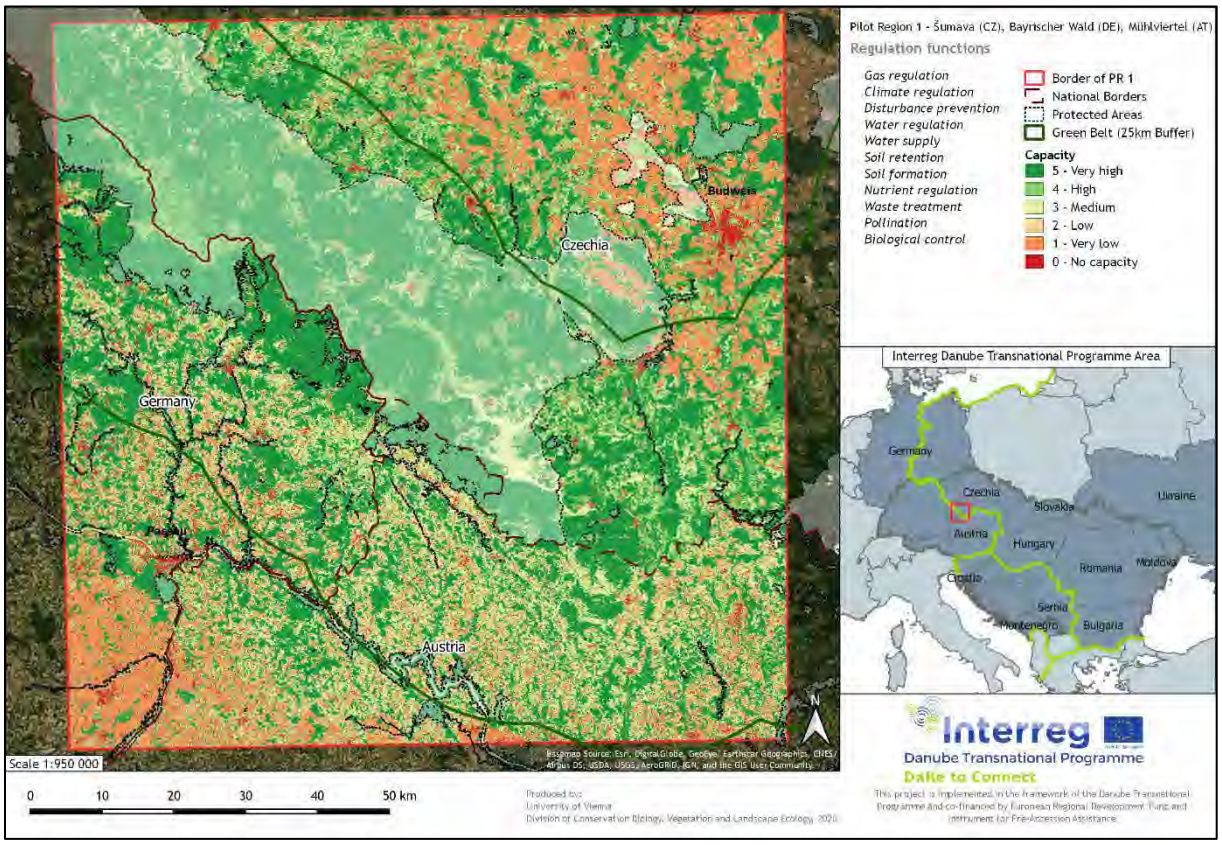

Figure 10: The map of the regulation functions capacity of the broader habitat types of pilot region 1 „Bavarian Forest-Mühlviertel-Šumava (DE/AT/CZ)".

By taking aspects of the ecological capacity of the landscape – like soil formation as well as the regulation of climate, water and nutrients – into account, we get a comprehensive picture of the regulation functions capacity of the region (Figure 10). It can be said, that the forests, both broad-leaved and coniferous, provide a very high (5) amount of regulation functions. Grassland used with medium intensity and natural grassland types also regulate to a high (4) extend. Intensively used grassland (pastures and meadows) show a medium (3) and intensive arable land a very low (1) capacity. No capacity (0) for regulation functions at all can be found in the urban, sealed areas.

