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Reduction of plant protection products in sensible areas in Germany in context of the SUR Proposal

Influence of data, methods and definitions on the assessment of agricultural land effected

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Summary

In agriculture, the application of plant protection products to cropland is important to prevent quality and yield reduction. The use of plant protection products implies negative effects on human health and the environment. Thus, a legal measure towards reducing the use of plant protection products is its restriction or ban especially in sensitive areas.

This is the first national study to use publicly and freely available geodata to access the area of agricultural land located in different types of sensitive areas according to the proposal for a new EU Regulation on the Sustainable Use of Plant Protection Products (SUR). We assess the impact of different scenarios for a German implementation. In this study we analyse publicly available geodata of CORINE land cover 5 ha of 2018 with geographic information systems (GIS) for different scenarios.

The results show that the impact of a pesticide ban or restriction for sensitive areas differs between regions and the type or combination of sensitive area. Using the CLC5-2018 data we estimate 19.6 million hectares of national agricultural area. Landscape Protection Area, Nature Parks and Water Protection Areas contain the largest proportion of agricultural land. A scenario which considers National Parks, Nature Reserves, Biosphere Reserves, Nature Parks, Natural Monuments, Landscape Protection Areas and Natura 2000 sites with Fauna-Flora-Habitat areas and Special Protected Areas for bird sanctuaries and Ramsar sites would affect 46.6% of the agricultural land use in Germany, ranging from 33.4% to 77.9% across different states.

Comparing our CLC5-2018 results to a similar study from 2023, which used LBM-DE as land use data, we find that there is little difference between the results of identical scenario definitions when expressed as proportions. Whereas different SUR scenario definitions can lead to significantly different outcomes.

Keywords

SUR, sensible areas, pesticides, spatial analysis

Introduction

Various crop protection practices are implemented in agriculture, including the use of pesticides, to prevent or decrease quality and yield reduction caused by plant diseases or insect pests, and to guarantee the production of food of exceptional quality (Cooper & Dobson, 2007).

Agriculture has a responsibility to evolve in order to ensure the protection of biodiversity (Tsiafouli et al., 2015) and to reduce negative effects of its practices on the environment (Geiger et al., 2010; Tang et al., 2021) and on human health (Kim et al., 2017; Nicolopoulou-Stamati et al., 2016).

In Germany, around 180,059 km², more than half of the land area is used for agriculture (BLE, 2023). Arable land and permanent cropland in the open predominate with a total share of 71.3% of the agricultural land (ibid.).

A legal measure towards reducing the use of chemical plant protection products is its restriction or ban in specific areas. As one of the reduction measures on EU Level, the adopted proposal for a new EU Regulation on the Sustainable Use of Plant Protection Products, from now on SUR, prohibits the use of all plant protection products in sensible areas. These include places such as urban green as well as protected areas in accordance with Natura 2000 and any ecologically sensitive area preserved for threatened pollinators as well as drinking water (EC, 2022). The SUR proposal is meant to replace the current Directive 2009/128/EC, which already stresses that the use of plant protection products can particularly be dangerous in very sensitive areas (EC, 2009). According to EC (2023) the ban of plant protection products in sensitive areas could be differentiated according to biocontrol, low-risk and other approved substances as well as all plant protection products allowed in organic agriculture differently.

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Eichler & Brühl (2023) first assessed the agricultural landscape within protected areas in Germany in context of a SUR scenario. The numbers that Eichler & Brühl (2023) present originate from a limited interpretation of the SUR proposal with respect to the types of protection areas to be considered. According to our understanding Nature Parks and specific zones of Biosphere Reserves should also be considered as the areas with pesticide use restriction are not yet defined.

The article focusses on the spatial delimitation of the various types of sensitive areas in Germany and gives answers on the affected agricultural land by region for different scenarios. We assess the agricultural landscape within protected areas with higher resolution agricultural use data. We compare our results with the study of Eichler & Brühl (2023) and discuss the influence of different methodology and input data on the results.

Material and Method

Data Sources

Ecological protection areas – sensitive areas protected for habitats and biodiversity

In Germany, various categories exist for nature conservation areas. We consider the following categories as possible sensitive areas according to the SUR proposal: National Parks (NP), Nature Reserves (NR), Biosphere Reserves (BR), Nature Parks (NK), Natural Monuments (NM), Landscape Protection Areas (LP) and Natura 2000 sites (Fauna-Flora-Habitat (FFH) areas and Special Protected Areas (SPA) for bird sanctuaries) and Ramsar sites (RAM). According to Walz and Schumacher (2010) Fauna-Flora-Habitat and Special Protected Areas have the intention to ensure the transnational protection of endangered wild native plant and animal species and their natural habitats. Whereas Nature Reserves aim to preserve, develop and restore biotopes and biotic communities of wild animal and plant species as well as biodiversity. National Parks are large-scale nature reserves and should remain largely untouched by human activities, such as agriculture, forestry and water management, in order to ensure the undisturbed course of natural processes. BfN (2023a) defines National Monuments as significant natural phenomena or outstanding geological-geomorphological phenomena as well as phenomena combining special natural and cultural values. Whereas Nature Parks serve both the protection and preservation of cultural landscapes with their biotope and species diversity as well as recreation, sustainable tourism and sustainable land use, and also education for sustainable development. Ramsar sites are wetlands of international importance, especially as habitats for waterfowl and wading birds (ibd.). BfN (2023b) provides German-wide geodata on protection areas with underlying metadata with an update as of: National Parks 31.12.2020, Landscape Protection Areas 31.12.2020, National Monuments January 2022, Nature Reserves 01.01.2022, Nature Parks January 2022, Biosphere Reserves January 2022, Fauna-Flora-Habitat December 2019, Special Protected Areas December 2019. According to BfN the geodata bases on nationally homogenized data sets. Other administrative levels in Germany (state, district, county, and municipality) may provide services on this topic with a higher spatial and temporal resolution. The geodata is Open-Data licenced.

Sensitive areas to protect the aquatic environment and drinking water (water protection areas)

The SUR omits the use of all pesticides on surface waters and within three meters of such waters (EC 2022). Instead, Germany implemented a buffer of 10 m from water bodies and a 5 m buffer in case of year-round vegetation (BMEL, 2021). The SUR gives member states the opportunity to ban or restrict pesticide use in drinking water protection areas (DWPA) and medicinal spring protection areas (MSPA). For the purpose of this study we consider the latter two categories as possible sensitive areas according to the SUR proposal and refer to them as water protection areas (WPA). The geodata stems from BfG (2021). BfG states that the geodata is based on nationally homogenized data sets. Similar to BfN (2023b) other administrative levels in Germany (state, district, county, and municipality) may provide services on this topic with a higher spatial and temporal resolution. The geodata is Open-Data licensed.

Agricultural land use datasets

For the analysis of land use in sensitive areas we use the geodata CORINE Land Cover 5 ha (CLC5-2018) (BKG, 2018; 2022). The dataset represents a description of the landscape in vector format according to the CLC5-2018 nomenclature, which on the one hand reflect the land cover, on the other hand also include aspects of land use. The basis for CLC5-2018 is the Land Cover Model Germany 2018 (LBM-DE2018) in the revised version of 2021 with its detailed breakdown into land cover (LB) and land use (LN) as well as information on the sealing (SIE) and vegetation (VEG) fraction with a minimum object size of 1 ha. Unique CLC5-2018 classes derive from the combinations of LB and LN, taking SIE and VEG into account. These data are generalized for CLC5-2018 to a minimum plot size of 5 hectares. The working scale of LBM-DE2018 and CLC5-2018 could be considered at 1:50 000. In contrast to LBM-DE2018 (BKG, 2020), CLC5-2018 is licensed as Open-Data.

The state of Brandenburg provides annually geodata on the farmer's area-based agricultural subsidy application based on the digital field plots. The dataset is part of the land parcel information system at EU level. We therefore refer to this dataset as Land Parcel Information System (LPIS). The application data is created digitally on the basis of the field block cadastre. In the field blocks, farms digitize the landscape elements and plots they want to cultivate. The working scale is 1:5,000 (LGB, 2023). From the point of thematic, temporal and geographical accuracy, this dataset must be considered as best-data-available. As only very few federal states give open access to this dataset, we used the Brandenburg LPIS dataset of 2018 only for reflecting our results of CLC5-2018 dataset against the LPIS dataset.

Administrative boundaries

The geodata for the administrative boundaries originates from the Federal Agency for Cartography and Geodesy and is the federal state dataset "VG25_LAN". The working scale is at 1:25,000 (BKG 2022). In this study, we only use the terrestrial areas within the federal state boundaries. This excludes the aquatic areas such as the North Sea and the Baltic Sea as well as Lake Constance in the south of the country. We do not include other areas where there is no clear affiliation with Germany like the joint German-Luxembourg territory.

