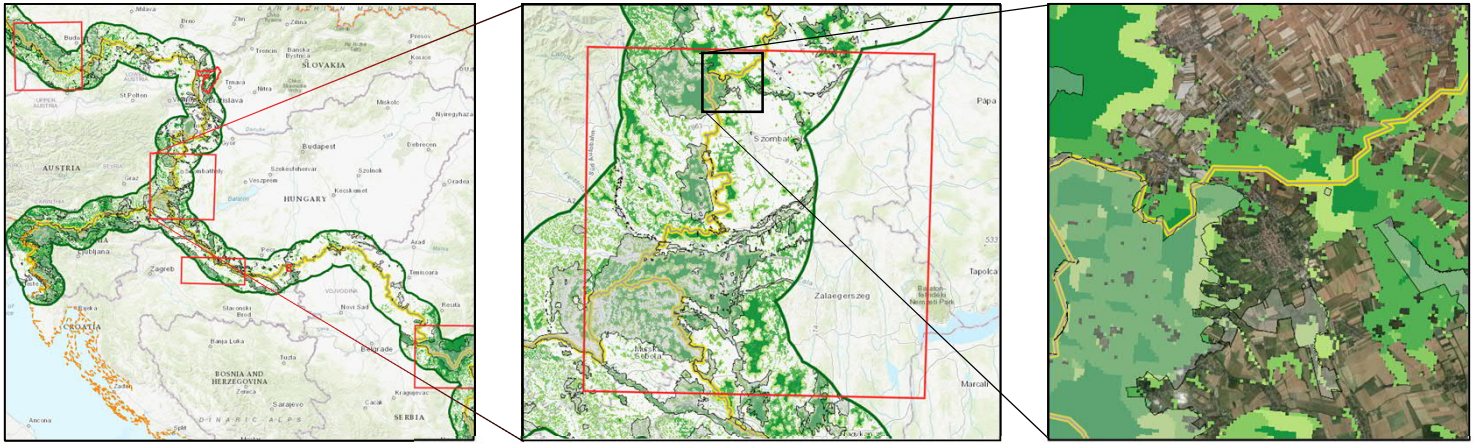
Interreg
Danube Transnational Programme
SaveGREEN

SaveGREEN Final conference

Mainstreaming Ecological Connectivity – Challenges, Ideas & Possible Solutions

DaRe to Connect (Interreg DTP)

Habitat classification & connectivity-functionality analysis along the European Green Belt



Interreg
Danube Transnational Programme
DaRe to Connect

european greenbelt

BUND Naturschutz in Bayern e.V.

BUND
FRIENDS OF THE EARTH GERMANY

Bundesministerium des Innern, für Bau und Heimat

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Ministry of Climate Action,
Radetzkystraße 2, Vienna
7. December 2022

Session
Exchange of Experience with other projects/initiatives

Project overview

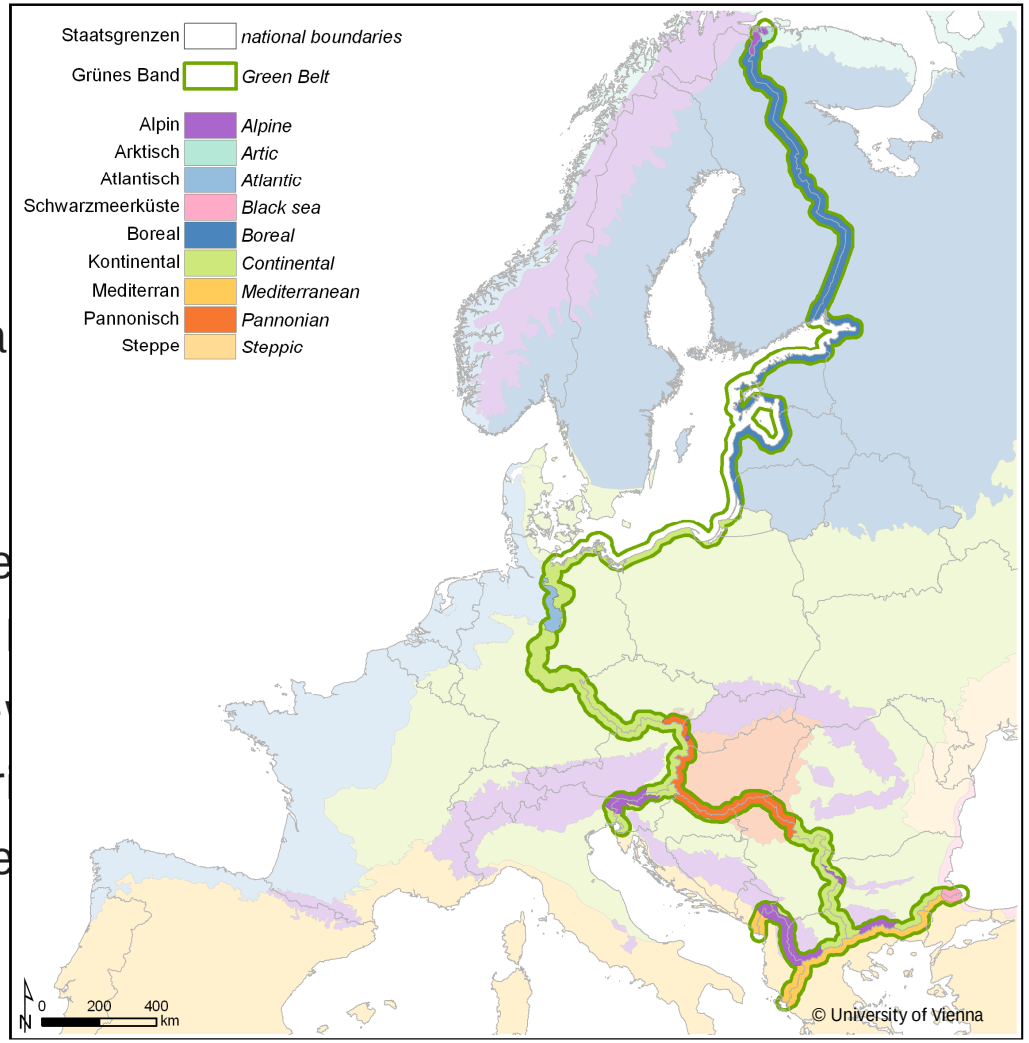
- Duration: June 2018 – November 2021
- Partner Consortium: 11 partners from 8 countries
  + 14 associated strategic partners from 10 countries
- Lead Partner: BUND Dept. Green Belt
- Overall Budget (ca. 2 Mio.€):
  - 80% ERDF (European Regional Development Fund)
  - 20% IPA (Instrument for Pre-Accession Assistance)

