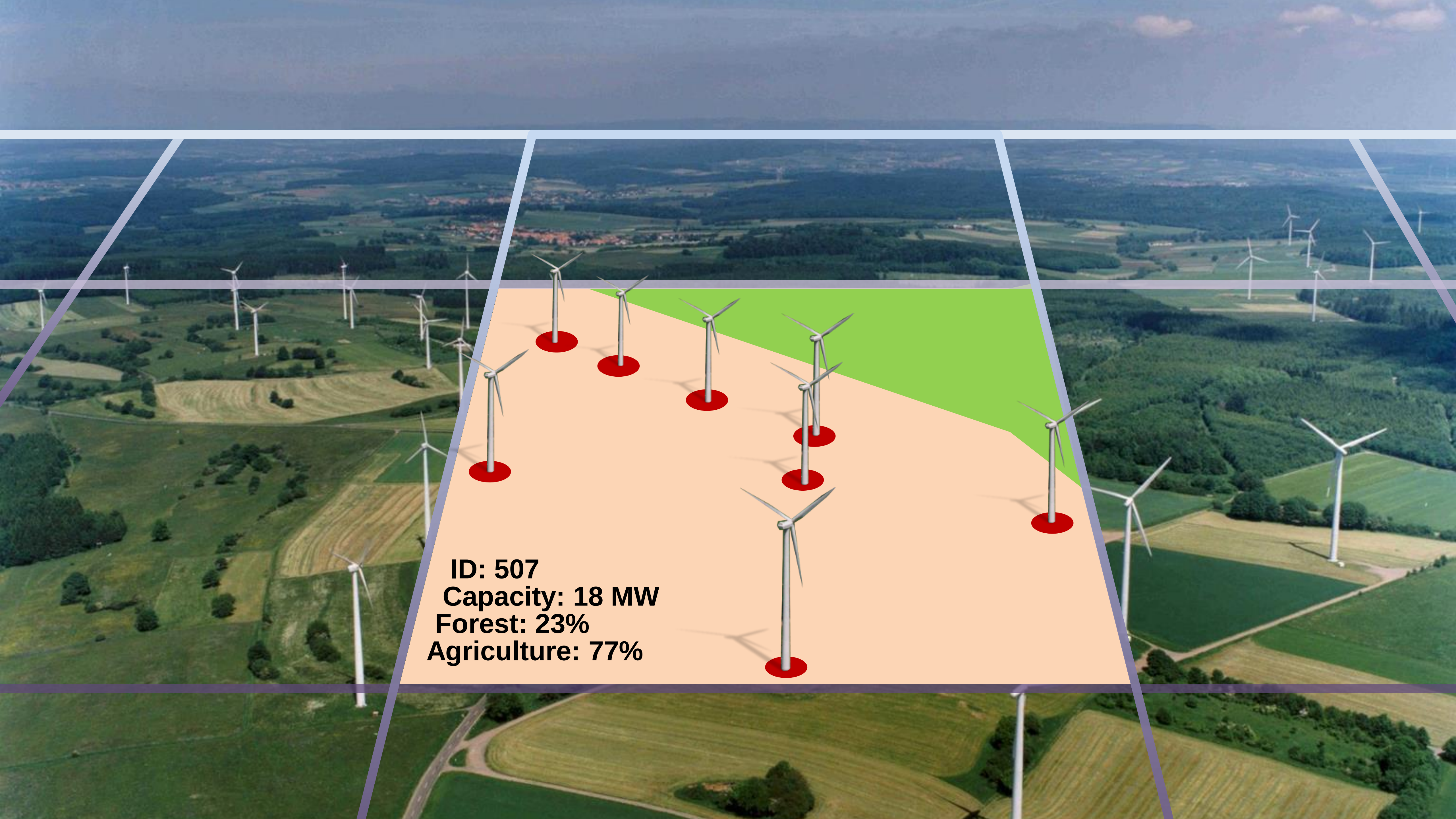
Wind power potential assessment for the Czech Republic based on Austrian and Danish site characteristics

Felix Nitsch[1,2], Johannes Schmidt[2], Stefan Höltinger[2]

UFZ EnergyDays Leipzig
24 September 2018

[1] Institute of Engineering Thermodynamics,
Energy System Analysis,
German Aerospace Center (DLR)

[2] Institute for Sustainable Economic Development,
University of Natural Resources and
Life Sciences, Vienna


ID: 507
Capacity: 18 MW
Forest: 23%
Agriculture: 77%


ID: 712
Forest: 30%
Agriculture: 70%

Research questions

Q1

What are the characteristics of today's wind power generation sites in terms of land use and site specifications?

Q2

What is the potential for future wind power expansion based on characteristics of installed wind power plants in the Czech Republic?

Q3

Following the renewable energy expansion scenarios from the literature, how do the requirements match with the availability of suitable land in Austria, Denmark and the Czech Republic?