Methodology to quantify agricultural land use in sensible areas

We determine agricultural land use within sensitive areas based on CLC5-2018 for individual protection areas and for combinations. For the category Biosphere Reserve we only use the geometries of the core area and the buffer area which contribute to the conservation of landscapes, ecosystems, species and genetic variation. We do not include the development zone because it is not designed for conservation purposes. We only considered water protection areas that have "established" status, as opposed to those that are still "in planning" (indicated by "STATUS=F").

We examine different scenarios for their impact on agricultural land use: 5 types of protection areas and 5 combinations of protection area types. We have labelled them from A to J for ease of reference. Within a protection area combination, we cleared any overlaps between the categories with the appropriate GIS-methods (ArcGIS method, Dissolve) (see supplementary Figs. S1–S10):

– A (BR)
– B (NR, NM, NP)
– C (FFH)
– D (SPA)
– E (SPA, RAM)
– F (FFH, SPA)
– G (WPA incl. DWPA/MSPA)
– H (NK)
– I (LP)
– J (NP, NR, NM, FFH, SPA, RAM, NK, BR, WPA incl. DWPA/MSPA, LP)

We define agricultural land based on the CLC5-2018 dataset categories "Non-irrigated arable land" (211), "Vineyards" (221), "Fruit and berry plantations" (222) and "Pastures (Grassland)" (231). We intersected all combinations of protected areas with those of the CLC5-2018 data.

The intersection determines the area of each class within the protected area combination. For Brandenburg an additional intersection with the 2018 field plot data is performed. To reduce the influence of the mismatch of the land use classes from the two datasets, we worked with the categories "arable and perennial crops" and "grassland". The category "arable crops and perennial crops" includes the LIPS attribute values "AL" and "DK". The category "Grassland" was mapped to the attribute value "DGL".

All data handling happen with ArcMap 10.8 in the ETRS 89 UTM 32 N coordinate reference system (EPSG: 25832).

Results

Agricultural land use in Germany according to CLC5-2018

As a point of reference for further results, we show in Table 1 the land use percentages and areas across the various Federal States of Germany as well as on national level based on CLC5-2018. In Germany, 19.6 million hectares classify as "agricultural land use", which includes arable land, grassland and permanent crops. Its share is 54.8%.

In the land use category labelled "Non-irrigated arable land" the states Saxony-Anhalt, Mecklenburg-Vorpommern, and Schleswig-Holstein have the greatest proportions, each exceeding 45% of the total area within their respective states. For Germany, the overall area measures 12.9 million hectares.

The CLC5-2018 provides information on vineyards for ten Federal States, with Rhineland-Palatinate and Baden-Württemberg having the largest areas and shares. For Germany, the total area is 126,921 hectares.

In the land use category labelled "Fruit trees and berry plantations", the largest areas are located in Baden-Württemberg, Bavaria, and Lower Saxony. The total area in Germany for this category is 195,693 hectares.

One third of the land in the category "Pastures (Grassland)" is located in Bavaria and Lower Saxony, with Schleswig-Holstein having the highest share at 27.2%. According to CLC5-2018, the total area for this category in Germany is 6.4 million hectares.

Upon closer examination of the aforementioned categories, it is evident that the largest proportion of agricultural land use is located in Bavaria and Lower Saxony, with each of an area of over 3 million hectares. Further analysis of this category unveils that the states of Schleswig-Holstein, Mecklenburg-Vorpommern, Saxony-Anhalt, and Lower Saxony have a share ranging from 64% to 73%.

Agricultural land use in ecological and water protection areas

Table 2 shows the results of the total area and the share of agricultural land use for ten protection areas and combinations (labels A to J) for Germany based on CLC5-2018 data. The table lists the results in ascending order for the agricultural land use category.

Label A refers to the results for the core and buffer areas of the Biosphere Reserve category. The impact on arable land is the lowest at 0.1%, and the highest on fruit and berry plantations at 1.8%.

Labels H and I indicate that the individual protection area types Natural Park and Landscape Protection Area have the highest impacts in all land use categories varying from 19.4%

Table 1. Area/percentage of agricultural land uses in German Federal States based on CLC5-2018[1,2].

	Total Area (in ha)	Non-irrigated arable land (CLC-Code = 211)		Vineyards (CLC-Code = 221)		Fruit trees and berry plantations (CLC-Code = 222)		Pastures (Grassland) (CLC-Code = 231)		Agricultural land use (CLC-Code = 211, 221, 222 or 231)	
		in ha	in %	in ha	in %	in ha	in %	in ha	in %	in ha	in %
BB	2,969,652	1,052,520	35.4	22	0.0	4,087	0.1	417,890	14.1	1,474,520	49.7
BE	89,237	2,102	2.4					2,338	2.6	4,440	5.0
BW	3,572,163	934,080	26.1	36,454	1.0	114,108	3.2	626,470	17.5	1,711,113	47.9
BY	7,054,966	2,220,263	31.5	7,107	0.1	21,736	0.3	1,398,911	19.8	3,648,016	51.7
HB	41,174	1,221	3.0					10,867	26.4	12,088	29.4
HE	2,109,933	530,775	25.2	4,536	0.2	8,429	0.4	415,221	19.7	958,960	45.4
HH	75,458	5,413	7.2			1,852	2.5	12,033	15.9	19,298	25.6
MV	2,330,547	1,134,189	48.7			2,614	0.1	386,596	16.6	1,523,398	65.4
NI	4,770,858	2,089,285	43.8			12,721	0.3	959,218	20.1	3,061,223	64.2
NW	3,409,660	1,232,167	36.1	33	0.0	3,518	0.1	566,544	16.6	1,802,262	52.9
RP	1,984,284	445,933	22.5	77,632	3.9	6,940	0.3	364,654	18.4	895,158	45.1
SH	1,579,430	715,678	45.3			597	0.0	430,206	27.2	1,146,481	72.6
SL	257,034	39,423	15.3	128	0.0	2,060	0.8	58,702	22.8	100,314	39.0
SN	1,847,823	746,873	40.4	330	0.0	4,907	0.3	264,788	14.3	1,016,898	55.0
ST	2,055,743	1,078,282	52.5	628	0.0	6,592	0.3	243,357	11.8	1,328,860	64.6
TH	1,619,851	669,566	41.3	52	0.0	5,533	0.3	228,780	14.1	903,930	55.8
GER	35,767,811	12,897,771	36.1	126,921	0.4	195,693	0.5	6,386,574	17.9	19,606,958	54.8

[1] Empty fields indicate, that the dataset gives no information of the agricultural land use category.
[2] Brandenburg (BB); Berlin (BE); Baden-Württemberg (BW); Bavaria (BY); Bremen (HB); Hesse (HE); Hamburg (HH); Mecklenburg-Vorpommern (MV); Lower Saxony (NI); North Rhine-Westphalia (NW); Rhineland-Palatinate (RP); Schleswig-Holstein (SH); Saarland (SL); Saxony (SN); Saxony-Anhalt (ST); Thuringia (TH)

Table 2. Area/percentage of agricultural land uses in protection areas and protection area combinations for Germany based on CLC5-2018[1].

	Protection Area & Combinations	Non-irrigated arable land (CLC-Code = 211; GER = 12,897,771 ha)		Vineyards (CLC-Code = 221 GER = 126,921 ha)		Fruit trees and berry plantations (CLC-Code = 222 GER = 195,693 ha)		Pastures (Grassland) (CLC-Code = 231 GER = 6,386,574 ha)		Agricultural land use (CLC-Code = 211, 221, 222 oder 231 GER = 19,606,959 ha)	
		in ha	in %	in ha	in %	in ha	in %	in ha	in %	in ha	in %
GER	A (BR)	11,937	0.1	863	0.7	3,451	1.8	86,924	1.4	103,174	0.5
GER	B (NR, NM, NP)	53,739	0.4	962	0.8	4,116	2.1	355,199	5.6	414,016	2.1
GER	C (FFH)	145,183	1.1	1,657	1.3	16,338	8.3	635,491	10.0	798,669	4.1
GER	D (SPA)	789,203	6.1	10,544	8.3	17,117	8.7	800,253	12.5	1,617,117	8.2
GER	E (SPA, RAM)	797,874	6.2	10,544	8.3	17,421	8.9	807,690	12.6	1,633,529	8.3
GER	F (FFH, SPA)	868,732	6.7	11,087	8.7	27,968	14.3	1,111,133	17.4	2,018,918	10.3
GER	G (DWP/MSP)	1,357,863	10.5	8,265	6.5	28,624	14.6	676,642	10.6	2,071,394	10.6
GER	H (NK)	2,506,052	19.4	17,849	14.1	48,996	25.0	1,871,728	29.3	4,444,624	22.7
GER	I (LP)	2,429,645	18.8	35,708	28.1	53,531	27.4	1,984,954	31.1	4,503,837	23.0
GER	J (NP, NR, NM, FFH, SPA, RAM, NK, BR, WPA, LP)	5,276,978	40.9	61,490	48.4	108,633	55.5	3,698,633	57.9	9,145,734	46.6

[1] National Parks (NP), Nature Reserves (NR), Biosphere Reserves (BR), Nature Parks (NK), Natural Monuments (NM), Landscape Protection Areas (LP) and Natura 2000 sites (Fauna-Flora-Habitat (FFH) areas and Special Protected Areas (SPA) for bird sanctuaries) Water Protection Areas (WPA) consisting of Drinking Water Protection Areas and Mineral Spring Protection Areas and Ramsar sites (RAM).

to 29.3% for Nature Parks and from 18.8% to 31.1% for Landscape Protection Areas.