Main objectives

- Contribute to the implementation of the EU Strategy for the Danube Region (EUSDR) by further development of the connectivity of protected areas along the Green Belt
- Identification of ecological corridors between existing Natura 2000 areas and other protected areas along the EGB and maintain and enhance ecosystems and their services
- To improve capacities and the level of trans-national and trans-boundary cooperation between GOs, NGOs and on policy level
- Support the aim of the EGB-Initiative to nominate the European Green Belt as UNESCO World Heritage

Project area

- The European Green Belt – Danube Region
- 12.500 km in length, passes through 8 biogeogra
- Includes:
  - Wilderness areas
  - Cultural landscapes
  - Water ecosystems and coasts
  - Endangered animal and plant spe
- Thus contributes significantly to the diversity of
- Makes an enormous contribution to the Europe-
- More than 1100 protected areas in a 100 km corr
- Unique European memorial that combines nature



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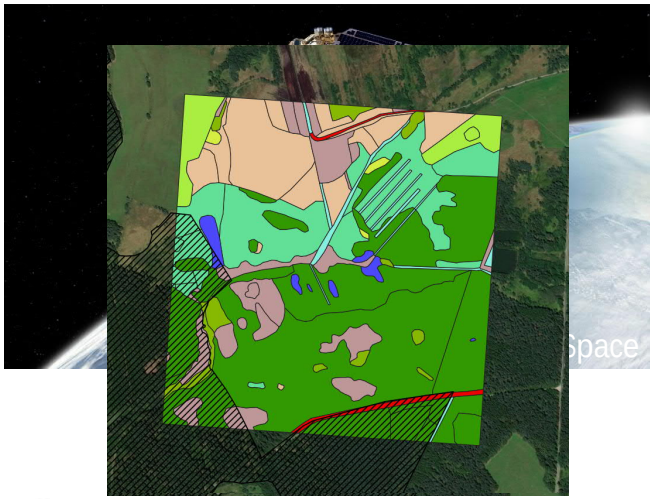
Project area

- 6 Pilot Regions along the EGB, Danube Region:
  1. Bavarian Forest-Mühlviertel-Šumava (DE/AT/CZ)
  2. Zahorie-Little Carpathians (SK)
  3. **Ő**rség-Gori**č**ko (HU/SL)
  4. Iron Gates-Djerdap (RO/SRB)
  5. Drava River in Virovitica-Podravina County (HR)
  6. Danube River oxbows (HU)

Source: http://www.interreg-danube.eu/approved-projects/d2c

Challenges: Regional approach

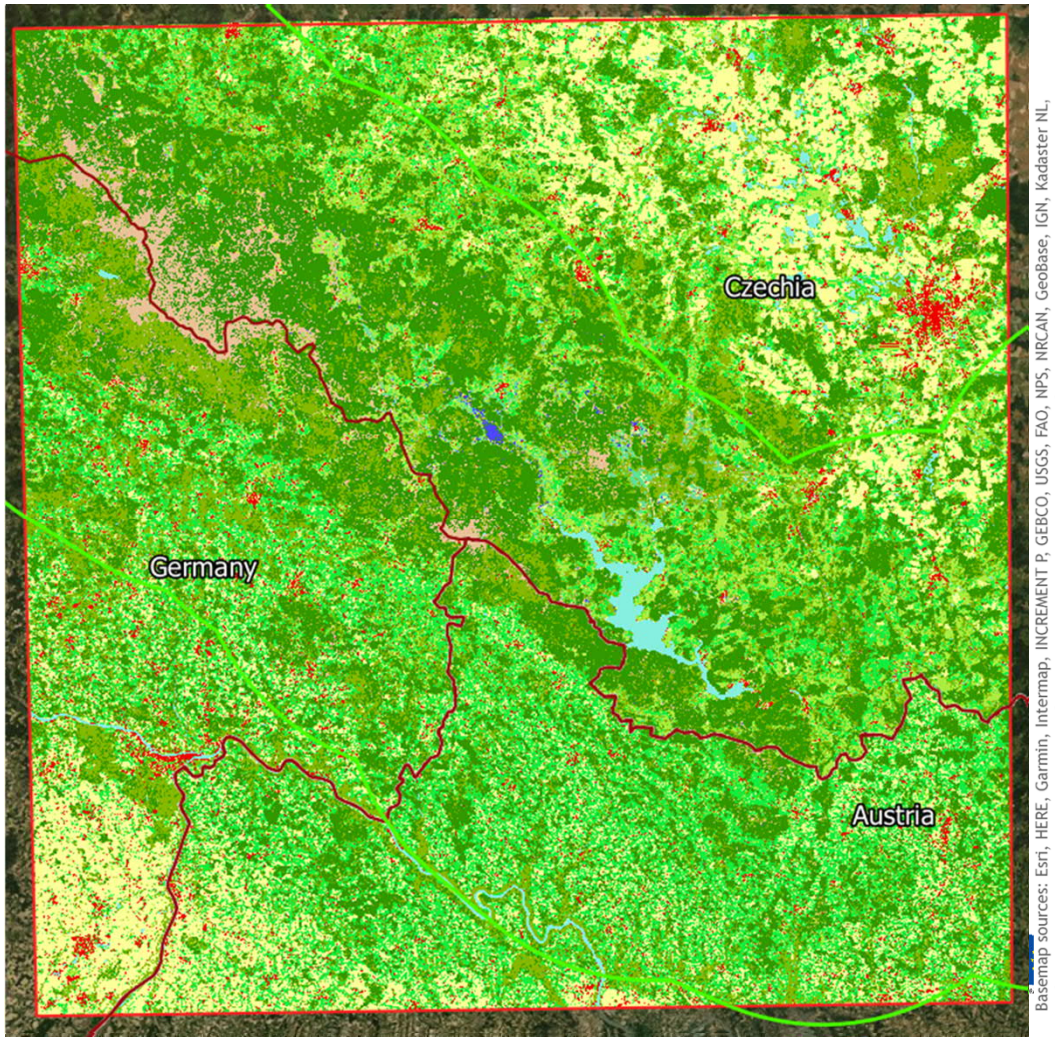
- Collect remote sensing data from the Sentinel-2 satellites
  - New data every 5 days, 10m resolution
- Time series of 2017/18:
  - Multi-sprectral data (10 of 13 bands – RGB, NIR, SWIR, etc.)
  - Products (NDVI, Moisture Index, NDWI, LAI)
  - Elevation products (EU-DEM, Slope, Aspect)
- Collect reference data:
  - Existing data (biotope mappings, etc.) as training sets
  - Ground truthing as validation
- Pixel-based classification by machine learning
  - Random Forest Classifier



Broader Habitat Types of PR 1 "Bavarian Forest-Mühlviertel-Šumava"

- Classification system for natural and anthropogenic land cover types (according to BUNCE et al. 2008, 2011)
- e.g. bogs, rivers, different kind of grasslands,...