Method overview

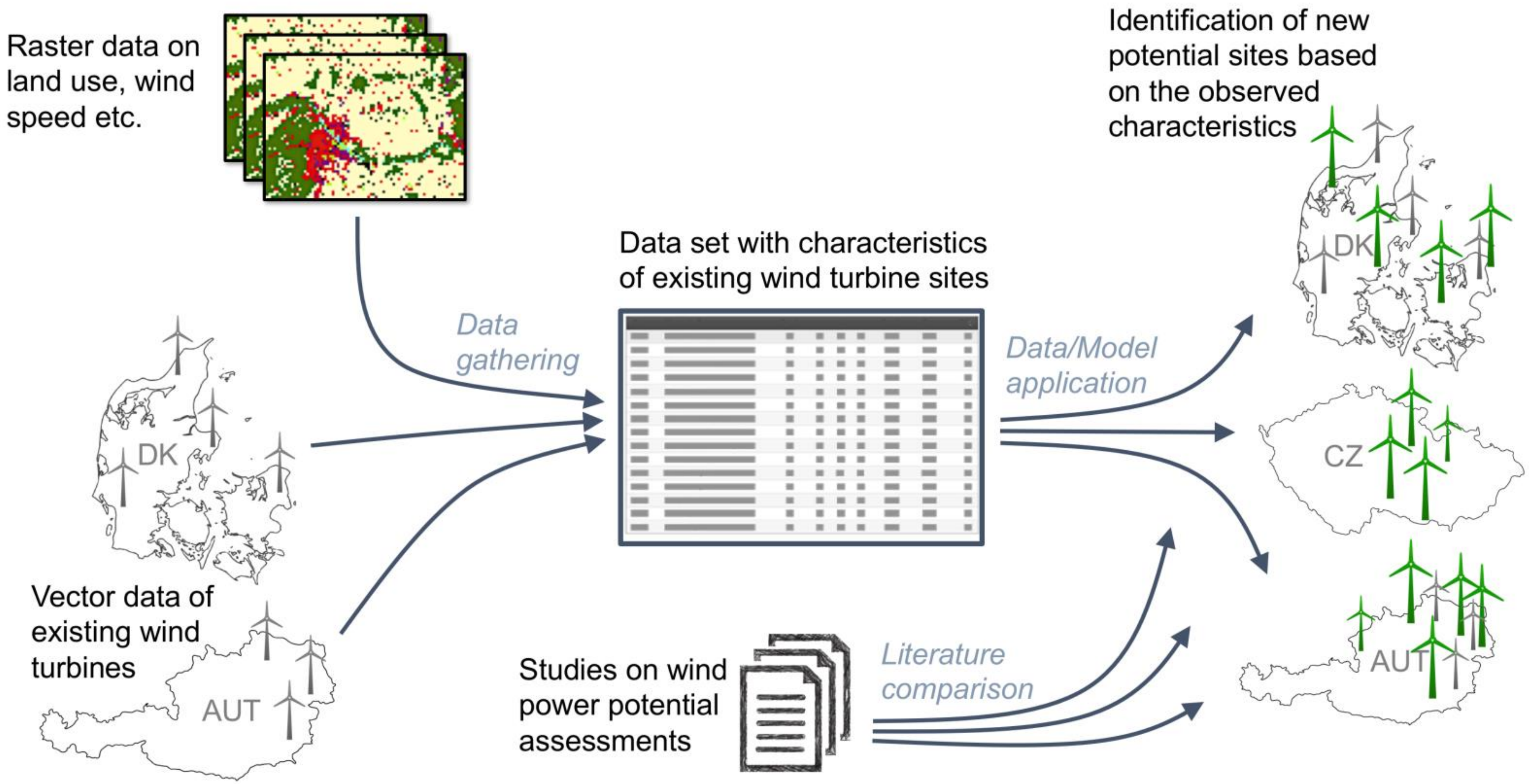


Fig.1: Schematic method overview

Material

Tab.1: Detailed description of materials used in the assessment

Name	Description	Area	Source	Format
Open Power System Data	Open source data set featuring information on location, capacity, year of installation, height, etc. of wind turbines in Denmark	Denmark	Open Power System Data (2017)	Vector
Austrian wind turbines	Data set featuring information on location, capacity, year of installation, height, etc. of wind turbines in Austria	Austria	Institute for Sustainable Economic Development (2017)	Vector
Wind speed	Mean wind speed in 100m und 200m height	World	International Renewable Energy Agency (2017)	Raster (1km)
Sea level	Digital elevation model	EU	European Environmental Agency (2017)	Raster (25m)
Land use	Land use in 2010 following the LUISA Modeling Plattform	EU	Lavalle (2014)	Raster (1km)
Population	Population distribution in 2010 following the LUISA Modeling Plattform	EU	Lavalle and Jacobs Crisioni (2014)	Raster (1km)
Natura2000	Natura2000 conservation areas	EU	European Environmental Agency (2018)	Vector
National parks	National parks, important wildlife and conservation areas	Denmark, Austria, Czech Republic	OpenStreetMap (2018)	Vector

Comparison of installed capacity densities

- Raster initialization
- Aggregation of installed wind turbine capacities
- Comparison between Austria & Denmark

