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Part B: GIS-based analysis of the protection level of the FOCUS-scenarios representative for Germany concerning climate and soil properties for the national risk assessment groundwater

by

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Kurzbeschreibung

Die beiden Szenarien Hamburg und Kremsmünster sind diejenigen der FOCUS Standardszenarien mit den Klima- und Bodenbedingungen, die im nationalen Zulassungsverfahren für Pflanzenschutzmittel als relevant für eine konservative Grundwasser-Risikobewertung angesehen werden (Holdt et al., 2011). Auch wenn diese zwei Szenarien als repräsentativ für die Ackerbaufläche in Deutschland gelten, liegen bisher keine differenzierten räumlichen Analysen auf nationaler Ebene vor, die ein entsprechendes Schutzniveau bzw. entsprechende Boden- und Klimaeigenschaften und ihren „realistic worst-case“ Charakter für die Ackerbaufläche in Deutschland bestätigen. Dieser „Teil B“ des F & E – Projektes zielte darauf ab, eine entsprechende Protektivitätsanalyse durchzuführen. Eine GIS basierte Analyse auf nationaler Ebene wurde unter Einbeziehung von deutschlandweit höchstmöglich aufgelösten Geodaten durchgeführt, um die Repräsentativität der FOCUS-Szenarien Hamburg und Kremsmünster bzw. der zugehörigen Klima- und Bodeneigenschaften zu untersuchen. Nach einer substanzunabhängigen Untersuchung wurden in einem zweiten Schritt erwartbare Sickerwasserkonzentrationen für unterschiedliche Substanzen und für eine Vielzahl verschiedener bundeweiter georeferenzierter Kombinationen aus Boden- und Klimaeigenschaften berechnet. Hierfür wurde das Modellierungstool PELMO (Pesticide Leaching Model) genutzt, indem ein ähnlicher Ansatz wie GeoPEARL_DE (Bangert, 2007) in einem „GISPELMO“ umgesetzt wurde. Auf Basis der Ergebnisse konnte das durch Hamburg abgedeckte räumliche Perzentil bewertet werden. Die Vergleiche zeigten, dass dieses Szenario nicht das 80. räumliche Perzentil für Deutschland repräsentiert. Es wurden deshalb Boden-/Klimakombinationen identifiziert, die das 80. räumliche Perzentil hinsichtlich der Pestizidkonzentration im Sickerwasser in 1 m Bodentiefe besser widerspiegeln. Diese zeichneten sich insgesamt durch niedrigere organische Kohlenstoffgehalte im Boden aus.

Abstract

The two scenarios Hamburg and Kremsmünster are those of the FOCUS standard scenarios with climatic and soil conditions which turned out to be most relevant for a conservative groundwater risk assessment for pesticides in the German national authorisation procedure (Holdt et al, 2011). Even though these two scenarios are considered to be representative for the areas of arable land use type in Germany there’s a lack of differentiated spatial analysis on national level regarding their protection level or their defined soil and climate properties respectively to confirm their “realistic worst-case” character for the agricultural area in Germany. This “Part B” of the R&D study aimed at the refinement of that lack of information. A GIS based analysis on national level was conducted using geodata with the nationwide highest possible resolution on the looking at the representativeness of the FOCUS-scenario Hamburg and Kremsmünster, their soil and climate properties respectively. After a substance independent analysis PEC groundwater were calculated for different substances and a lot of different geo-referenced combinations of soil and climate data. The modelling tool PELMO (Pesticide Leaching Model) was used therefor by implementing a similar approach to GeoPEARL_DE (Bangert, 2007) in a “GISPELMO”. Based on the results an evaluation of the actual percentile of the FOCUS Hamburg scenario was conducted. The comparisons indicated that this scenario is not representing the 80th spatial percentile in Germany. Hence soil weather combinations better representing the 80th percentile of pesticide percolate concentration in 1m soil depth were identified, which were overall based on less organic carbon in soil.

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1 Zusammenfassung

Die Bewertung der potentiellen Versickerung von Wirkstoffen aus Pflanzenschutzmitteln und/oder deren Metaboliten basiert in der EU auf neun FOCUS Standardszenarien (Hamburg, Kremsmünster, Chateadun, Okehampton, Sevilla, Piacenca, thiva, Porto and Jokioinen), welche erstmals in FOCUS (2000) beschrieben und in FOCUS (2009/2014) weiterentwickelt wurden. Die beiden Szenarien Hamburg und Kremsmünster sind diejenigen der FOCUS Standardszenarien mit den Klima- und Bodenbedingungen, die im nationalen deutschen Zulassungsverfahren für Pflanzenschutzmittel derzeit als relevant für eine konservative Grundwasser-Risikobewertung angesehen werden (Holdt et al., 2011).