Label J refers to a scenario which combines all protected areas where restrictions on pesticide use may be possible according to the SUR proposal and national interpretations. In all land use categories the share is higher than 40%, with the highest shares in the categories pasture and fruit trees and berry plantations at 56% and 58% respectively. For all agricultural land uses the share in this scenario is 46.6% which means an effect on 9.1 million hectares agricultural land.

If we look at the extent to which the individual federal states are affected for scenario J (Table 3), we see that there are large differences. The extent varies greatly, ranging from 33.7% (Schleswig-Holstein) to 77.9% (Bremen). Looking at the absolute area, we see the largest impacts in Baden-Württemberg, Bavaria, Lower Saxony and North Rhine-Westphalia, all with more than 1 million hectares in protected areas according to scenario J.

For the state of Brandenburg, we calculate the percentage of agricultural land use based on the CLC5-2018 data (Table 4) and compare the results with the LPIS results (Table 5). The percentage of arable and perennial crops in the total area of protected areas differs slightly between the CLC5-2018 data and the LPIS data in all combinations, with an average delta of 0.20%. In scenario F we see the largest delta in absolute hectares with 4,927 hectares. In the grassland category the average delta between LPIS and CLC5-2018 is 3.42% with a minimum delta of 0.84% for scenario B and the larges delta of 4.46% for scenario I. In absolute hectares the largest delta is for scenario J with 68,408 hectares.

Discussion

Agricultural land use in ecological and water protection areas varies by region

In this paper, we estimate the amount of agricultural land within different types of protection areas using open access geodata describing agricultural land use with the German CLC5-2018 dataset and protection areas with BfN (2023b) and BfG (2021) datasets. Based on CLC5-2018 we estimate 19.6 million hectares of national agricultural area with 12.9 million hectares of cropland. Our results show that 46.6% of this area is located in types of protected area that we consider potentially affected by a restriction or ban on pesticides in context of the SUR. A differentiated picture of the impact emerges when examining the individual federal states. The extent varies significantly, ranging from 33.4% to 77.9% across different states.

Table 3. Area/percentage of agricultural land uses in protection area combination J (NP, NR, NM, FFH, SPA, RAM, NK, BR, WPA, LP) for German Federal States based on CLC5-2018[1,2].

Protection Area & Combinations J (NP, NR, NM, FFH, SPA, RAM, NK, BR, WPA, LP)	Non-irrigated arable land (CLC-Code = 211)		Vineyards (CLC-Code = 221)		Fruit trees and berry plantations (CLC-Code = 222)		Pastures (Grassland) (CLC-Code = 231)		Agricultural land use (CLC-Code = 211, 221, 222 or 231)	
	in ha	in %	in ha	in %	in ha	in %	in ha	in %	in ha	in %
BB	434,596	41,3	7	30.3	1,135	27.8	280,589	67.1	716,327	48.6
BE	839	39,9	-		-		1,538	65.8	2,378	53.5
BW	494,632	53,0	24,628	67.6	75,565	66.2	448,911	71.7	1,043,737	61.0
BY	737,554	33,2	3,577	50.3	4,635	21.3	648,147	46.3	1,393,912	38.2
HB	771	63,1	-		-		8,651	79.6	9,422	77.9
HE	374,272	70,5	2,008	44.3	7,607	90.3	340,005	81.9	723,892	75.5
HH	2,762	51,0	-		623	33.6	8,732	72.6	12,117	62.8
MV	482,891	42,6	-		989	37.8	241,900	62.6	725,780	47.6
NI	750,964	35,9	-		939	7.4	387,753	40.4	1,139,656	37.2
NW	739,932	60,1	31	95.9	2,991	85.0	485,014	85.6	1,227,968	68.1
RP	171,936	38,6	30,269	39.0	3,704	53.4	210,454	57.7	416,364	46.5
SH	215,668	30,1	-		434	72.7	170,155	39.6	386,257	33.7
SL	29,267	74,2	128	100.0	1,466	71.2	44,243	75.4	75,105	74.9
SN	265,493	35,5	219	66.3	1,702	34.7	146,871	55.5	414,285	40.7
ST	369,637	34,3	620	98.7	4,511	68.4	142,740	58.7	517,508	38.9
TH	205,764	30,7	3	5.5	2,331	42.1	132,928	58.1	341,026	37.7
GER	5,276,978	40,9	61,490	48.4	108,633	55.5	3,698,633	57.9	9,145,734	46.6

[1] Empty fields indicate, that the dataset gives no information of the agricultural land use category

[2] Brandenburg (BB); Berlin (BE); Baden-Württemberg (BW); Bavaria (BY); Bremen (HB); Hesse (HE); Hamburg (HH); Mecklenburg-Vorpommern (MV); Lower Saxony (NI); North Rhine-Westphalia (NW); Rhineland-Palatinate (RP); Schleswig-Holstein (SH); Saarland (SL); Saxony (SN); Saxony-Anhalt (ST); Thuringia (TH).

Table 4. Area/percentage of agricultural land uses in protection areas and protection area combinations for Brandenburg based on CLC5-2018.

	Protection Area Combination	Total Area (of Administrative Boundaries VG25_LAN (BKG))	Area of Protection Area Combination		Field Crops and perennial Crops (CLC-Code = 211, 221, 222)		Grassland (CLC-Code = 231)	
CLC18		in ha	in ha	in % *	in ha	in % **	in ha	in % **
BB	A	2,969,652	52,451	1.8	3,770	7.2	12,654	24.1
BB	B	2,969,652	244,352	8.2	12,077	4.9	50,739	20.8
BB	C	2,969,652	332,480	11.2	23,746	7.1	68,487	20.6
BB	D	2,969,652	649,546	21.9	213,468	32.9	153,778	23.7
BB	E	2,969,652	649,823	21.9	213,476	32.9	153,813	23.7
BB	F	2,969,652	777,356	26.2	225,841	29.1	177,343	22.8
BB	H	2,969,652	713,796	24.0	177,216	24.8	100,051	14.0
BB	I	2,969,652	1,171,109	39.4	297,448	25.4	201,968	17.2
BB	J	2,969,652	1,624,982	54.7	435,738	26.8	280,589	17.3

Table 5. Area/percentage of agricultural land uses in protection areas and protection area combinations for Brandenburg based on the LPIS dataset.

	Protection Area Combination	Total Area (of Administrative Boundaries VG25_LAN (BKG))	Area of Protection Area Combination		Field Crops and perennial Crops LPIS-Class = 'AL', 'DK')		Grassland LPIS-Class = 'DGL')	
LPIS		in ha	in ha	in % *	in ha	in % **	in ha	in % **
BB	A	2,969,652	52,451	1.8	4,016	7.7	10,656	20.3
BB	B	2,969,652	244,352	8.2	12,315	5.0	48,681	19.9
BB	C	2,969,652	332,480	11.2	23,226	7.0	60,311	18.1
BB	D	2,969,652	649,546	21.9	209,080	32.2	129,444	19.9
BB	E	2,969,652	649,823	21.9	209,092	32.2	129,469	19.9
BB	F	2,969,652	777,356	26.2	220,914	28.4	148,023	19.0
BB	H	2,969,652	713,796	24.0	177,010	24.8	73,713	10.3
BB	I	2,969,652	1,171,109	39.4	297,930	25.4	149,689	12.8
BB	J	2,969,652	1,624,982	54.7	431,660	26.6	212,181	13.1

Why we did not only use best available data

Considering geodata on protection areas we use with BfN (2023b) and BfG (2021) best available data in terms of spatial resolution. With regard to temporal resolution, we note that comparable impact studies such as Eichler & Brühl (2023) and Eichler et al. (2022) use similar geodata on protection areas, but collect them from the federal states themselves rather than from the federal agencies BfN and BfG, which combine the data from the federal states in certain time periods. The use of federal states data might lead to a higher temporal resolution in these studies, but makes reproducibility more difficult. However, this difference is one of various possible factors that might lead to discrepancies in the results of the analysis. Concerning the land use dataset we decide for open data and reproducibility instead of best available data in terms of spatial resolution. With a minimum mapping unit of 5 hectares (BKG, 2018) CLC5-2018 aggregates especially small patch land uses such of the type vineyards and fruit trees and berry plantations in favour of larger land use classes such as grassland and cropland.