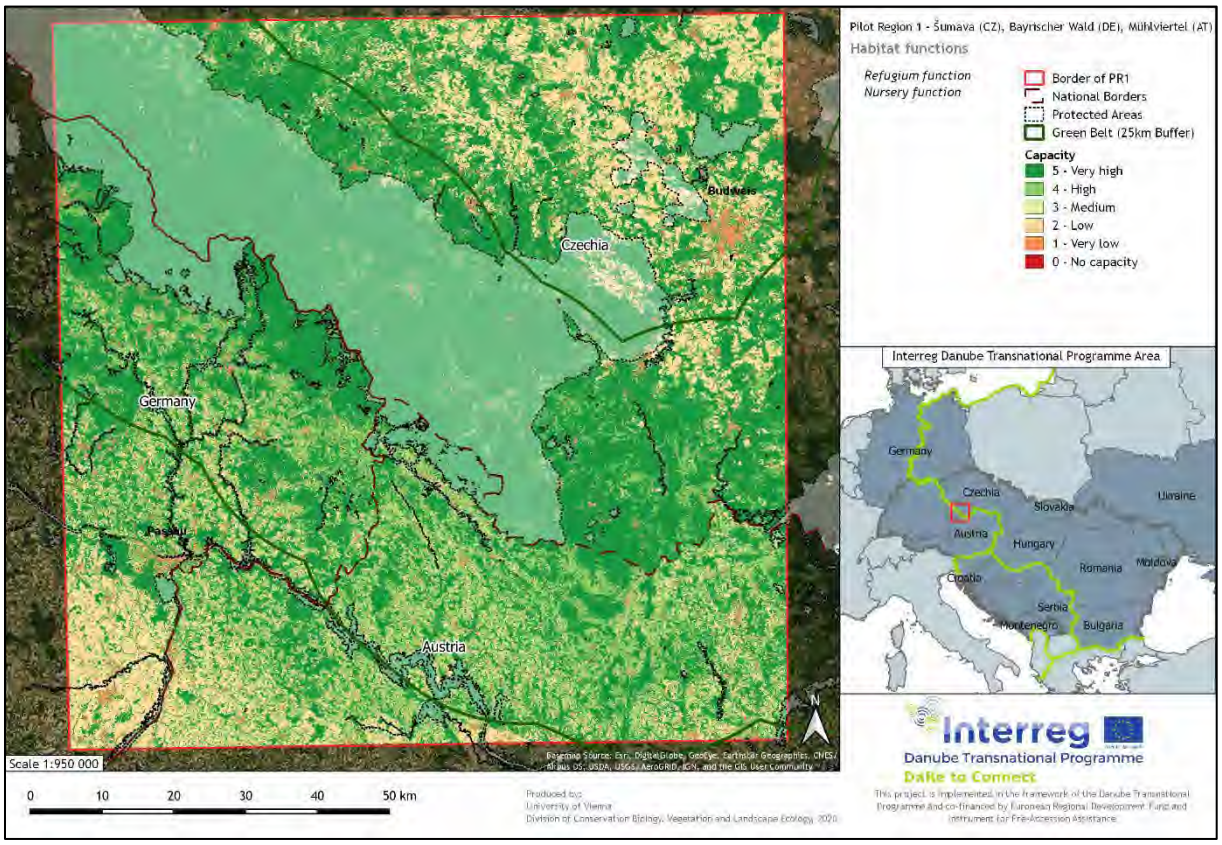

Figure 11: The map of the habitat functions capacity of the broader habitat types of pilot region 1 „Bavarian Forest-Mühlviertel-Šumava (DE/AT/CZ)".

Considering the habitat functions (Figure 11) of the BHT in the project area, a high to very high capacity can be identified among most of the broader habitat types. Forests and extensively used grassland in particular function here as a habitat for species, followed by more intensively used grassland. Again, the exceptions here are the intensively used arable land and sealed surfaces, which have a lower score, but still a certain capacity for some species.