C1 - Inland surface waters
D - Mires, bogs and fens
E1 - Dry grasslands
E2.6 - Agriculturally-improved, re-seeded and heavily fertilised grassland
E2b - Mesic grassland, medium intensive
Permanent mesotrophic pastures and aftermath-grazed meadows
E3 - Seasonally wet and wet grasslands
G1 - Broadleaved deciduous woodland
G3 - Coniferous woodland
G5.8/E5 - Woodland fringes and clearings and tall forb stands
I1 - Arable land and market gardens - intensive
Ja - Constructed, industrial and other artificial habitats



Transnational approach

- Comprehensive dataset needed along the entire EGB

→ EUNIS habitat classification (100m res.)

- Thematic resolution: EUNIS Level 1&2 (→ broadleaved deciduous forests, coniferous forests, mesic grassland, etc.)

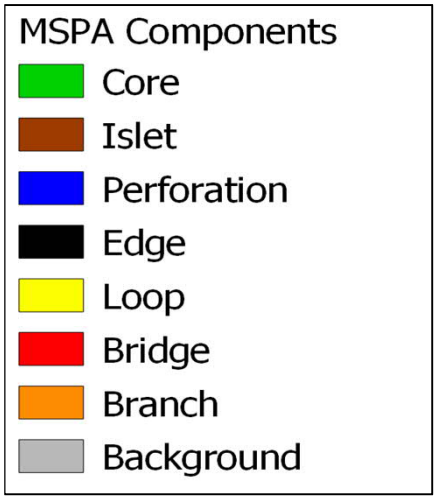
→ Translation to the Broader Habitat Types for further analysis

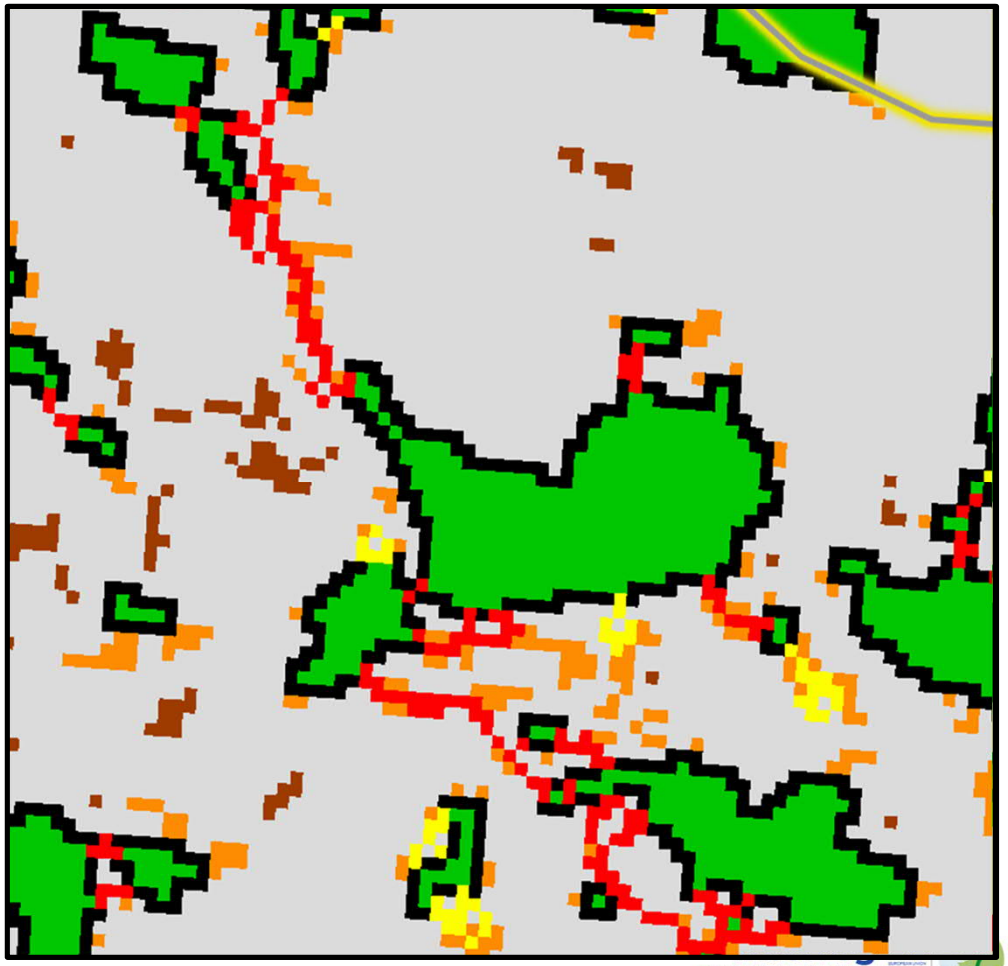
Analysis of Connectivity

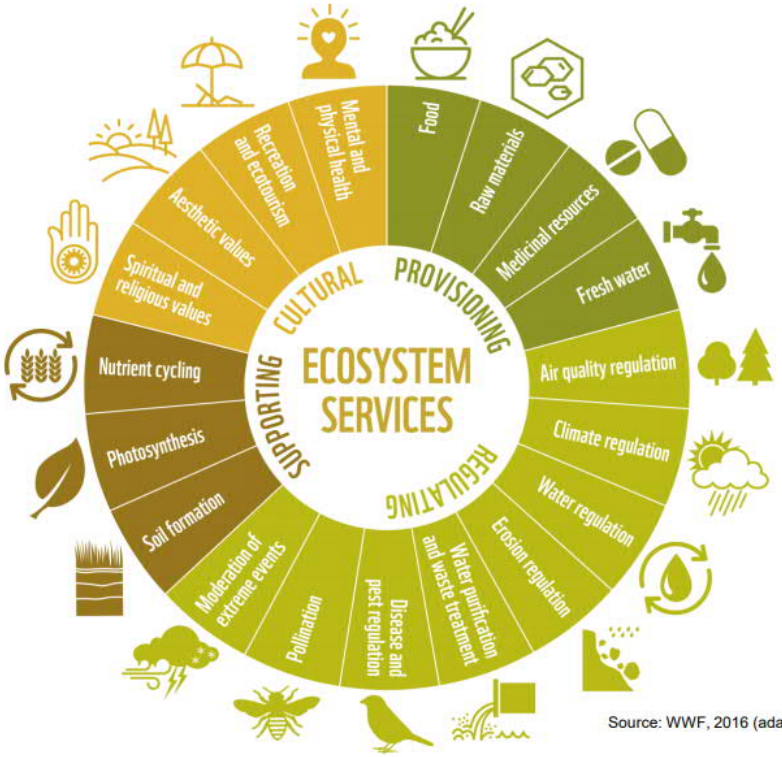
https://forest.jrc.ec.europa.eu/en/activities/lpa/gtb/