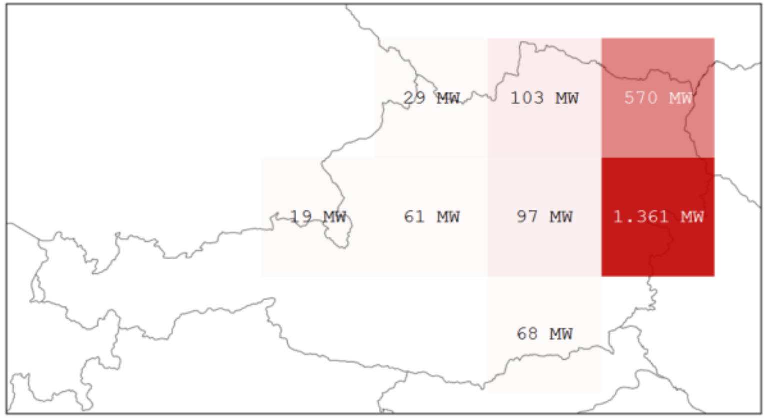


Fig.2: Exemplary density calculation for Austria

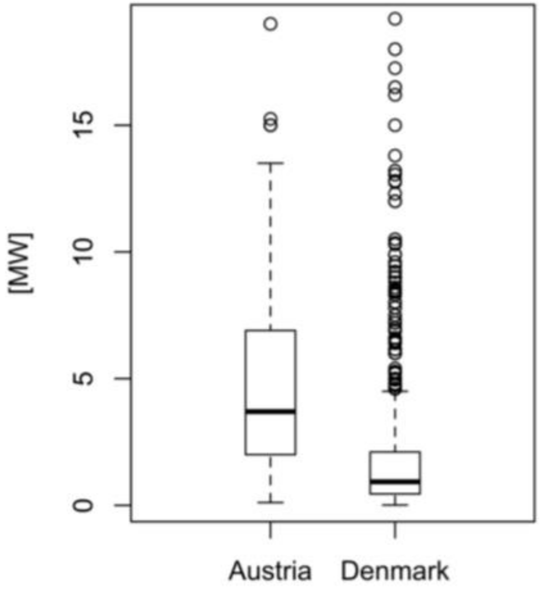


Fig.3: Installed densities of wind turbines in MW/km^2

Site characteristics

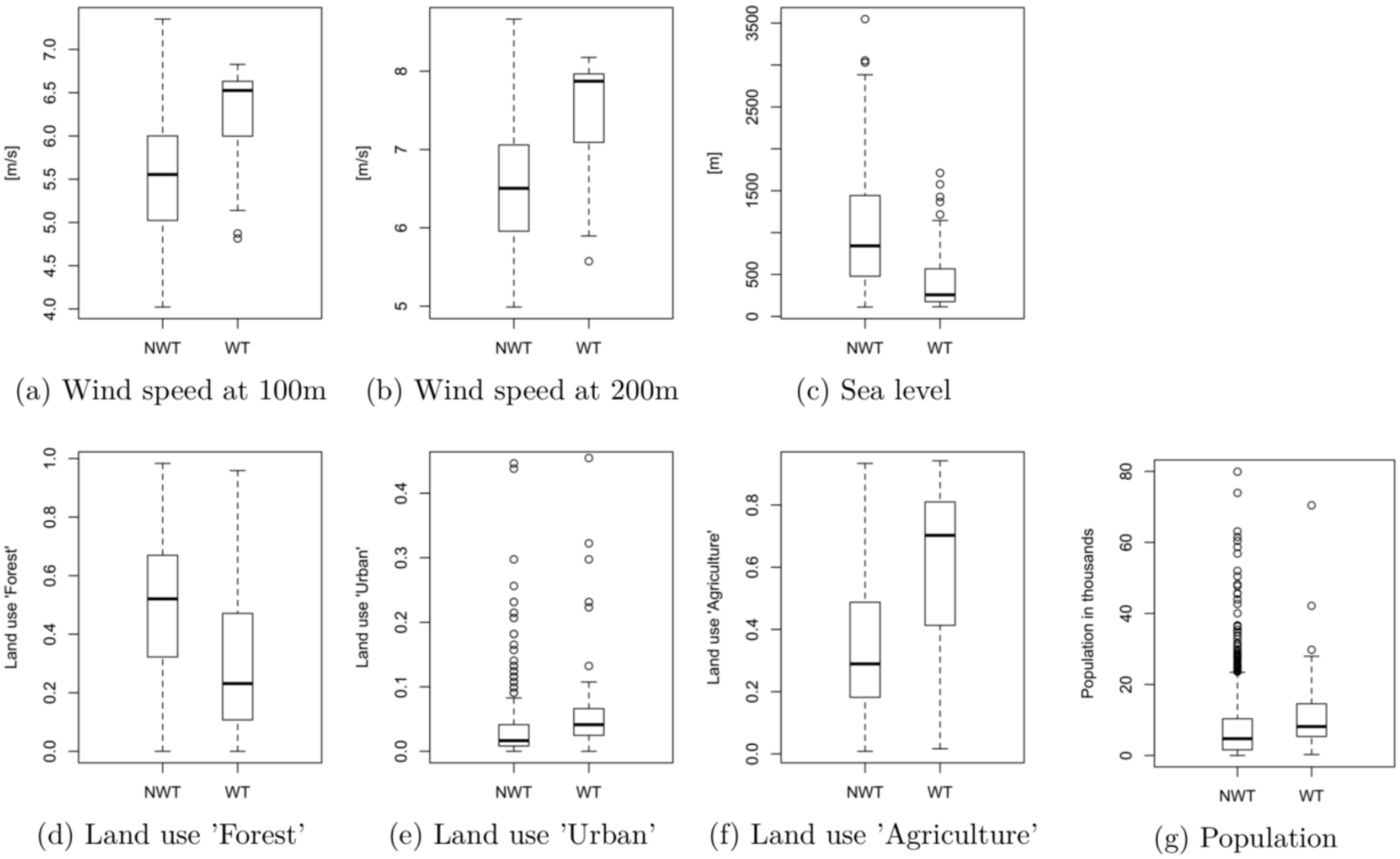


Fig.4: Site characteristics in Austria for raster cells with installed wind turbines (WT) and with no wind turbines (NWT)

Defining the main scenario

Raster cells currently without WT

have to pass the thresholds

Raster cells with WT

are defining the thresholds

$$mean(ws100_{no\_wind}) \geq mean(ws100_{wind})$$

$$mean(ws200_{no\_wind}) \geq mean(ws200_{wind})$$

$$mean(pop_{no\_wind}) \leq mean(pop_{wind})$$

$$mean(elevation_{no\_wind}) \leq mean(elevation_{wind})$$

$$mean(LU\_Agriculture_{no\_wind}) \leq mean(LU\_Agriculture_{wind})$$

$$mean(LU\_Forest_{no\_wind}) \geq mean(LU\_Forest_{wind})$$

$$mean(LU\_Urban_{no\_wind}) \leq mean(LU\_Urban_{wind})$$

$$mean(LU\_Wetlands_{no\_wind}) \leq mean(LU\_Wetlands_{wind})$$

$$mean(LU\_Water_{no\_wind}) \leq mean(LU\_Water_{wind})$$

$$NP_{no\_wind} \leq mean(NP_{wind})$$

$$N2000_{no\_wind} \leq mean(N2000_{wind})$$

$$NP_{no\_wind} + N2000_{no\_wind} = 0$$

- Differentiation between upper and lower boundary conditions
- Progressive subscenario including N2000 areas, conservative subscenario strictly excluding all conservation areas
- Cells matching all requirements are considered to be eligible