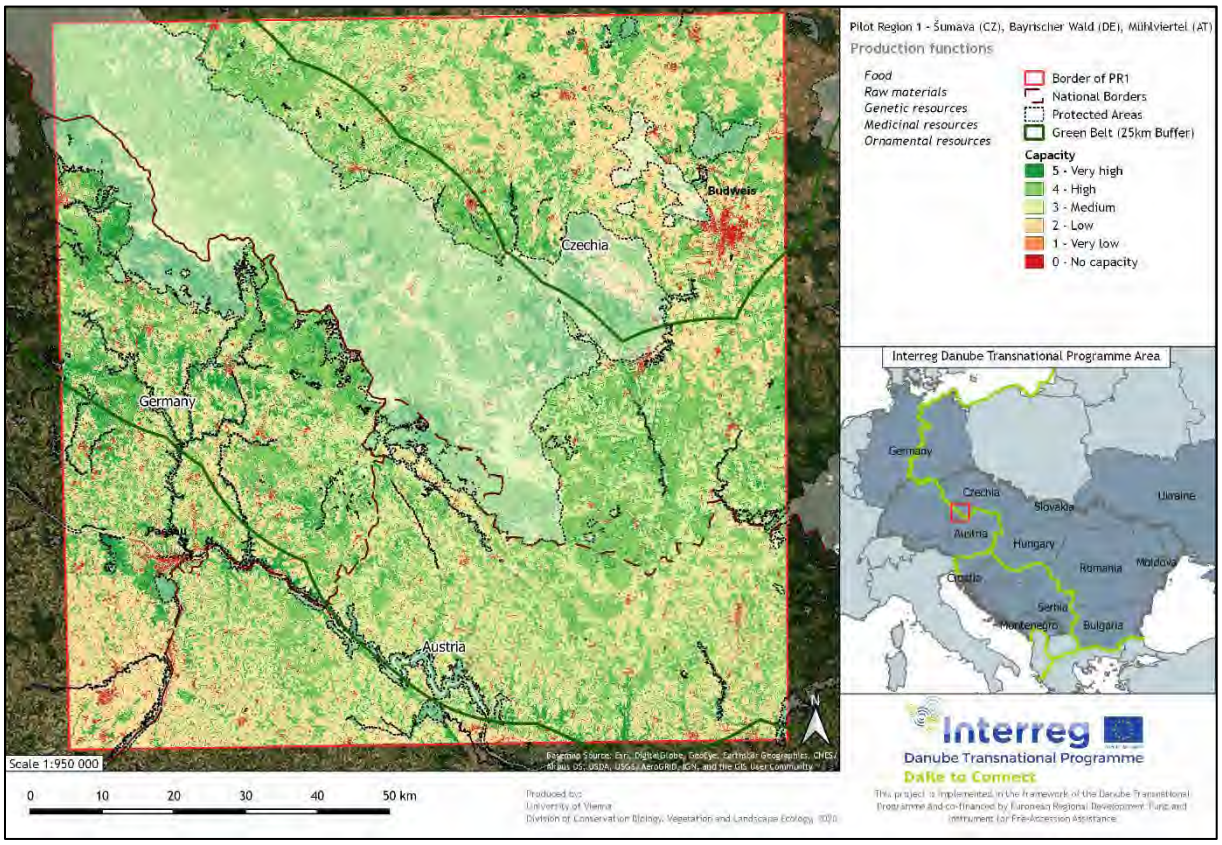

Figure 12: The map of the production functions capacity of the broader habitat types of pilot region 1 „Bavarian Forest-Mühlviertel-Šumava (DE/AT/CZ)".

Considering that most of the ESS of the production functions (Figure 12) evaluate resources of more natural land cover types like genetic and medicinal resources or raw materials, the forested areas show the highest production capacity, especially broad-leaved woodland (5), whereas the agricultural land have an overall lower value, providing mainly for food production. Grasslands of any kind fall in the same capacity category on the level of main services, but definitely differ within the single ecosystem services, such as genetic resources. However, sealed surfaces obviously do not have such functions.