Differences to other studies due to composition of sensitive areas

Based on the Digital Land Cover Model 2018 (LBM-DE), Eichler et al. (2022) estimated 12.3 million hectares of arable land in Germany. Their study identified 44,071 hectares of arable land within nature reserves and 128,323 hectares of arable land within nature reserves and FFH areas, respectively. Compared with our results on CLC5-2018 data, we estimate higher absolute hectares of 9,668 hectares for nature reserves and 16,860 hectares for FFH areas. In terms of the proportion of agricultural land, our findings closely align with those of Eichler et al. (2022) and Eichler & Brühl (2023). We estimate the share of arable land in FFH areas and SPA area with 1.1% and 6.1% respectively. Whereas Eichler and Brühl estimated 0.9% and 6.2%.

Low influence of different data sources when looking at relative results expressed as percentages

The impact of various geodata on the overall outcomes demonstrates a relatively minor influence when considering the percentage results. However, a closer examination reveals noteworthy disparities arising from the generalization rules embedded in the CLC5-2018 dataset. Notably, larger land use categories like arable land and grassland tend to be overrepresented due to these rules, whereas smaller land uses such as hop cultivation, viticulture, and orchards face a disadvantage. The discrepancies become particularly apparent when scrutinizing the results for orchards, where the absolute hectares exhibit a seemingly elevated value. This anomaly may be attributed to the inherent limitations of CLC5-2018 in distinguishing between orchards and commercial orchards with precision. The dataset's inability to make this nuanced distinction results in an overestimation of the coverage of commercial orchards, thereby emphasizing the need for careful interpretation and consideration of data limitations in drawing conclusions from CLC5-2018 derived results.

Impact assessment for individual farms require access to LPIS data

In order to comprehensively assess the influence of pesticide restrictions within protected areas on individual farms, it becomes evident that relying solely on the CLC5-2018 dataset may introduce limitations due to its coarse spatial and temporal resolution. To enhance the precision and specificity of our analysis, it is imperative to consider alternative data sources. In this context, the LPIS data emerge as a promising resource, providing detailed and up-to-date information on parcel level for individual farms (Guilpart et al., 2022).

Additionally, leveraging remote sensing products dedicated to crop classification can offer invaluable insights, allowing us to pinpoint specific land use patterns and management practices at a finer spatial scale. By integrating LPIS data or remote sensing data on crop distribution into our assessment framework, we aim to attain a more accurate understanding of how pesticide restrictions impact farming practices within protected areas on farm level.

Limitations

Although buffer zones are an integral part of the concept of the SUR, we did not consider the effects of buffer zones towards protection areas on agricultural land uses. First results of the impact on arable land for nature reserves and FFH areas have been presented by Eichler et al. (2022).

Conclusion

The statistics obtained based on open data contribute to the discussions on mitigating biodiversity damage and to the current debates on the SUR regulations and their consequences for the use of pesticides in protected areas.

We observe minimal discrepancies between similar studies using different land use datasets when comparing the proportions obtained. Though the dissimilar datasets used for land use can clarify the difference in absolute impact. Unlike LBM-DE, CLC5-2018 estimates a larger overall agricultural area in Germany, which explains why our presented results tend to be higher. Overall both data sets are appropriate for this type of analysis when expressed as a share of the results.

Regarding the SUR scenarios utilised, we have determined a 10% greater impact when compared to that of Eichler & Brühl (2023). This is due to the distinct nature of the scenario definition, which in our scenario incorporates nature parks as a protected area that we consider of possibly being impacted by pesticide restrictions under the SUR; however, no determinations have been made yet.

Overall, our study represents the first national research utilising publicly and freely available geodata to assess the agricultural land surface located in varied types of sensitive areas and reflecting the impact of different input geodata.

Conflicts of interest

The authors declare that they do not have any conflicts of interest.