Reference scenario for Austria

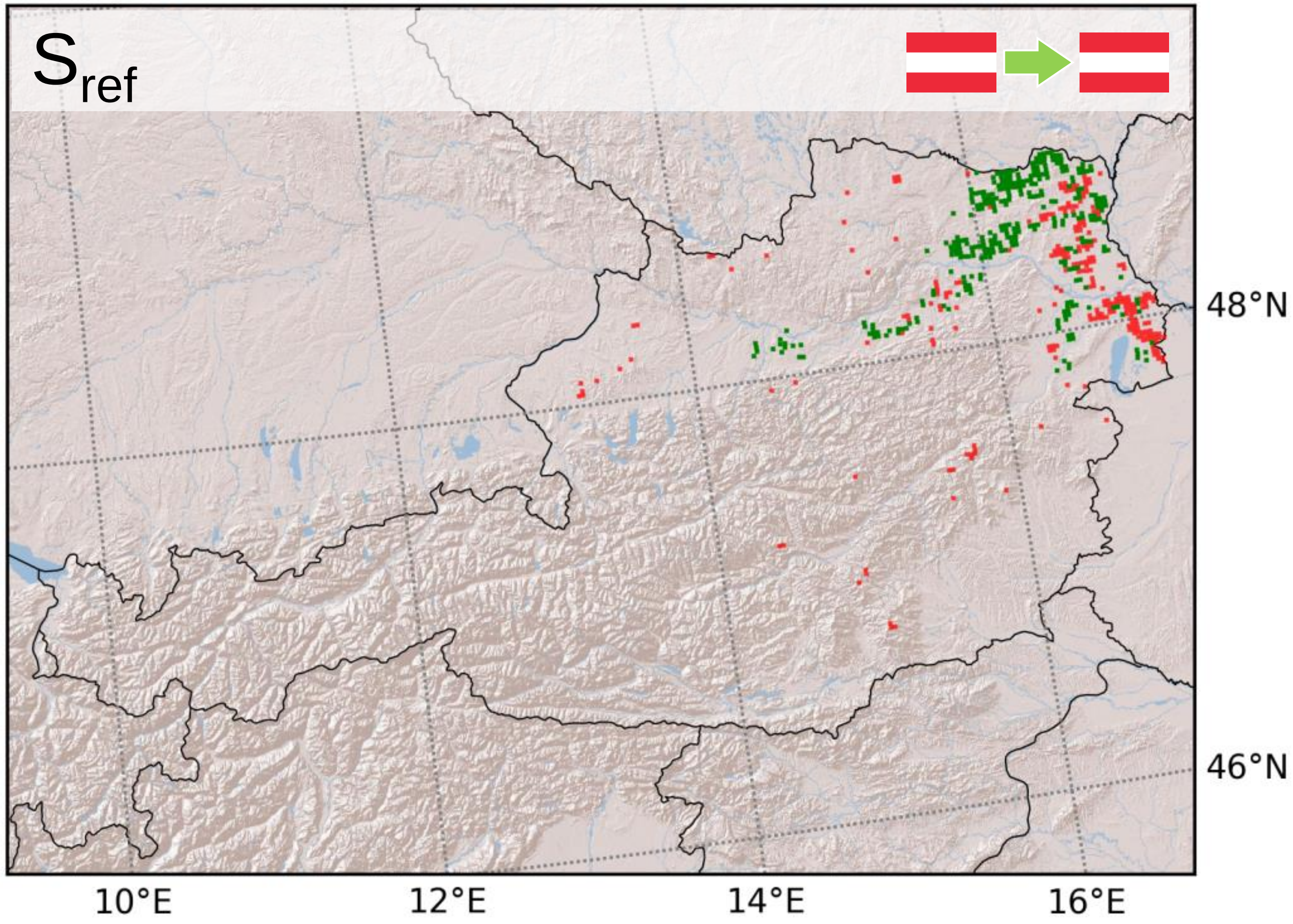


Fig.5: Current sites with wind turbines (red) and potentially areas for new wind turbines following the scenario (green)

Tab.2: Result of the reference scenario for Austria. New capacity is calculated by the multiplication of the mean density observed in Austria (4.79 MW/km^2). Results marked with „*“ exclude conservation areas.

Current area [km^2]	New area [km^2]	New capacity [MW]
479	1,175 | 1,125*	5,631 | 5,391*

2,800 MW (already installed) + 5,631 MW = 8,431 MW

Reference:
Jacobson et al. (2017) proposed 35,927 MW in a fully renewable system.

Main scenario for the Czech Republic

Tab.3: Result of the main scenario for the Czech Republic comparing the thresholds from Austrina and Danish site characteristics. New capacity is calculated by the multiplication of the mean density observed in Austria (4.79 MW/km^2). Results marked with „*“ exclude conservation areas.

New area Scenario S1 – AUT [km^2]	New area Scenario S2 – DK [km^2]	New capacity Scenario S1 – AUT [MW]	New capacity Scenario S2 – DK [MW]
769 | 704*	519 | 499*	3,685 | 3,374*	913 | 878*

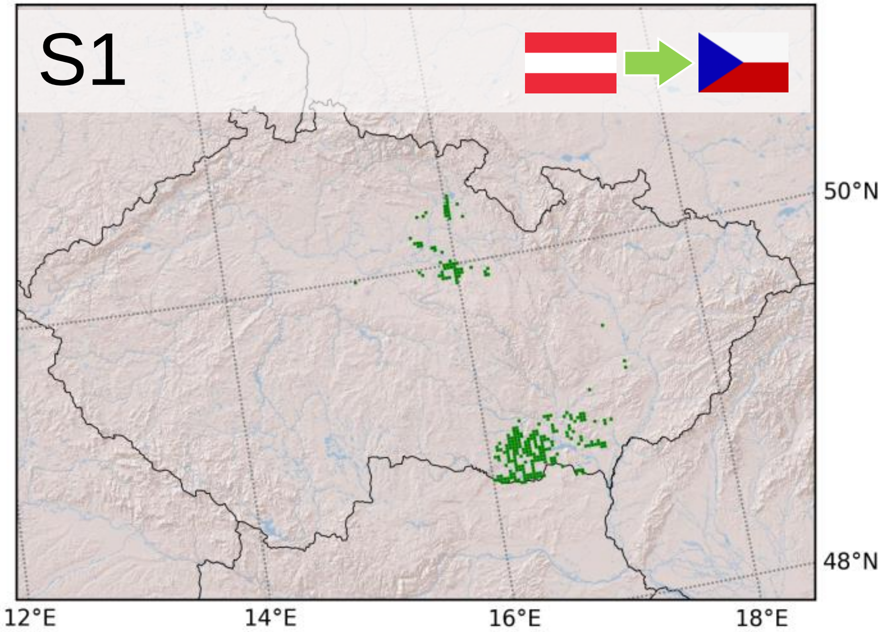


Fig.6: Potential areas for new wind turbines following the site characteristics observed in **Austria**