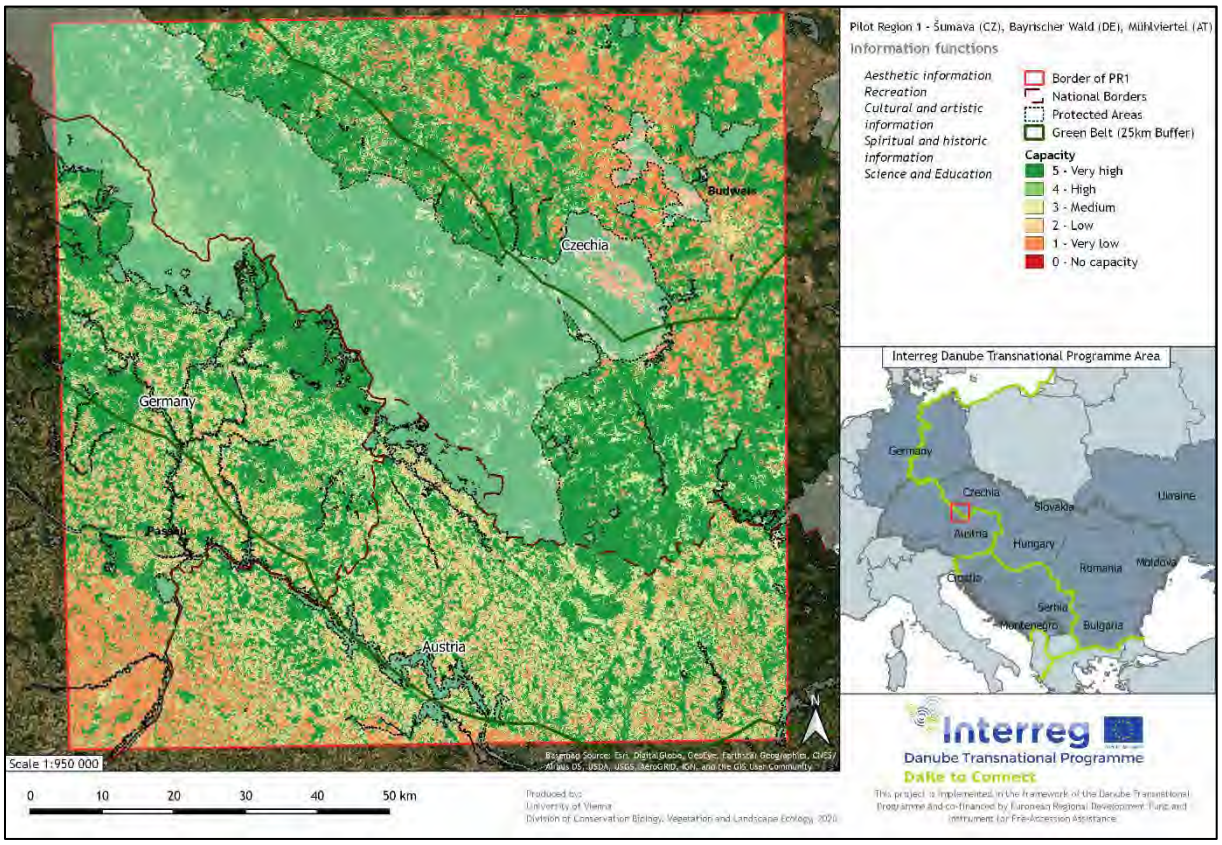

Figure 13: The map of the information functions capacity of the broader habitat types of pilot region 1 „Bavarian Forest-Mühlviertel-Šumava (DE/AT/CZ)".

Regarding the map of capacity for information functions (Figure 13), it is striking, that forests and less intensive grassland as well have a very high (5) value for information. Intensively used meadows on the other hand only provide a medium amount of information functions. Considering, that also cultural or historical information were taken into account, it is no surprise that urban areas show at least a low capacity here. Arable land, in turn, is very low in its informative ecosystem value.