- free software package by the Joint Research Centre (JRC) of the European Commission (Vogt & Riitters, 2017)
- Data input: binary raster image (BHTs of interest = foreground, other BHTs = background)
- Morphological Spatial Pattern Analysis (MSPA)
  → describes the geometry, connectivity & spatial arrangement of image components (Vogt et al., 2007)
- Classification in one of 7 MSPA categories
- In our case: Broader Habitat Types (all or specific habitats)

Example:
Connectivity analysis of
broadleaved & coniferous forests







Source: WWF, 2016 (adapted from Millennium Ecosystem Assessment, 2005)

- all goods and services that landscapes provide for sustaining life as well as benefit for human well-being
- includes potentials, materials and processes of the nature (e.g. raw materials, biomass, biodiversity etc.)
- services of cultural elements and constructions that come into being through human creation (e.g. agriculture, buildings, infrastructure etc.)
- Indicator for the functional quality of Broader Habitat Types







Analysis of Functionality

- Capacity Matrix of Ecosystem Services (ESS) linked to the BHTs

  →describes the functional quality & highlights benefits for human well-being

  - 30 single ESS (Climate regulation, Refugium function, Genetic resources, etc.)
  - 5 Main services (Regulation, Habitat, Production, Information & Carrier functions)
  - Total amount of all ESS = Total Function Value

TOTAL function value

= total amount of capacity of all landscape services

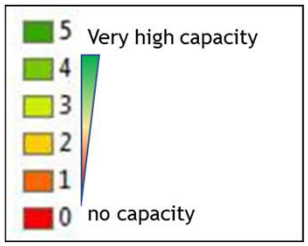
→ indicator for multifunctionality of GI and landscape elements

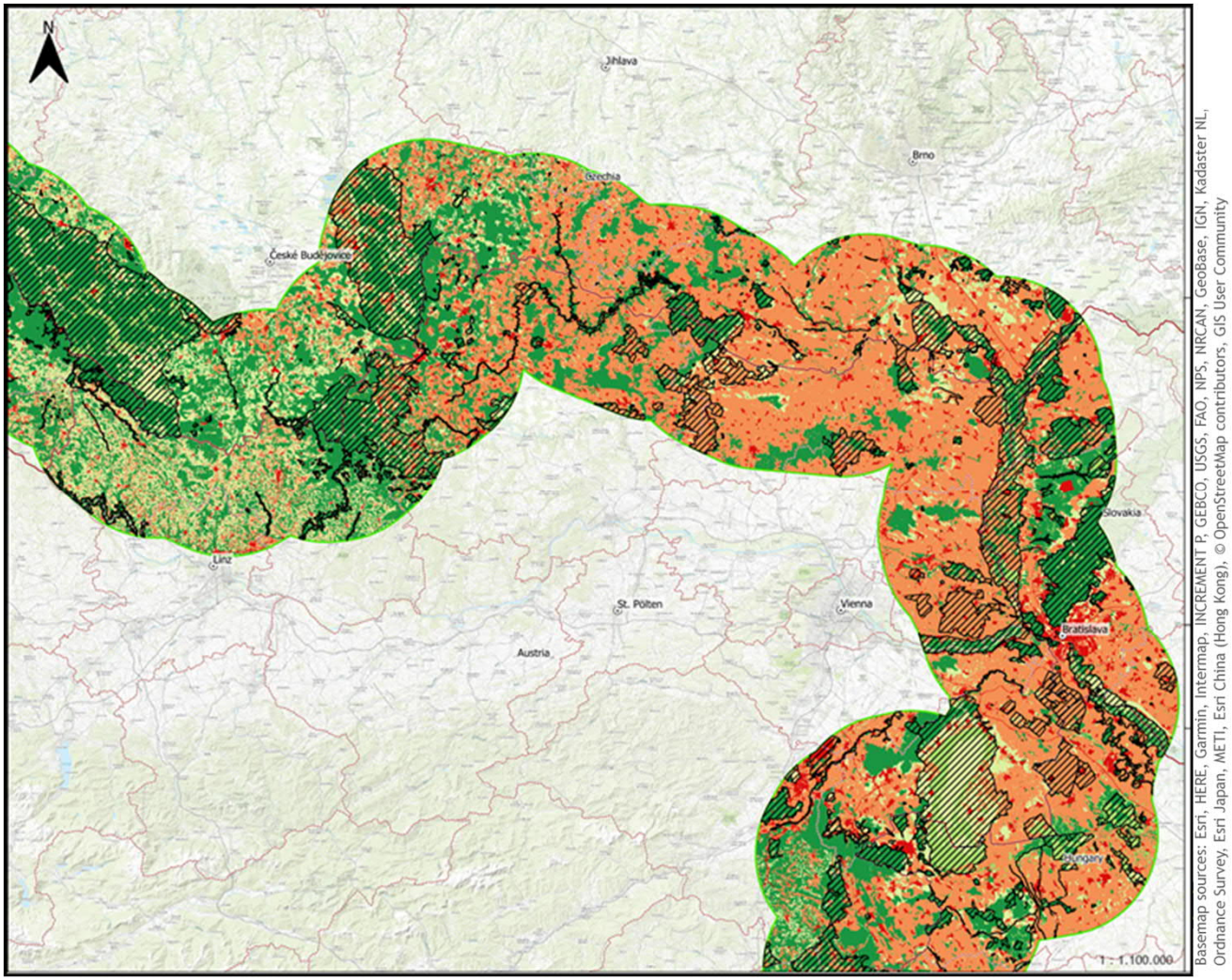
Σ Regulation services
Σ Habitat services
Σ Provision services
Σ Information services
Σ Carrier services