Data availability

Provided upon request

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Supplementary information

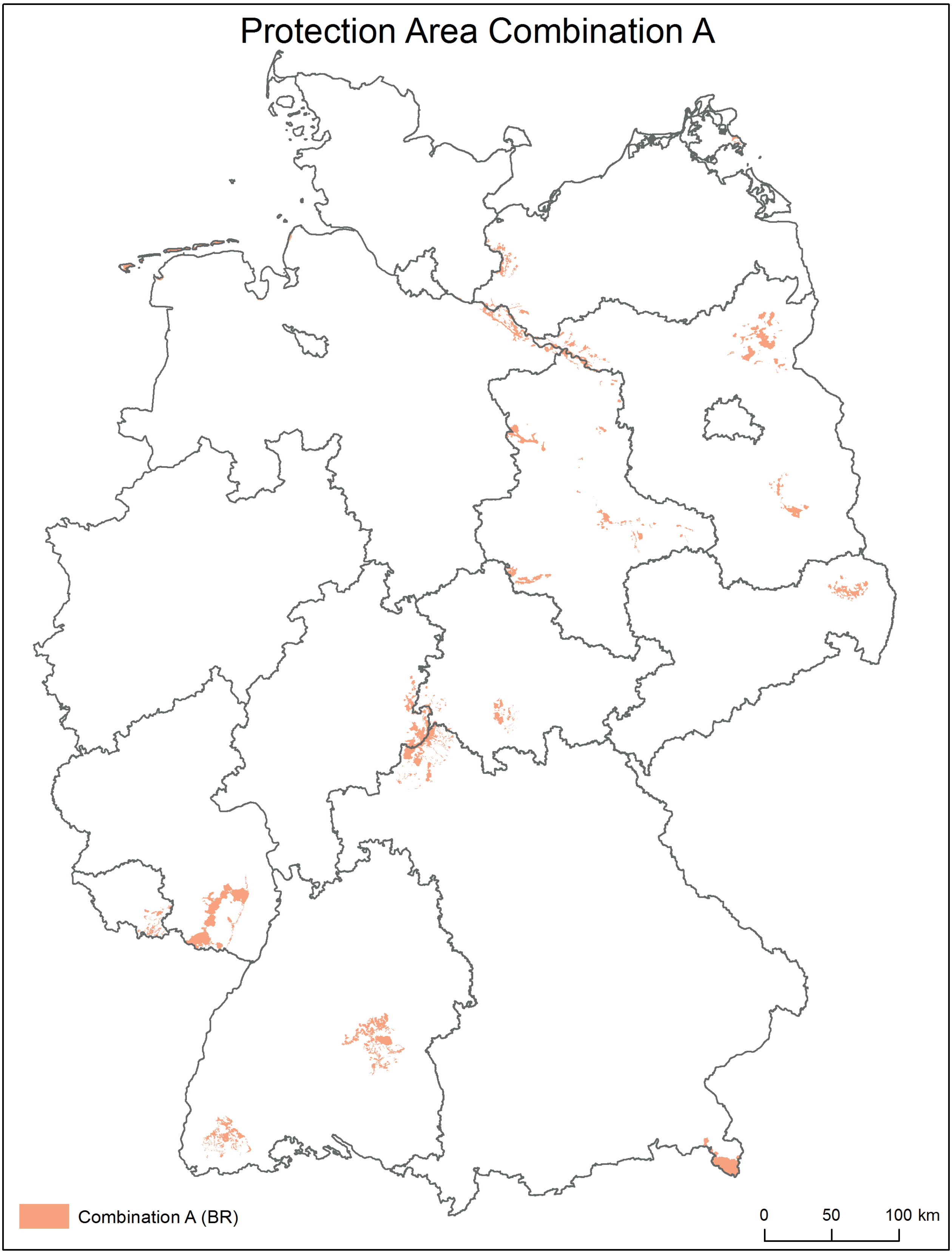

Fig. S1. Protection Area Combination A

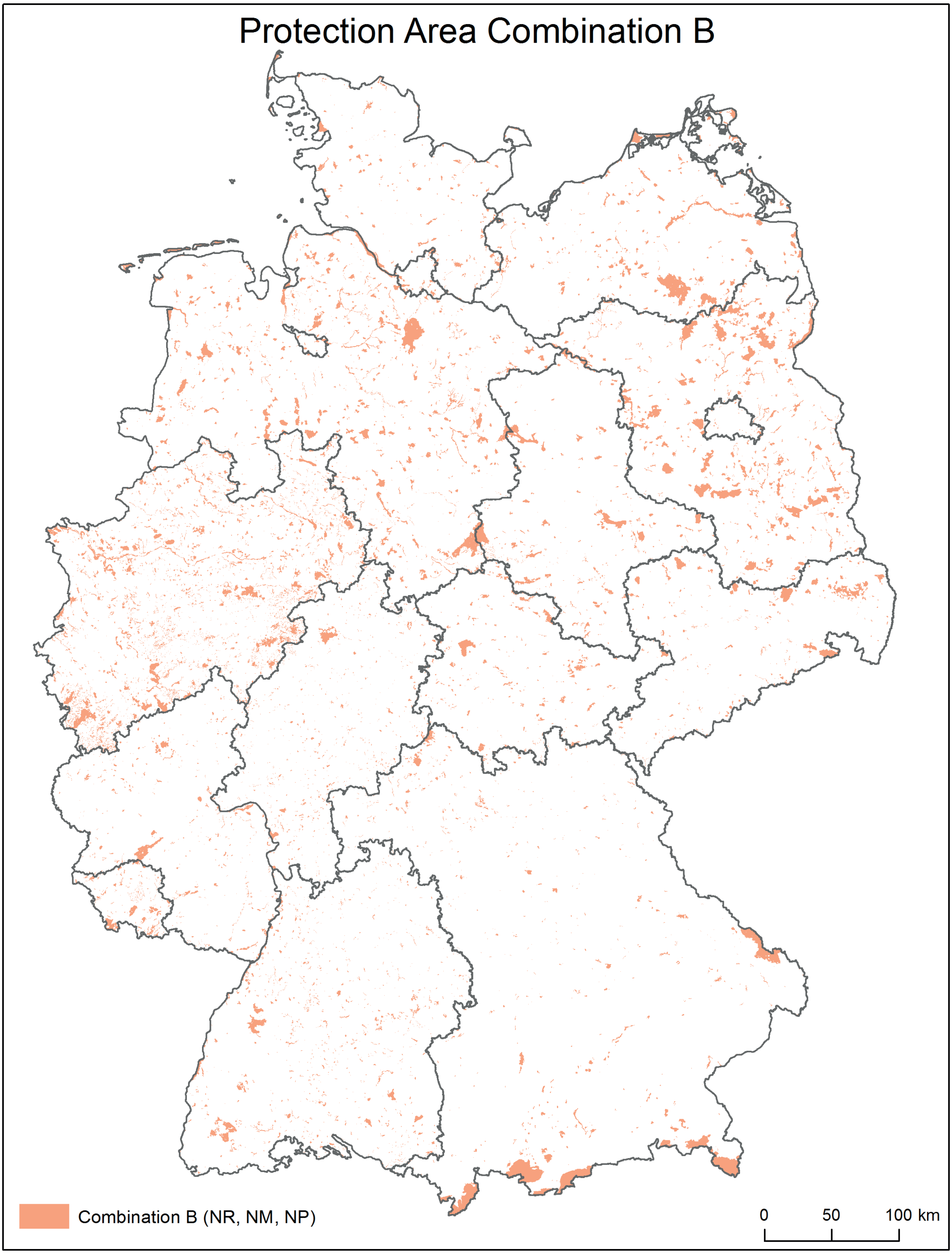