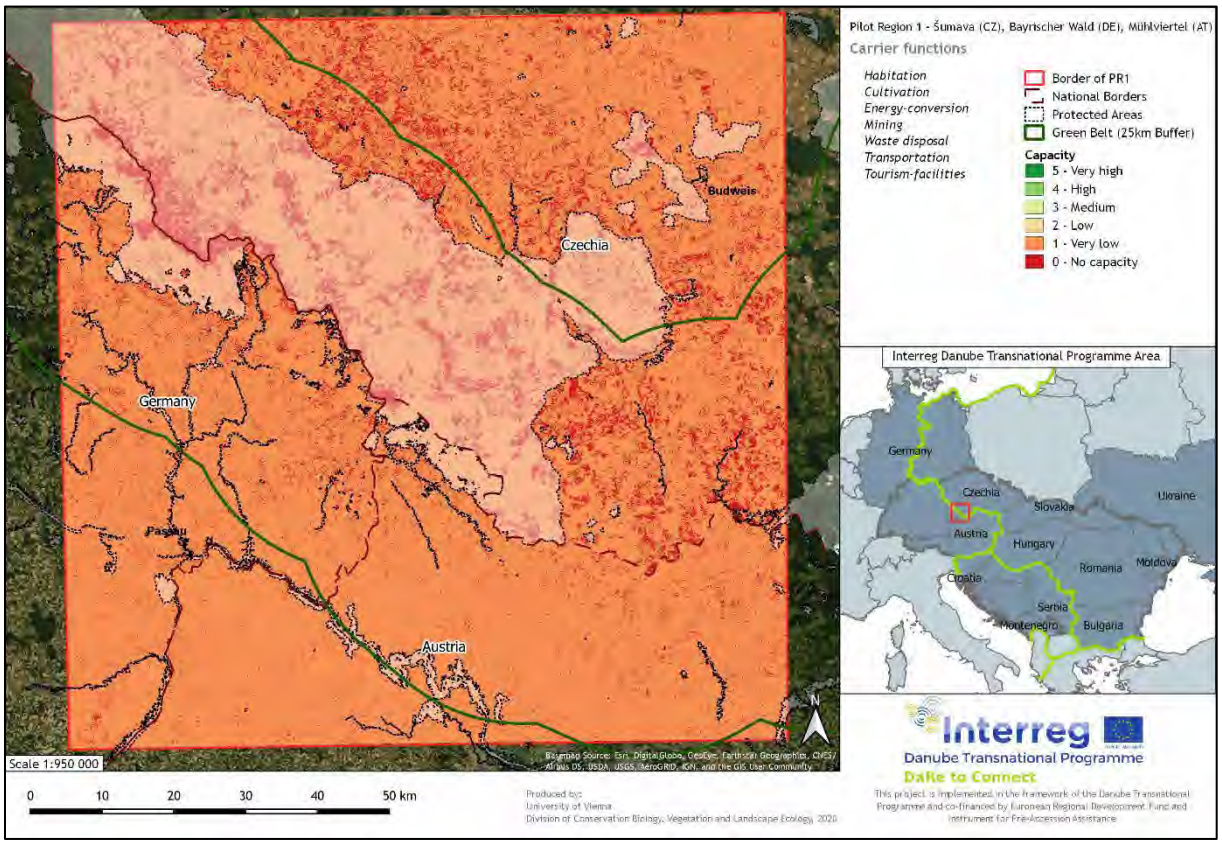

Figure 14: The map of the carrier functions capacity of the broader habitat types of pilot region 1 „Bavarian Forest-Mühlviertel-Šumava (DE/AT/CZ)".

If we look at the carrier function (Figure 14), where the single ESS differ quite a lot in their functions (mining, habitation, cultivation etc.), we see an accordingly low overall capacity. Within the protected areas, there can often be seen no capacity for carrier functions at all, which makes sense, since this main service is a very anthropocentric one with highly altered nature and environment.

3.2.2 Total Function Value

To visualize the multifunctionality of the landscape, all ESS of each main category can be summed up to one indicator – the total function value (Figure 15). As seen in the map, the result shows, as already seen in most of the main service maps, a generally higher multifunctionality within the 25km buffer alongside the Green Belt than outside this corridor, but also large habitat patches and linked networks of valuable habitat types (potentially) connecting the wider Green Belt region laterally.

However, the total function value is a good indicator for pointing out region of interest with a high capacity of ecosystem services for nature and humans, especially on a larger scale. But in order to develop concrete strategies for connecting protected areas and generally increase the ecological value of the Green Belt area, also the connectivity analysis must be taken in account. For realizing local projects, it is also reasonable to visualize zoomed in sections with single ESS that are important for the specific case.