= TOTAL FUNCTIONAL VALUE

BHT Code	BHT_	C Code		ion functions	ulation	egulation	nce prevention	gulation	pply	ntion	ation	egulation	eatment	n	l control	functions	n function	function	ion functions		erials	esources	l resources	tal resources	ion functions	information	on	and artistic information	and historic information	and education	functions	Habitation	Cultivation	Energy-conversion	Mining	Waste disposal	Transportation	Tourism-facilities	Total Function Value
C1	Inland surface waters - sta																														0	0	3	0	0	3	3	69
C2	Inland surface waters - wa																														0	0	4	0	0	3	3	70
C3	Lithoral zone of inland wate																														0	0	0	1	0	0	1	63
C3/E5	Wetlands with reed, tall her																														0	0	0	1	0	0	1	63
D	Mires, bogs and fens																														0	0	2	2	0	0	1	60
E1	Dry grasslands																														0	1	0	0	0	0	1	67
E2a	Mesic grassland, intensive																														0	5	0	0	0	0	1	51
E2b	Mesic grassland, medium i																														0	1	0	0	0	0	1	67
E2c	Mesic grassland, unmanag																														0	1	0	0	0	0	1	67
E3	Seasonally wet and wet gra																														0	1	0	0	0	0	1	67
E5	Woodland fringes and clea																														0	1	0	0	0	0	0	63
E7	Sparsely wooded grassland																														0	3	3	0	0	0	1	54
F3.1	Temperate thickets and sc																														0	0	1	0	0	0	1	69
F4.2	Dry heaths																														0	0	1	0	0	0	1	69
F9	Riverine and fen scrubs																														0	0	1	0	0	0	1	69
FA	Hedgerows																														0	5	0	0	0	0	1	51
G1	Broadleaved deciduous w																														0	1	1	0	0	0	2	79
G1.D	Fruit and nut tree orchards																														0	5	0	0	0	0	1	40
G3	Coniferous woodland																														0	1	1	0	0	0	2	78
G4	Mixed deciduous and conif																														0	1	1	0	0	0	2	77
G5.1/FA	Lines of trees or hedgerow																														0	1	0	0	0	0	0	63
G5.8	Recently felled areas																														0	1	0	0	0	0	0	63
H	Inland unvegetated or spar																														0	0	0	0	0	0	0	40
J1a	Arable land and market ga																														0	5	0	0	0	0	0	31
J1b	Arable land and market ga																														0	3	1	0	0	0	2	49
J2	Cultivated areas of garden																														1	4	0	0	0	0	1	39
J3	Extractive industrial sites																														0	0	0	5	2	0	0	4
J4	Transport networks and ot surfaced areas																														0	0	0	0	0	5	2	8
J6	Waste deposits																														0	0	0	0	5	0	0	3
Ja	Constructed, industrial and other artificial habitats - with significant green spaces		112	Discontinuous urban fabric	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	2	3	3	4	2	0	1	4	0	1	0	0	3	2	18
Jb	Constructed, industrial and other artificial habitats - high imperviousness		111	Continuous urban fabric	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3	3	4	2	0	2	5	0	1	0	0	3	2	16

Example:
Regulation functions at the AT section of the EGB





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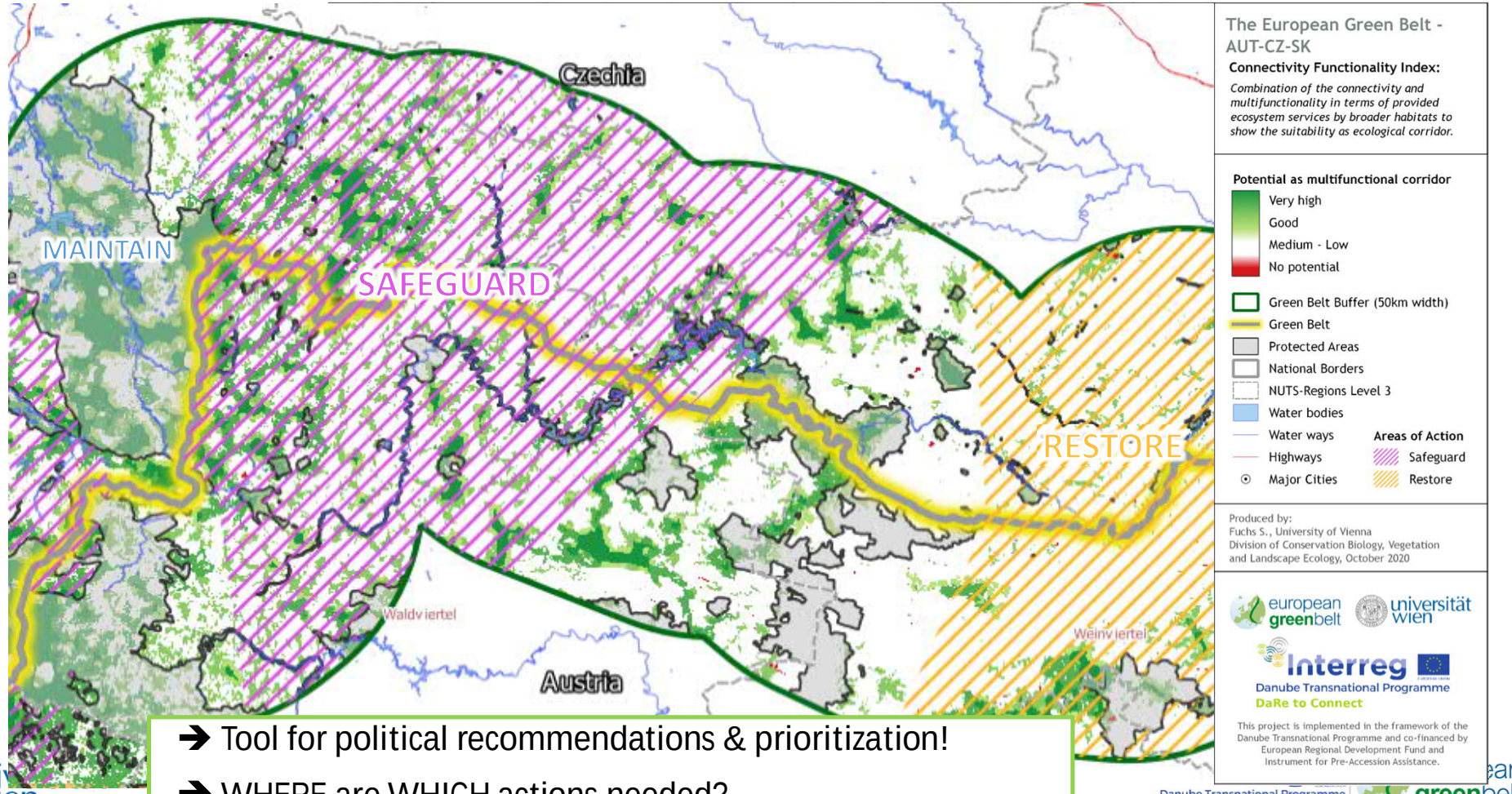
Mainstreaming Ecological Connectivity – Challenges, Ideas & Possible Solutions



➔ Tool for political recommendations & prioritization!

➔ WHERE are WHICH actions needed?