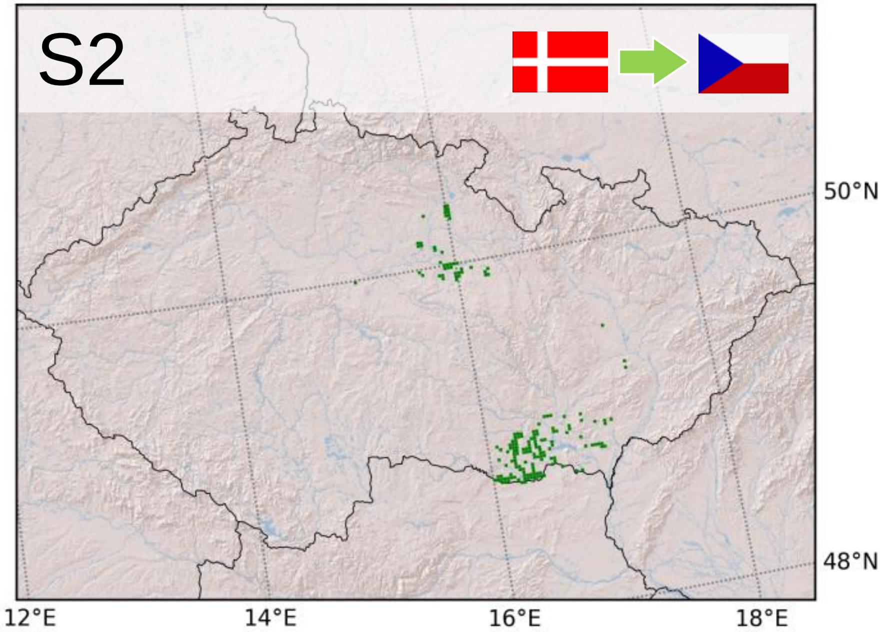


Fig.7: Potential areas for new wind turbines following the site characteristics observed in **Denmark**

300 MW (already installed) + 3,685 MW = 3,985 MW

Reference:
Jacobson et al. (2017) proposed 30,713 MW in a fully renewable system.