Fig. S2. Protection Area Combination B

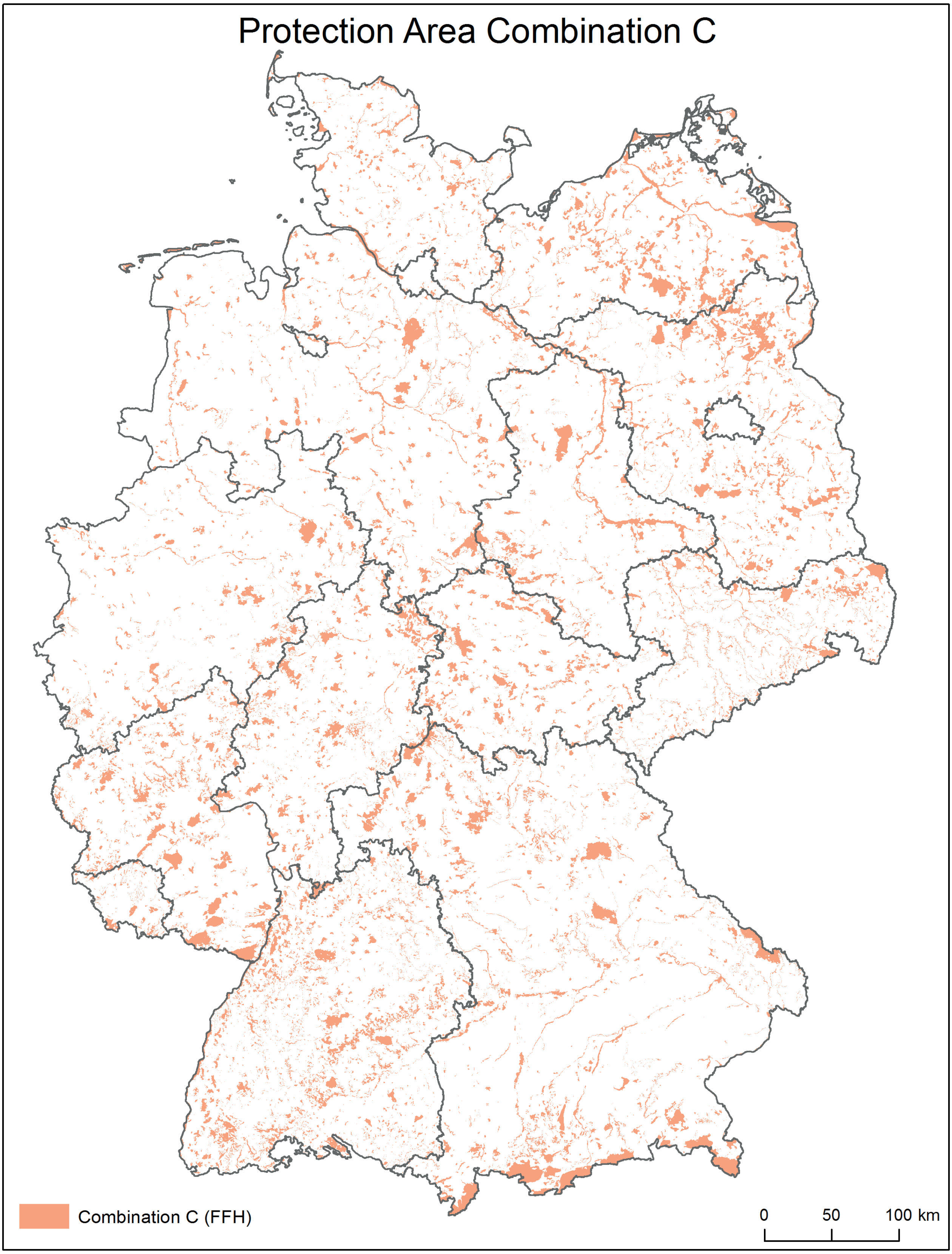

Fig. S3. Protection Area Combination C

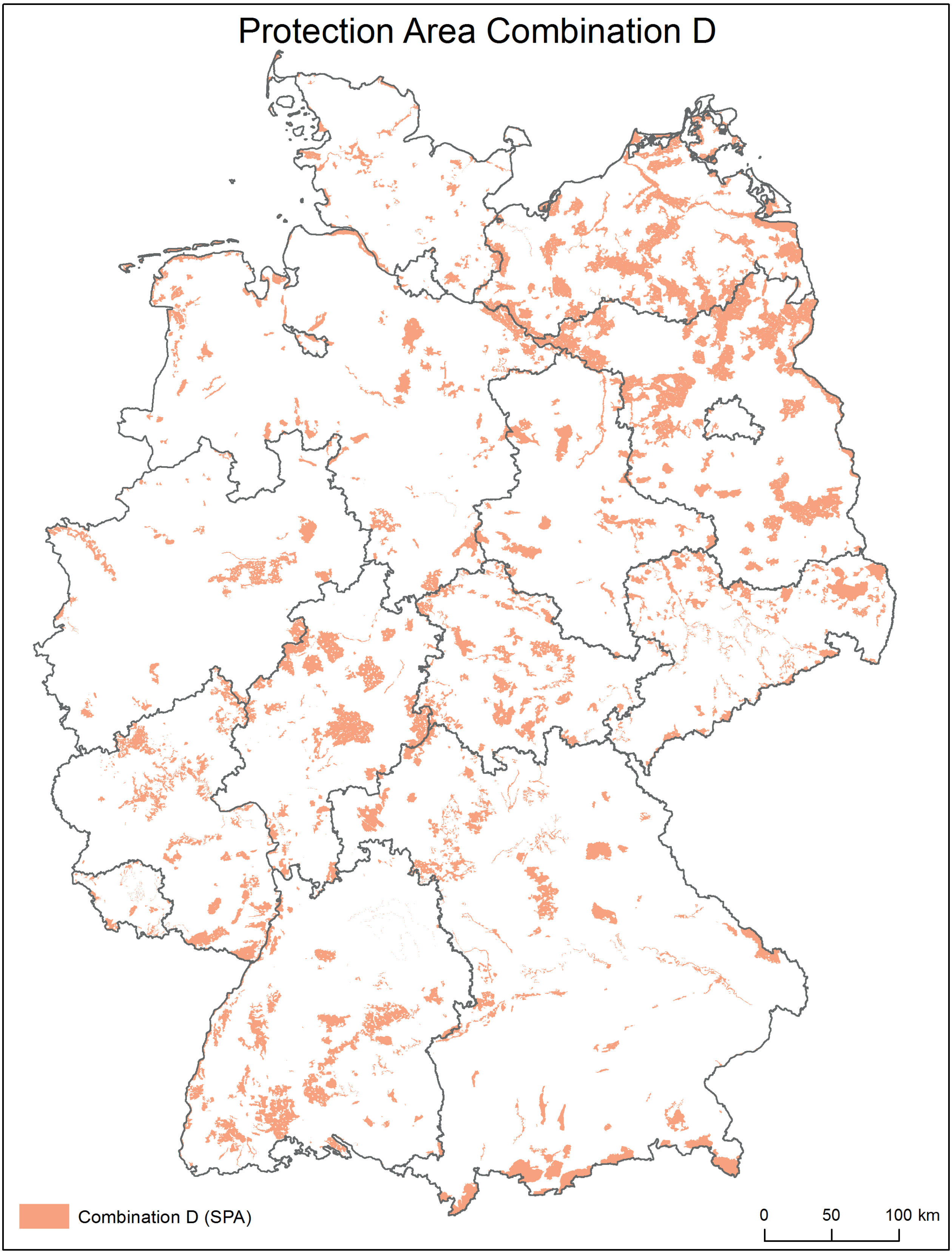

Fig. S4. Protection Area Combination D