Achievements

- Pilot regions:
  - Broad awareness raising for regional stakeholders
  - Mapping and Connectivity analysis
  - Detailed connectivity concepts
  - Implementations (anchored in national policy (SK), barriers removed (SI), basis for other projects)
- Transnational corridor analysis:
  - Computation of potential multifunctional corridors via Connectivity-Functionality Index
- Identification of 15 Areas of Action on transboundary level:
  - Safeguarding or restoring Green Infrastructure
  - Crucial for future development of ecological corridors & ecosystem-service
- Results are mainstreamed via a D2C transnational strategic vision

Lessons learnt...

- Switch of all interaction to the online format due to COVID-19:
  - Partner meetings, Scientific Conference, Final Conference, etc.
  - Many technical possibilities to communicate digitally
  - But: practical implementation and general exchange in person hard to replace
- Sentinel-approach requires a lot of qualitative data on habitats
  - Broad range of landscape along the PRs of the EGB
  - Many different data sets + new mapping from the project partners
  - → sound trainings data and thus classification results
  - The more data, the better!

Thank you for your attention!

Contact:

Interreg Danube Transnational Programme DaRe to Connect

DaRe to Connect

www.interreg-danube.eu/d2c

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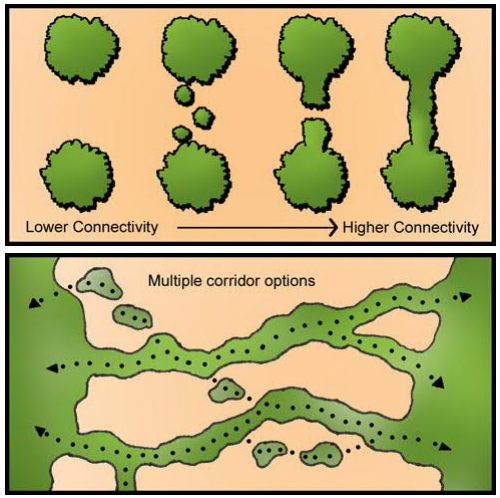
Ecological corridors

- Ecological corridors are essential for a functioning network:
  - Enable species migration
  - Exchange between populations
  - Maintain biodiversity (genetical, taxonomic, ecosystemic, functional)

➔ Preservation of species and habitats

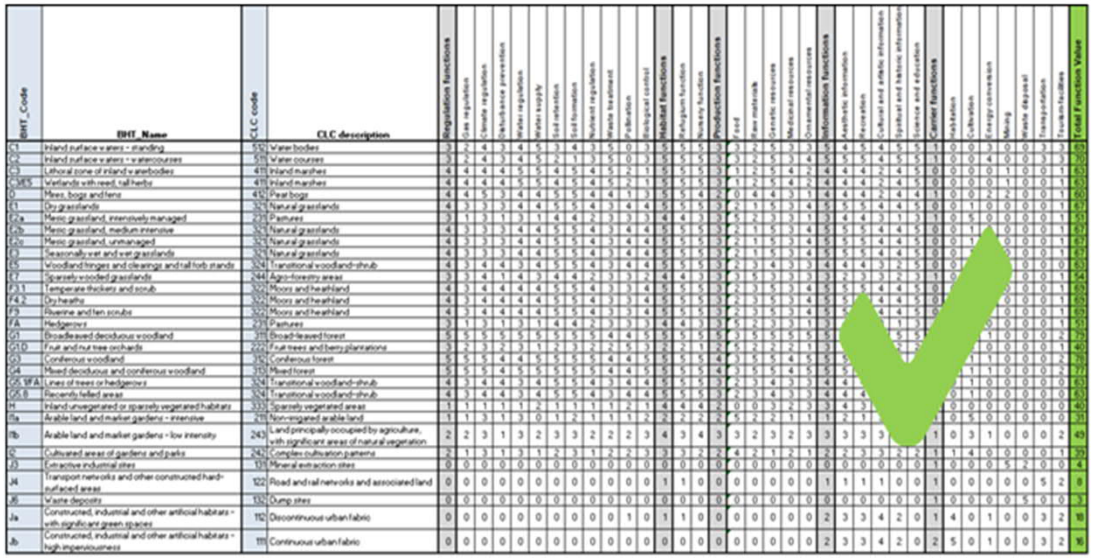
- Stepping Stones – Continuous Corridors



Source: USDA National Agroforestry Center

Specific objectives (WP3)

- Enhancement of connectivity of Natura 2000-areas along the Green Belt in the Danube Region (corridor of 50 km)
- Identification of suitable ecological corridors between and areas for the improvement of connectivity of protected areas
  - analysis of the current connectivity of the Natura 2000-network
  - and the areas between Natura 2000 sites
- Analysis of suitable transnational ecological corridors
  - potential for implementation
  - provision of ecosystem services (ESS)