Spatial sensitivity analysis

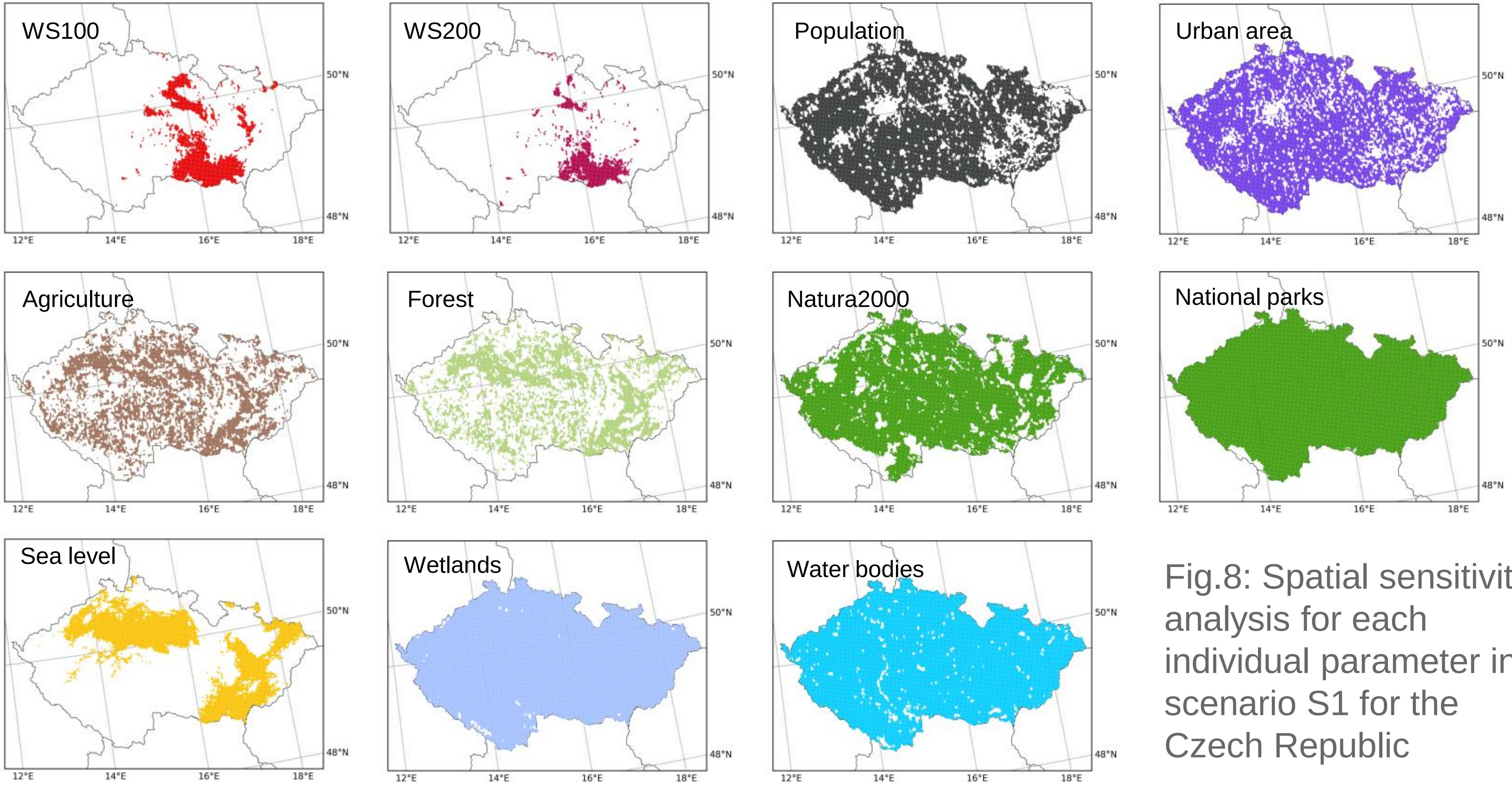


Fig.8: Spatial sensitivity analysis for each individual parameter in scenario S1 for the Czech Republic

Influence of a single parameter

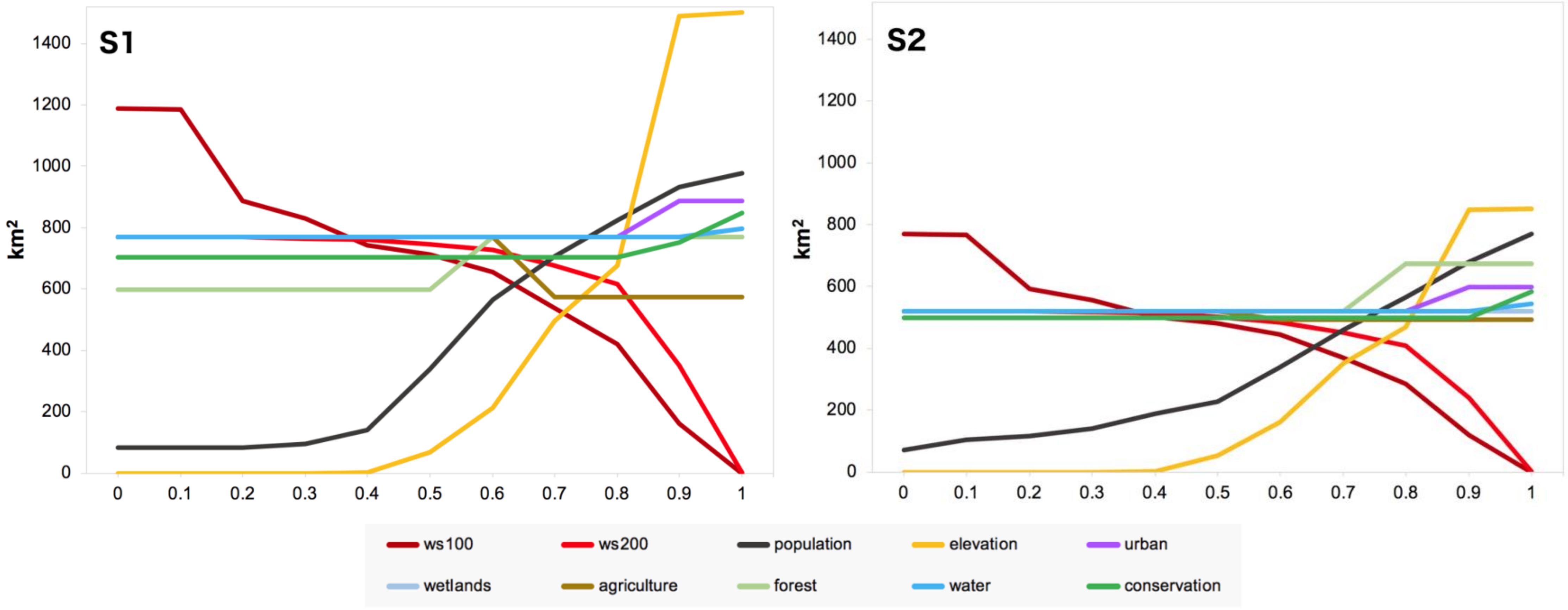


Fig.9: Comparison of single attributes in the scenario S1 (left) and S2 (right) showing the influence of a parameter on the resulting area suitable for wind power generation in km^2 with the respective percentile on the x-axis (i.e. 0.25 means 25% percentile)

Discussion

- Static & linear model without any feedback-loops (e.g. public opinion for WT can change)
- Early state of the model excluding additional attributes (e.g. land use changes, connection to the power grid, ownership structures etc.)
- Focus on a single technology without consideration of synergy effects, sector coupling
- Different starting point for Austria (only onshore WT) and Denmark (onshore & offshore WT)
- Technological improvements and turbine growth could change the results

Conclusion

- Alternative approach for wind power potential assessments
- Scalable for largest parts of the EU and after additional data gathering for most parts of the world
- Results show WT potential for the Czech Republic, however the proposed numbers for a fully renewable electricity system are ambitious
- Sea level, population densities and wind speeds are the main limiting characteristics for the Czech Republic
- New potential sites are identified in Austria and Denmark
- Exclusion of conservation areas slightly reduces new capacities

Thank you for your attention!