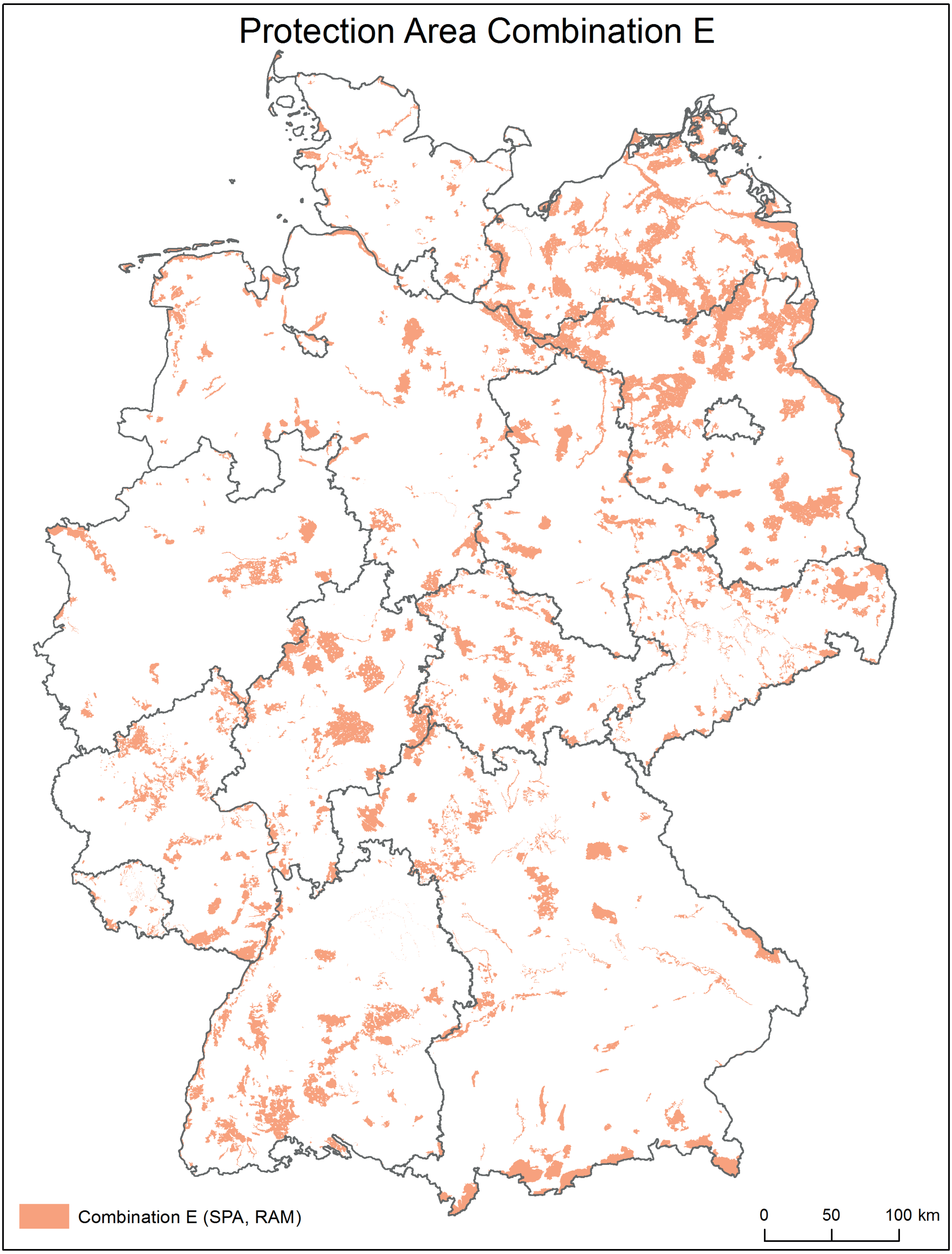

Fig. S5. Protection Area Combination E

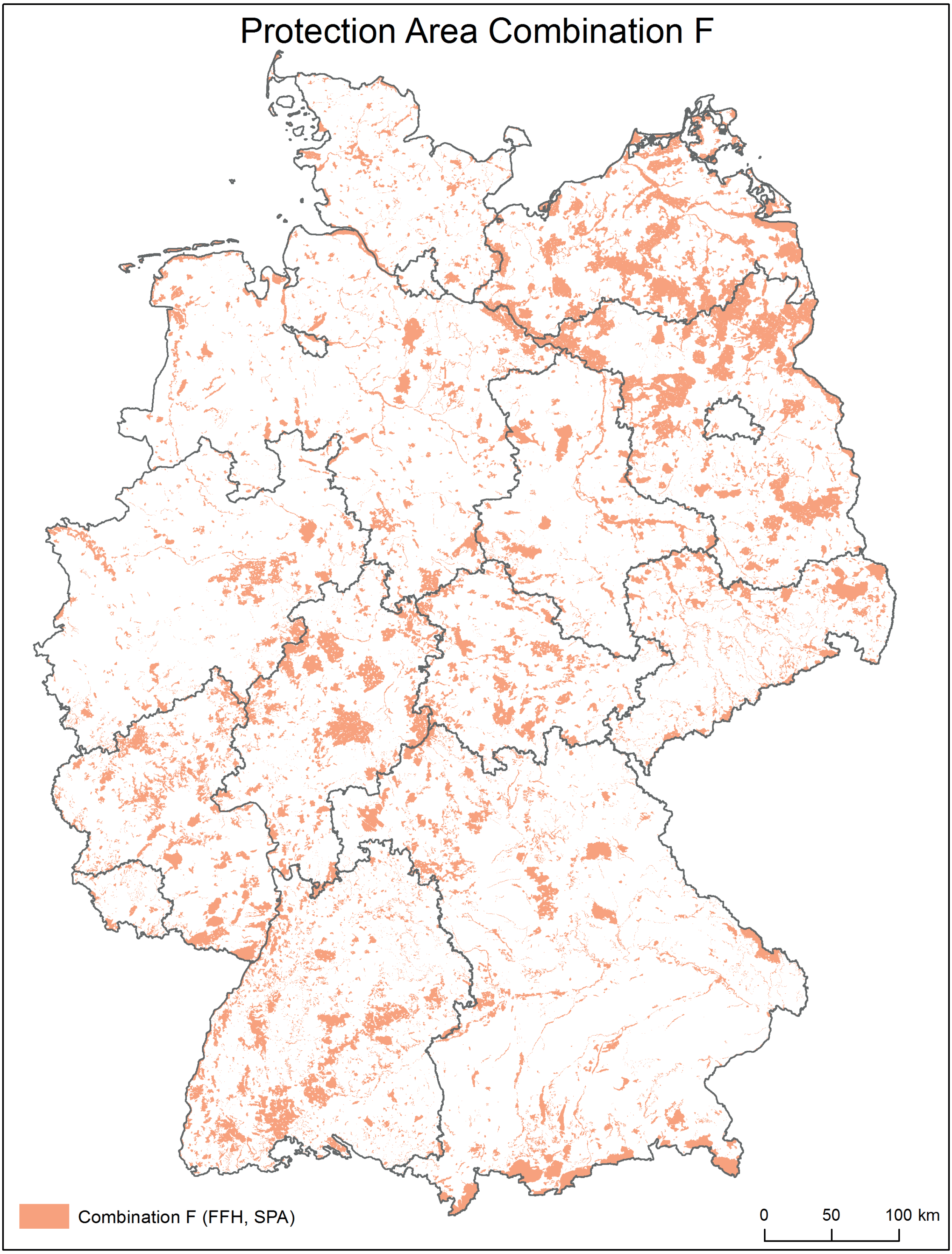

Fig. S6. Protection Area Combination F

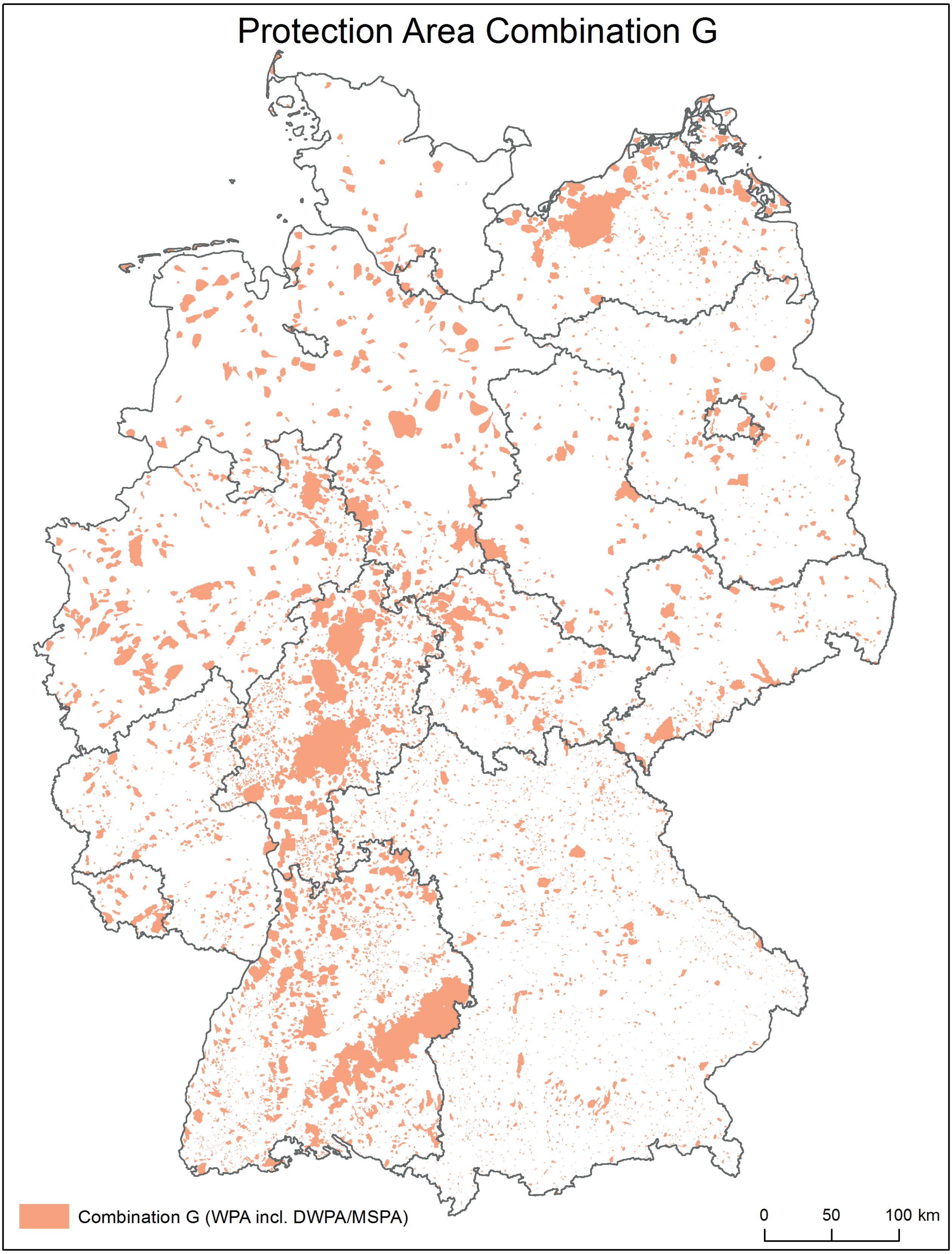

Fig. S7. Protection Area Combination G