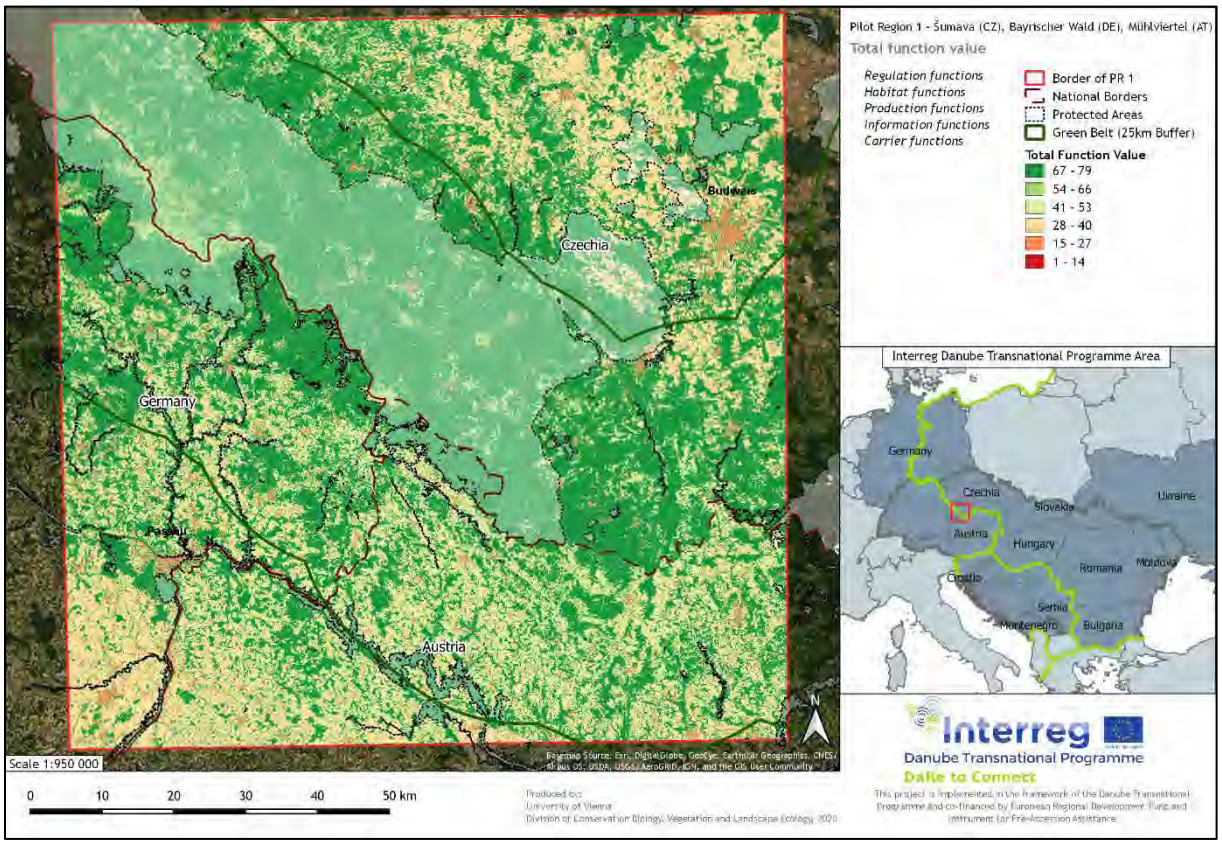

Figure 15 The map of the total function value of the broader habitat types of pilot region 1 „Bavarian Forest-Mühlviertel-Šumava (DE/AT/CZ)".

4. Conclusion

Bearing in mind the results from the connectivity and functionality analyses, the two scenarios for a better network of broad-leaved and coniferous forests as well as dry and mesic grasslands between the protected areas in pilot region 1 lead to the following, (partly) different conclusions.

Considering the BHT of forests, with their many large but also a lot of smaller patches, which are both partly connected through linear elements, the potential of gap closure by forest BHT is high. One advantage here is the fact, that the protected areas mostly consist of forests and thus provide a good basis for an extended network. Especially inside the Green Belts border, several areas, feasible as corridors, could be identified by the MSPA, offering possibilities to connect the core area of the national parks with the neighboring Natura 2000 sites in the West, South and East of the pilot region.

Since the grassland BHTs are more fragmented and clearly smaller, the scenario for the grassland depicts a smaller scale of networks, that do not reach as far as the woodland, in particular on the German and Austrian side. Also, there are less protected areas dedicated to this BHT. However, these BHT serve as important habitats and stepping stones regardless of their size.
The focus here should be put on the Czech part by building on in the North and East of the pilot region 1, but also the few existing areas in the south are important, since they bear the potential to connect with the near Natura 2000 sites dedicate to biotope types of grassland.

Despite of their differences in the extent, the results of the functionality analysis show, that both habitat types definitely not only have a high significance as habitat for a broad range of species, but also deliver many other ecosystem services for humans. This is well illustrated by the map of the total function vale (Figure 15), where forests as well as natural grassland are classified with the highest capacity of providing multifunctionality.

To close the gaps between the BHTs of each scenario, the conversion from forest to grassland and vice versa would not be realistic in most cases. A much more feasible way would be the establishment and strengthening of a network of linear wooden structures, like shelter belts and hedges, to connect the residual forests between the protected areas through the agricultural land. Furthermore, the extensification of the meadows and pastures would lead to a development towards low intensity to natural dry and mesic grassland.
Existing target BHT, of course, should be appropriately maintained and by doing so, not only ensuring their preservation, but also leading the a more natural state. Thinking of, for example, of suitable mowing and grazing or increase the ratio of site-specific tree-species.

In either case the key for finding local solutions is the cooperation of with land owners and other stake holders and build on the results above.

5. References

Burkhard B., Kroll F., Müller F., Windhorst W. (2009): Landscapes' capacities to provide ecosystem services – a concept for land-cover based assessments. Landsc. Online 15: 1–22.