HNT_Code	HNT_Name	CLC code	CLC description	Regulation functions														Habitat functions			Production functions					Information functions						Carrier functions								Total Function Value
C1	Inland surface waters - standing	512	Water bodies	3	2	4		3	4	5		4						5			3					4	4	5				0	0	0	3		1	0	0	69
C2	Inland surface waters - watercourses	511	Water courses	3	2	4		3	4	5	2	1	3	5	0	0	3	5	5	5	3	2	5	3	4	5	5	5	4	5	5	0	0	0	4	0	0	0	1	69
C3	Littoral zone of inland waterbodies	411	Inland marshes	4	4	4	4	5	5	4	5	4	5	2	1	5	5	5	5	3	2	5	4	2	4	4	4	4	2	4	5	0	0	0	0	1	0	0	1	69
C4/5	Wetlands with reed, tall herbs	411	Inland marshes	4	4	4	4	5	5	4	5	4	5	2	1	5	5	5	5	3	2	5	4	2	4	4	4	4	2	4	5	0	0	0	0	1	0	0	1	69
D	Mires, bogs and fens	412	Peat bogs	4	4	5	3	4	4	5	5	4	4	3	3	5	5	4	2	5	4	3	5	3	4	4	4	4	2	4	4	0	0	0	0	0	0	0	1	69
E1	Dry grasslands	321	Natural grasslands	4	3	3	3	4	4	5	5	4	4	3	4	4	5	5	5	3	2	5	4	3	5	4	5	5	4	4	5	0	0	0	0	0	0	0	1	69
E2a	Mesic grassland, intensively managed	231	Pastures	3	3	3	3	3	3	4	4	2	3	3	3	4	4	5	5	3	2	5	4	3	5	4	4	5	4	4	5	0	0	0	0	0	0	0	1	69
E2b	Mesic grassland, medium intensive	321	Natural grasslands	4	3	3	3	4	4	5	5	4	4	3	4	4	5	5	5	3	2	5	4	3	5	4	5	5	4	4	5	0	0	0	0	0	0	0	1	69
E2c	Mesic grassland, unmanaged	321	Natural grasslands	4	3	3	3	4	4	5	5	4	4	3	4	4	5	5	5	3	2	5	4	3	5	4	5	5	4	4	5	0	0	0	0	0	0	0	1	69
E3	Seasonally wet and wet grasslands	321	Natural grasslands	4	3	3	3	4	4	5	5	4	4	3	4	4	5	5	5	3	2	5	4	3	5	4	5	5	4	4	5	0	0	0	0	0	0	0	1	69
E5	Woodland fringes and clearings and tall forb stands	324	Transitional woodland-shrub	4	3	4	4	3	4	5	5	4	4	3	4	4	5	5	5	3	2	5	4	3	5	4	4	4	4	4	5	0	0	0	0	0	0	0	1	69
E7	Sparsely wooded grasslands	244	Agro-forestry areas	3	3	4	3	4	3	4	4	2	3	3	2	4	4	3	3	3	2	5	3	2	5	3	2	3	2	3	3	0	0	0	0	0	0	0	1	64
F3.1	Temperate thickets and scrub	322	Moors and heathland	4	3	4	4	4	4	5	5	4	4	3	3	4	5	5	5	3	2	5	4	3	5	4	5	5	4	4	5	0	0	0	0	0	0	0	1	69
F4.2	Dry heaths	322	Moors and heathland	4	3	4	4	4	4	5	5	4	4	3	3	4	5	5	5	3	2	5	4	3	5	4	5	5	4	4	5	0	0	0	0	0	0	0	1	69
F9	Riverine and fen scrubs	322	Moors and heathland	4	3	4	4	4	4	5	5	4	3	3	4	4	5	5	5	3	2	5	4	3	5	4	5	5	4	4	5	0	0	0	0	0	0	0	1	69
FA	Hedgerows	231	Pastures	3	3	3	3	3	3	4	4	2	3	3	3	4	4	3	3	3	2	5	3	2	5	3	2	3	2	3	3	0	0	0	0	0	0	0	1	64
G1	Broadleaved deciduous woodland	311	Broad-leaved forest	5	5	5	5	5	5	5	5	5	4	4	5	5	5	5	5	3	2	5	5	5	5	5	5	5	4	5	5	0	0	0	0	0	0	0	2	82
G1.D	Fruit and nut tree orchards	222	Fruit trees and berry plantations	3	2	3	3	3	3	3	2	2	2	2	1	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	0	0	0	0	0	0	0	1	49
G3	Coniferous woodland	312	Coniferous forest	5	5	5	5	5	5	5	5	5	4	4	5	5	5	5	5	3	2	5	5	5	5	5	5	5	4	5	5	0	0	0	0	0	0	0	2	82
G4	Mixed deciduous and coniferous woodland	313	Mixed forest	5	5	5	4	5	5	5	5	5	4	4	5	5	5	4	5	3	2	5	4	3	5	4	5	5	4	4	5	0	0	0	0	0	0	0	1	69
G5.WA	Lines of trees or hedgerows	324	Transitional woodland-shrub	4	3	4	4	3	4	5	5	4	4	3	4	4	5	5	5	3	2	5	4	3	5	4	4	4	4	4	5	0	0	0	0	0	0	0	1	69
G5.B	Recently felled areas	324	Transitional woodland-shrub	4	3	4	4	3	4	5	5	4	3	3	4	4	5	5	5	3	2	5	4	3	5	4	4	4	4	4	5	0	0	1	0	0	0	0	1	69
H	Inland unvegetated or sparsely vegetated habitats	333	Sparsely vegetated areas	1	1	1	1	1	1	2	1	1	1	2	1	4	4	2	1	3	2	2	3	3	3	3	3	3	3	3	3	0	0	0	0	0	0	0	1	46
I1a	Arable land and market gardens - intensive	211	Non-irrigated arable land	1	1	3	1	3	0	1	2	1	1	1	2	2	1	2	2	2	1	2	2	1	2	1	1	1	1	1	1	0	5	0	0	0	0	0	0	46
I1b	Arable land and market gardens - low intensity	243	Land principally occupied by agriculture, with significant areas of natural vegetation	2	2	3	1	3	2	3	3	2	2	2	3	4	3	4	3	3	2	3	2	3	3	3	3	3	1	1	0	3	1	0	0	0	2	49
I2	Cultivated areas of gardens and parks	242	Complex cultivation patterns	2	1	3	1	3	1	2	3	1	2	2	3	3	3	2	2	4	2	1	2	1	2	2	3	3	2	2	2	1	1	4	0	0	0	0	1	46
I3	Extractive industrial sites	131	Mineral extraction sites	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	2	0	0	0	4
J4	Transport networks and other constructed hard-surfaced areas	122	Road and rail networks and associated land	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	1	1	1	0	0	1	0	0	0	0	5	2	0	8
J6	Waste deposits	132	Dump sites	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	5
Ja	Constructed, industrial and other artificial habitats - with significant green spaces	112	Discontinuous urban fabric	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	2	3	3	4	2	0	1	4	0	1	0	0	3	2	18
Jb	Constructed, industrial and other artificial habitats - high imperviousness	111	Continuous urban fabric	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3	3	4	2	0	2	5	0	1	0	0	3	2	35

1. Basis for capacity values: existing matrix for the whole of Europe by Stoll et al. (2015)
2. First round of expert based revision by D2C partners (group discussion)
3. Second round of expert based validation by D2C partners (consensus)
4. Final matrix of ecosystem services for the European Green Belt

Connectivity-Functionality Index (CFI)

- Combination of the analyses results

→ CFI: Indicator for areas with high potential as multifunctional corridor between protected areas

- Elements of high functional value & connecting importance

Areas of Action

- SAFEGUARD:
  - located outside of existing large-scale protected areas
  - analyses indicate a high potential as a multifunctional corridor
  - future nature conservation measures should mainly focus on preserving the existing conditions to improve the ecological EGB network
  - might lead to the designation of new protected areas
  - prevention of converting valuable habitats to non-sustainable forms of land-use
  - potential within the area as multifunctional corridor be enhanced and amplified wherever possible

Areas of Action

- RESTORE:
  - points out larger areas that are both:
    - Outside of existing protected areas
    - Having a low potential as a multifunctional corridor
  - future implementation of nature conservation measures should focus on:
    - Reinstallation of functional elements for the ecological network
    - Restauration of functionality of the existing habitats
  - considering existing valuable landscape elements as well