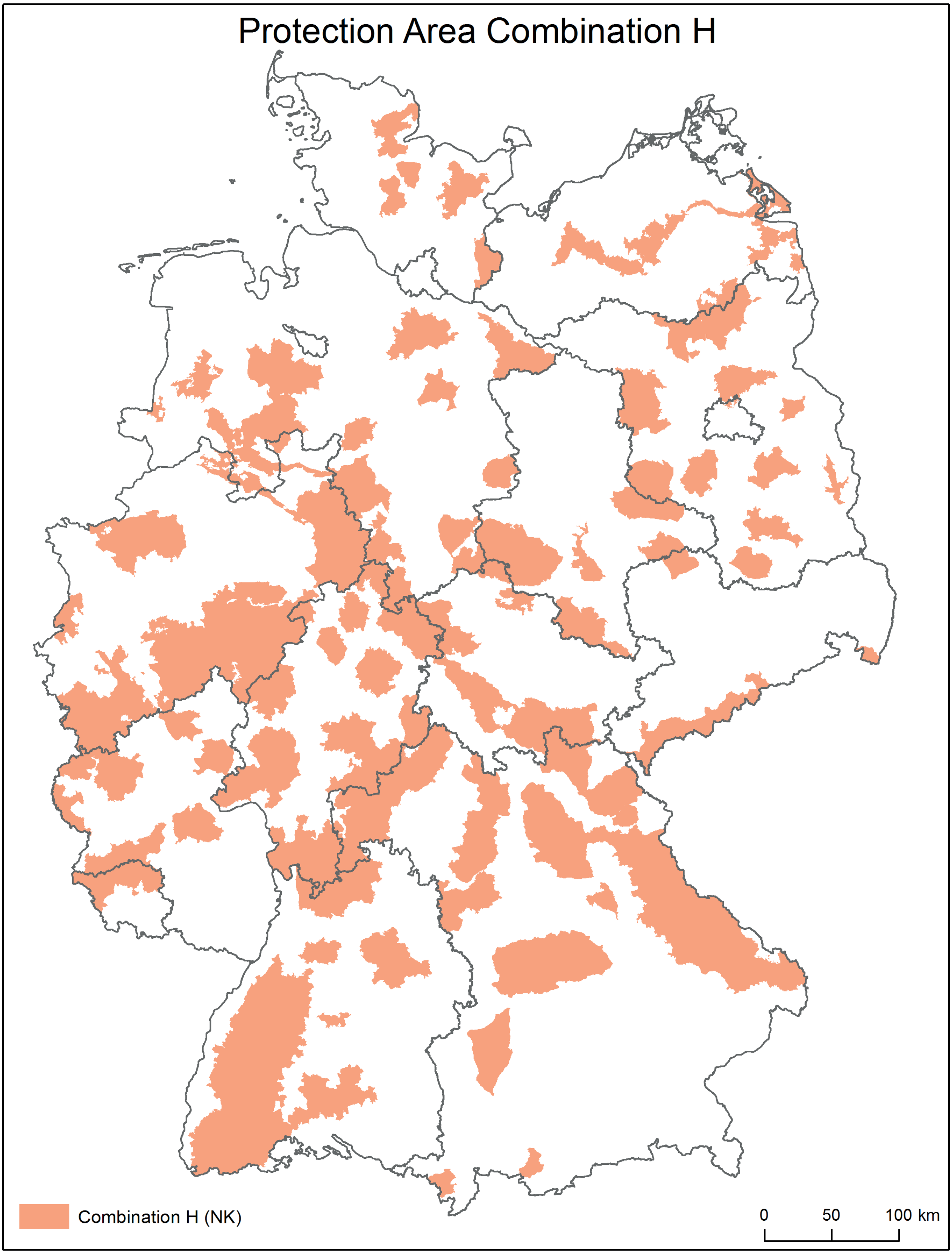

Fig. S8. Protection Area Combination H

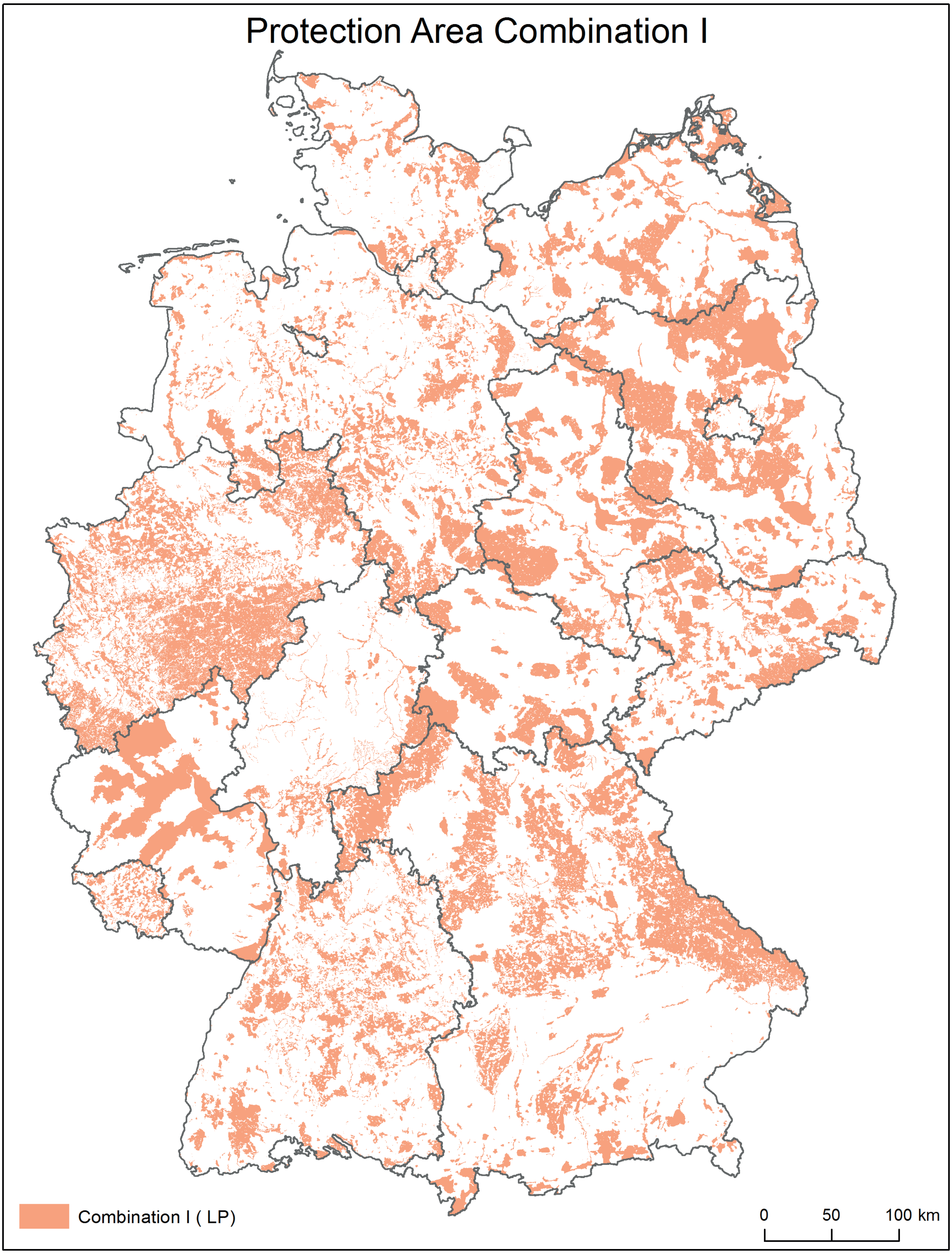

Fig. S9. Protection Area Combination I

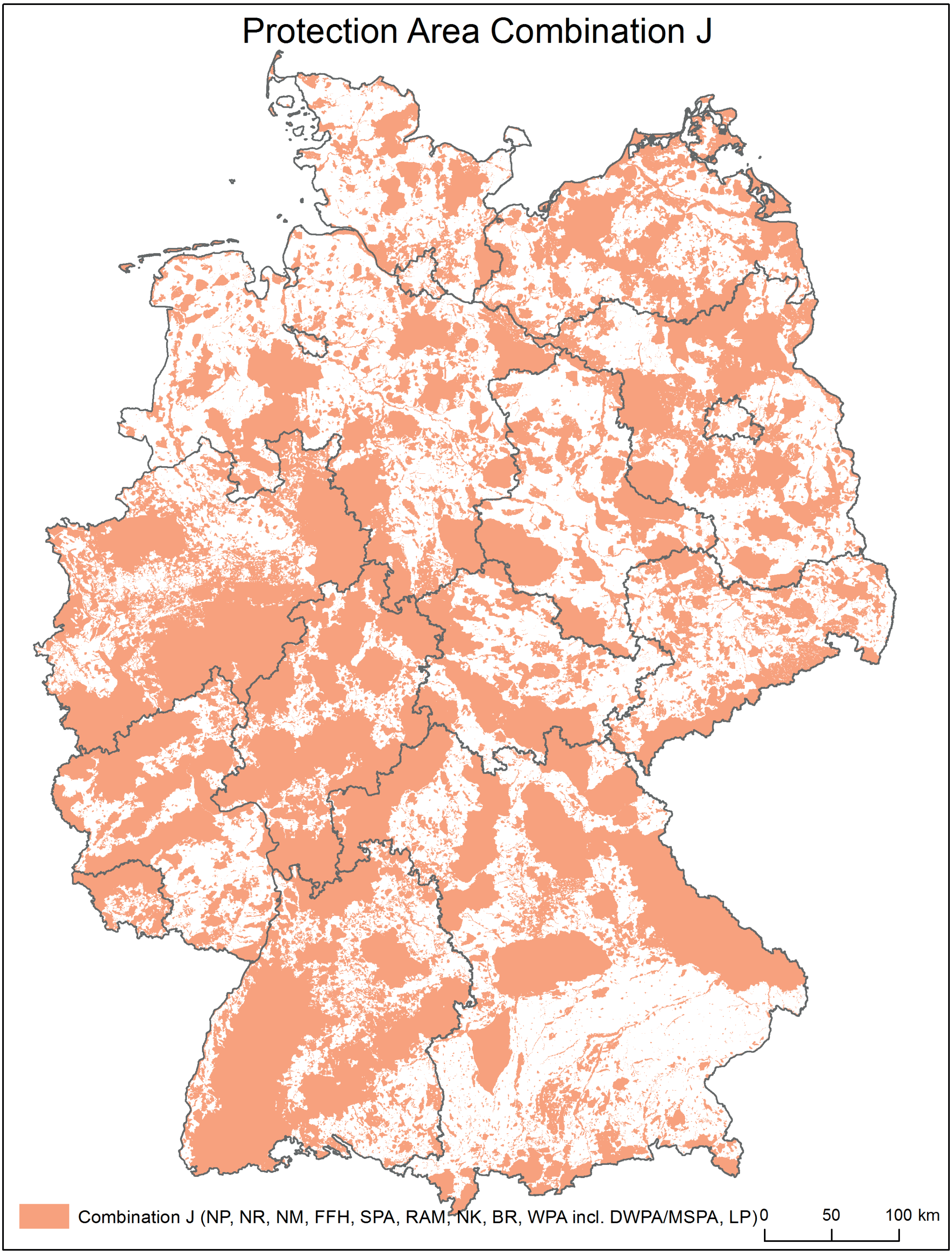

Fig. S10. Protection Area Combination J