Burkhard B., Kroll F., Nedkov S., Müller F. (2012): Mapping ecosystem service supply, demand and budgets. Ecol. Indic. 21: 17–29.

de Groot R. S. (2006): Function-analysis and valuation as a tool to assess land use conflicts in planning for sustainable, multifunctional landscapes. Landscape and Urban Planning 75: 175-186.
Retrieved from http://dx.doi.org/10.1016/j.landurbplan.2005.02.016

de Groot R. S., Alkemade R., Braat L., Hein L., Willemen L. (2010): Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. Ecological Complexity 7: 260-272.
Retrieved from http://dx.doi.org/10.1016/j.ecocom.2009.10.006

de Groot R. S., Wilson M. A., Boumans R. M. J. (2002): A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecological Economics 41(3): 393-408. Retrieved from http://dx.doi.org/10.1016/S0921-8009(02)00089-7

European Environmental Agency (EEA) (2017): Crosswalk between EUNIS habitats classification and Corine land cover.
Retrieved from https://www.eea.europa.eu/data-and-maps/data/eunis-habitat-classification/documentation/eunis-clc.pdf

European Environmental Agency (EEA), 2020a. Nationally designated areas (CDDA). European Environment Agency. Internet: https://www.eea.europa.eu/data-and-maps/data/nationally-designated-areas-national-cdda-14 (accessed: 2020/03/05)

European Environmental Agency (EEA), 2020b. Natura 2000 data - the European network of protected sites. Temporal coverage: 2018. Internet: https://www.eea.europa.eu/data-and-maps/data/natura-10 (accessed: 2020/03/05)

IPBES (2019) The global assessment report on BIODIVERSITY AND ECOSYSTEM SERVICES.
https://ipbes.net/system/tdf/ipbes_global_assessment_report_summary_for_policymakers.pdf?file=1&type=node&id=35329

Millennium Ecosystem Assessment (2005): Ecosystems and Human Well-being: Synthesis. Island Press. Washington, DC.
Retrieved from http://www.millenniumassessment.org/documents/document.356.aspx.pdf

European Environment Agency (2020): Europe's state of the environment 2020;
https://www.eea.europa.eu/highlights/soer2020-europes-environment-state-and-outlook-report

Soille P. & Vogt P. (2008): Morphological segmentation of binary patterns. Pattern Recognition Letters

30(4): 456-459.
Retrieved from https://dx.doi.org/10.1016/j.patrec.2008.10.015

Stoll S., Frenzel M., Burkhard B., Adamescu M., Augustaitis A., Baeßler C., Boneth F.J., Carranza M.L., Cazacu C., Cosor G.L., Díaz-Delgado R., Grandin U., Haase P., Hämäläinen H., Loke R., Müller J., Stanisci A., Staszewski T., Müller F. (2015): Assessment of ecosystem integrity and service gradients across Europe using the LTER Europe network. Ecological Modelling 295: 75-87.
Retrieved from https://doi.org/10.1016/j.ecolmodel.2014.06.019

TEEB (2010): The Economics of Ecosystems and Biodiversity: Mainstreaming the Economics of Nature: A synthesis of the approach, conclusions and recommendations of TEEB.

Vallés-Planells M., Galiana F., and Van Eetvelde V. (2014): A classification of landscape services to support local landscape planning. Ecology and Society 19(1): 44.
Retrieved from http://dx.doi.org/10.5751/ES-06251-190144

Vogt P. & Riitters K. (2017): GuidosToolbox: universal digital image object analysis. European Journal of Remote Sensing, 50(1): 352-361.

Vogt P., Riitters K. H., Iwanowski M., Estreguil C., Kozak J. & Soille P. (2007): Mapping landscape corridors. Ecological Indicators, 7(2): 481-488.

Wickham J. D., Riitters K. H., Wade T. G. & Vogt P. (2010): A national assessment of green infrastructure and change for the conterminous United States using morphological image processing. Landscape and Urban Planning, 94(3-4): 186-195.