Felix Nitsch*,
Johannes Schmidt,
Stefan Höltinger

*felix.nitsch@dlr.de

Institute of Engineering Thermodynamics,
Energy System Analysis,
German Aerospace Center (DLR)

References

European Environmental Agency, 2017: Copernicus Land Monitoring Service - EU-DEM. European Environmental Agency, https://www.eea.europa.eu/data-and-maps/data/copernicus-land-monitoring-service-eu-dem (29/08/2018).

Institute for Sustainable Economic Development, 2017: Datensatz zu installierten Windradanlagen in Österreich.

International Renewable Energy Agency, 2017: Global Atlas for Renewable Energy. https://irena.masdar.ac.ae/ (29/08/2018).

Jacobson, M. Z., Delucchi, M. A., Bauer, Z. A., Goodman, S. C., Chapman, W. E., Cameron, M. A., Bozonnat, C., Chobadi, L., Clonts, H. A., Enevoldsen, P., et al. (2017). 100% clean and renewable wind, water, and sunlight all-sector energy roadmaps for 139 countries of the world. Joule, 1:108–121.

Lavalle, C., 2014: OUTPUT - Population distribution (LUISA Platform REF2014). Euro- pean Commission, Joint Research Centre, http://data.jrc.ec.europa.eu/dataset/jrc-luisa- population-ref-2014 (29/08/2018).

Lavalle, C. and Jacobs Crisioni, C., 2014: OUTPUT - Population distribution (LUISA Platform REF2014). European Commission, Joint Research Centre, http://data.jrc.ec.europa.eu/dataset/jrc-luisa-population-ref-2014 (29/08/2018).

Open Power System Data, 2017: A free and open platform for power system modelling. http://data.open-power-system-data.org/ (29/08/2018).

Open Street Map, 2018: Die freie Weltkarte. http://openstreetmap.org (29/08/2018).

Ryberg, D., Robinius, M., and Stolten, D., 2018: Evaluating land eligibility constraints of renewable energy sources in europe. 11:1246.

Photo Credits:

Photo with wind turbines: Hessen Energie, 2015: Kommunaler Windpark Helpershain https://www.hessenenergie.de/GBereiche/Wind/wind-kom/kom-kwph/KWP-Hel/L-Helpershain-G.jpg (29/08/2018).

Photo without wind turbines: Hellbühl, 2018: Das Dorf Hellbühl http://www.neuenkirch.ch/index.php?nav=3,20,23 (29/08/2018).

Appendix I

Table A.1: Typical constraint expressions for land eligibility analyses (Ryberg et al., 2018)

Constraint	Freq. %	Excludes		Data Source
Social and Political				
Settlements	87	below	500 m	CLC [23]
Urban Settlements	43	below	1000 m	EuroStat [65]
Roadways	55			
Main	23	below	200 m	OpenStreetMap [66]
Secondary	13	below	100 m	OpenStreetMap [66]
Airports	53			
Large and Commercial	6	below	5000 m	CLC [23], EuroStat [67]
Airfields	4	below	3000 m	CLC [23], EuroStat [67]
Agricultural Areas	45	below	50 m	CLC [23]
Railways	34	below	150 m	OpenStreetMap [66]
Power Lines	32	below	200 m	OpenStreetMap [66]
Industrial Areas	19	below	300 m	CLC [23]
Recreational Areas	17			
Tourism	8	below	800 m	OpenStreetMap [66]
Camping sites	4	below	1000 m	OpenStreetMap [66]
Leisure areas	4	below	1000 m	OpenStreetMap [66]
Mining Sites	15	below	100 m	CLC [23]
Physical				
Slope	68	above	10°	EU-DEM [63]
Water Bodies	62	below	300 m	CLC [23]
Lakes	28	below	400 m	HydroLAKES [68]
Rivers	25	below	200 m	EuroStat [69]
Coast	9	below	1000 m	CLC [23]
Woodlands	40	below	300 m	CLC [23]
Wetlands	30	below	1000 m	CLC [23]
Elevation	19	above	1800 m	EU-DEM [63]
Ground Composition	15			
Sandy Areas	6	below	1000 m	CLC [23]
Aspect	7	above	3°N	EU-DEM [63]
Conservation				
Protected FFH	79			
Habitats	42	below	1500 m	WDPA [64]
Birds Areas	33	below	1500 m	WDPA [64]
Biospheres	13	below	300 m	WDPA [64]
Wildernesses	6	below	1000 m	WDPA [64]
Protected Areas	64			
Landscapes	21	below	500 m	WDPA [64]
Reserves	17	below	500 m	WDPA [64]
Parks	28	below	1000 m	WDPA [64]
Monuments	9	below	1000 m	WDPA [64]
Technical Economic				
Resource	62			
Windspeed	45	below	4.5 m/s	Global Wind Atlas [70]
Irradiance	17	below	3.0 kWh/m^2 day	Global Solar Atlas [71]
Connection Distance	47	above	10 km	OpenStreetMap [66]
Access Distance	45	above	5 km	OpenStreetMap [66]