D2C transnational strategic vision

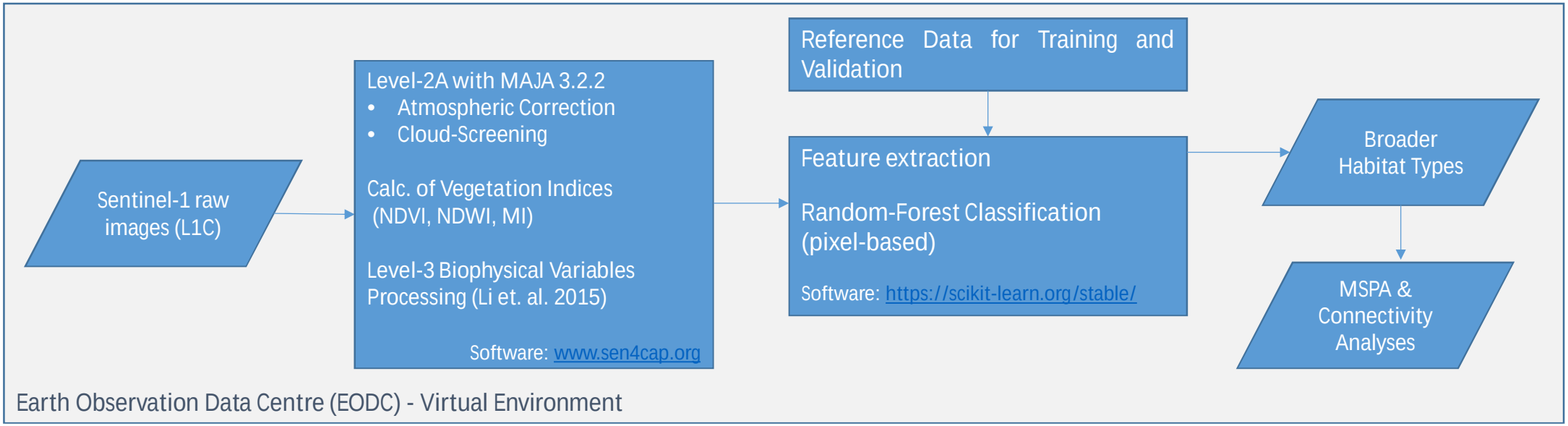
- European Green Belt as Focal Region for Implementation of Policy Strategies (Biodiversity Strategy, EUSDR PA 6)
- Implementation of a TEN-G/TEN-N scheme
- Enabling agriculture and forestry to act ecologically and economically sustainable
- Improve ecological Connectivity along the EGB under consideration of local and regional specifics of nature, landscape and culture
- Foster bi- and/or trilateral trans-boundary cooperation
- Bring forward a nomination of the European Green Belt as UNESCO world natural AND cultural heritage

CFI: Areas of Action

- Regions with a crucial role for the further development of connectivity
- 2 important categories that summarize areas with the need of different measures to:
  - Strengthen the network of protected areas
  - by enhancing ecological corridors
- ...along the European Green Belt in the Danube Region

Input Data & Workflow

- Sentinel-2 – L2A - Multispectral data (10 spectral channels)
- Vegetation Indices (NDVI, NDWI, MOISTURE INDEX)
- Biophysical Variables (LAI, FAPAR & FCOVER)



Accuracy Assessment

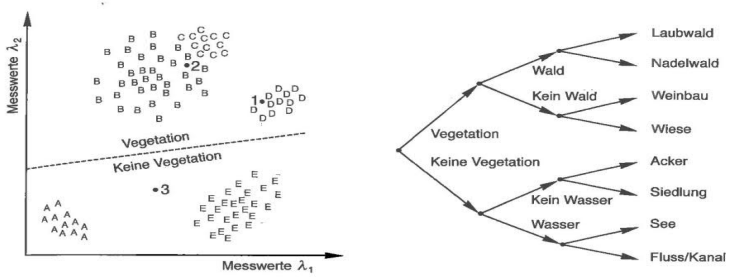
Classification \ Reference	1	2	3	4	5	6	7	8	9	10	11	12	UA
G3 - Coniferous woodland	380	0	0	0	10	0	0	2	0	0	0	2	0.96
E2b - Mesic grassland, medium intensive	0	68	2	8	0	0	0	23	2	0	0	1	0.65
E2.1 - Mesotrophic pastures and aftermath-grazed meadows	0	0	0	0	0	0	0	0	0	0	0	0	0.00
E3 - Seasonally wet and wet grasslands	0	0	1	3	0	0	0	0	1	0	0	1	0.50
G1 - Broadleaved deciduous woodland	5	3	0	0	295	3	0	1	0	0	0	3	0.95
C1 - Inland surface waters	0	0	0	0	0	61	1	0	0	0	0	0	0.98
Ja - Constructed, industrial and other artificial habitats	0	0	0	0	0	2	89	0	0	0	0	0	0.98
E2.6 - Agriculturally improved intensive grassland	1	75	6	12	2	1	0	627	5	8	0	0	0.85
E1 - Dry grasslands	0	0	0	0	0	0	0	1	0	0	0	1	0.00
I1 - Arable land and market gardens - intensive	0	0	0	3	0	1	2	13	1	303	2	2	0.93
D - Mires, bogs and fens	0	0	0	1	0	0	0	0	0	0	2	0	0.67
G5.8 - Recently felled areas	3	0	0	1	0	0	0	1	3	0	5	35	0.73
PA	0.98	0.47	0.00	0.11	0.96	0.90	0.97	0.94	0.00	0.97	0.22	0.78	
Σ reference samples	389	146	9	28	307	68	92	668	12	311	9	45	2084
												overall accuracy	0.89

RFmodel-parameters: ntree=1000, total nr. of input features=623, mtry=24

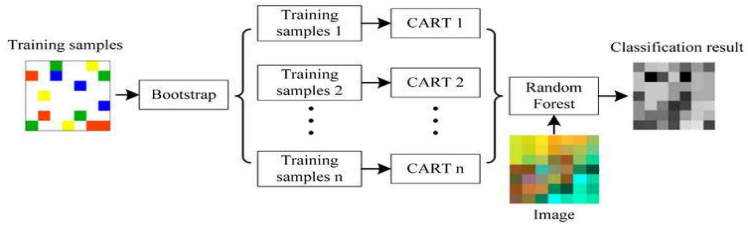
by Markus Pöchtrager (Uni Vie), Martin Neuwirth (UBA)

Random Forest Classification

- Random Forest (Breimann, 2001)
  - Creation of multiple non-correlating decision trees/classification trees.
  - Each tree counts as "one vote" for the resulting class
  - Importance measures: Mean Decrease Accuracy, Mean Decrease Gini



Source: Albertz (2007)



Source: Quanlong et.al. (2015)