6. Annex I

6.1 Maps of highly important bridges to improve connectivity in Pilot region 1

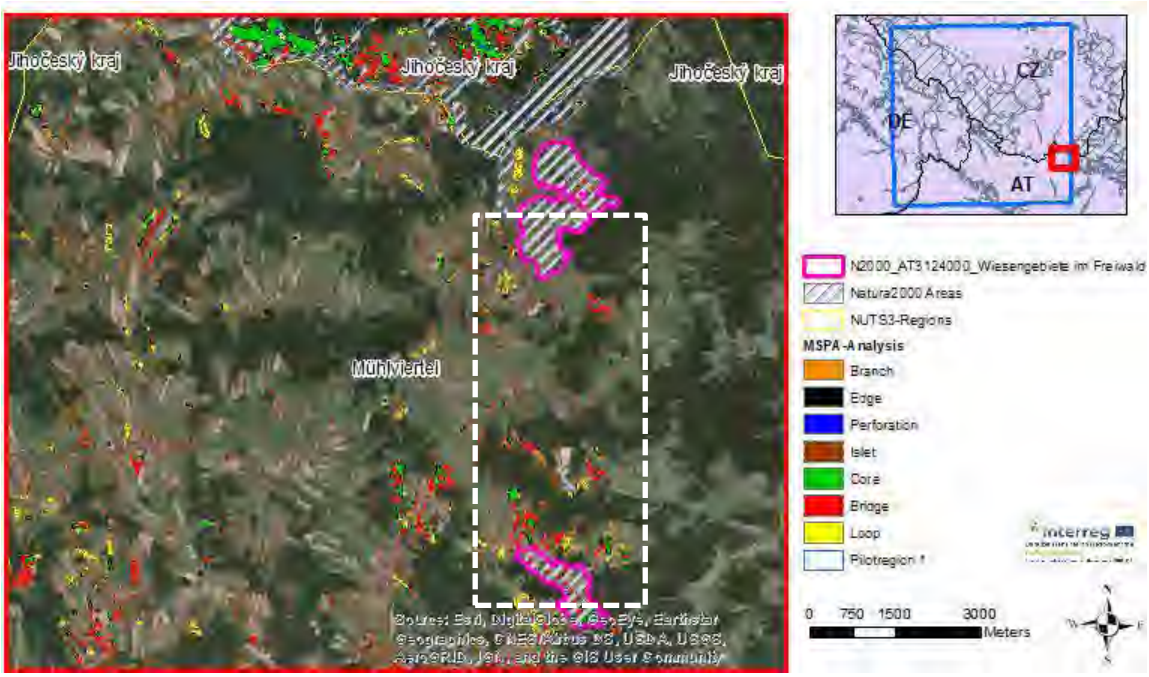

Figure 16: Example for a possible corridor-area to improve the connectivity of extensive meadows between and within Natura 2000 Sites – AT 3124000 Wiesengebiete im Freiwald (see white dashed line with a very low amount of core areas)

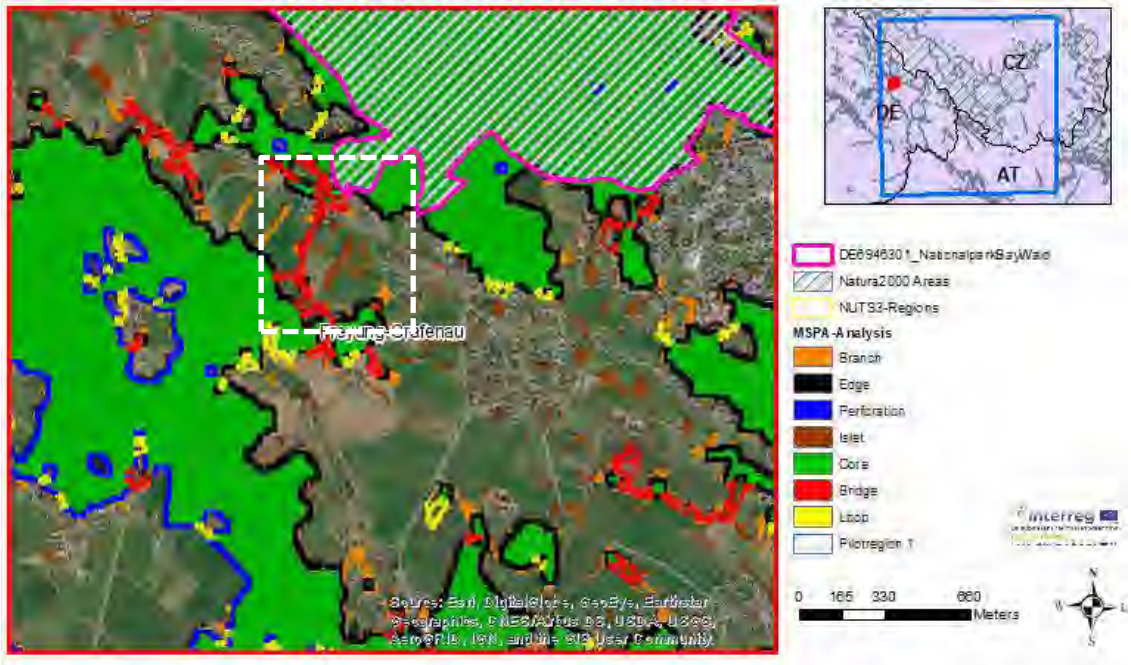

Figure 17: Example for highly important bridges and links to improve the connectivity of forest next to the Natura2000 Site Nationalpark Bayrischerwald (see white dashed line)