Auch wenn diese zwei Szenarien als repräsentativ für die Ackerbaufläche in Deutschland gelten, wurden bisher auf nationaler Ebene keine differenzierten räumlichen Analysen durchgeführt, die das Schutzniveau der FOCUS Szenarien bzw. ihre Boden- und Klimaeigenschaften untersucht haben, um den „realistic worst-case“ Charakter der Szenarien für die bundesweite Ackerbaufläche in Deutschland zu bestätigen. Frühere Analysen, die durch FOCUS (2009/2014) durchgeführt wurden, zielten nicht darauf ab, das Schutzniveau von einzelnen EU-Szenarien für einzelne Mitgliedsstaaten zu bewerten. Sie sollten eher die Frage beantworten, welche Flächen der EU generell hinsichtlich der Boden- und Klimaeigenschaften durch die FOCUS-Szenarien repräsentiert sind. Dementsprechend wurden für entsprechende europäischen Analysen räumlichen Datensätze mit einer relativ geringen Auflösung und nur mit Informationen über die Oberböden verwendet.

Dieser „Teil B“ des F & E (Forschungs- und Entwicklungs-) – Projektes zielte daher darauf ab, eine Protektivitätsanalyse der FOCUS Szenarien Hamburg und Kremsmüntser für Deutschland durchzuführen. Eine GIS basierte Analyse auf nationaler Ebene wurde unter Einbeziehung von bundesweit höchstmöglich aufgelösten Geodaten durchgeführt, um die Repräsentativität und Protektivität der beiden FOCUS-Szenarien bzw. ihrer Klima- und Bodeneigenschaften zu untersuchen. Die Analysen wurden in zwei Teile untergliedert („Step 1“ und „Step 2“). Inhalt von „Step 1“ war eine substanzunabhängige Untersuchung des Auftretens von Boden- und Klimaeigenschaften auf Ackerbauflächen in Deutschland im Vergleich zu den entsprechenden Eigenschaften der FOCUS-Szenarien. Im Zuge dessen wurden Flächen identifiziert, welche, hinsichtlich bestimmter Boden- und Klimaeigenschaften, die die Versickerung von Pflanzenschutzmitteln beeinflussen, anfälliger sind als die beiden FOCUS Szenarien.

Bezüglich der Klimabedingungen kann angenommen werden, dass Hamburg keinen „realistic worst-case“ repräsentiert. Etwa 60 % der Ackerbaufläche ist durch niedrigere jährliche Niederschläge als das FOCUS Szenario charakterisiert. Im Winter ist das räumliche Schutzniveau ein wenig höher (etwa 65 %) als im Sommer (etwa 56 %). Für den Parameter mittlere Jahrestemperatur ist die relevante Fläche, die durch das Hamburg Szenario abgedeckt ist, sogar niedriger (etwa 45 %), wobei die mittlere Sommertemperatur ein höheres räumliches Schutzniveau zeigt (76 %) als die Temperatur im Winter (25 %).

Die „Step 1“ Analyse zeigte weiterhin, dass das FOCUS Hamburg Bodenprofil mit 1.5 % organischem Kohlenstoff im obersten Bodenhorizont ein mittleres Szenario für das Vorkommen von organischen Kohlenstoffgehalten in deutschen Ackerböden repräsentiert. 44 % der deutschen Ackerböden zeigen niedrigere organische Kohlenstoffgehalte im obersten Bodenhorizont verglichen mit dem Hamburg Szenario. Vorbereitende Analysen zeigten außerdem, dass im Gegensatz zum FOCUS Hamburg Szenario die meisten der Ackerbau-Bodenprofile der originalen BÜK 1000 N (Nutzungsdifferenzierte Bodenübersichtskarte 1:1000000) bereits im zweiten Bodenhorizont organische Kohlenstoffgehalte von null aufweisen. Diese konservative Parametrisierung in der BÜK 1000 N kann einen signifikanten Einfluss auf das abzuschätzende Versickerungsverhalten haben. Da es nicht wahrscheinlich erschien, dass die organische Substanzklasse h0 weitgehend schon in Bodentiefen von 50 cm vorgefunden wird, wurden die ursprünglichen C_{org}-Gehalte durch aktuellere Daten nach Düwel et al. (2007) und Utermann et al. (2009) ersetzt. Die Ergebnisse hinsichtlich des auf 1 Meter tiefengewichteten organischen Kohlenstoffgehaltes bestätigen zusätzlich, dass der FOCUS Hamburg Boden weit davon entfernt ist, ein „realistic worst-case“ zu sein. 73 % der ackerbaulich genutzten Böden in Deutschland zeigten nach Düwel et al. (2007) und Utermann et al. (2009) niedrigere gemittelte organische Kohlenstoffgehalte als das FOCUS Hamburg Bodenszenario und somit ein niedrigeres Potential für die Adsorption von Pflanzenschutzmitteln.

Ein quantitatives Schutzniveau des FOCUS Hamburg Szenarios für Deutschland kann jedoch letztendlich nur dann abgeleitet werden, wenn andere wichtige Modellparameter neben Klima- und Bodeneigenschaften, wie z.B. das Applikationsmuster, Substanzeigenschaften oder die Kultur mit in Betracht gezogen werden. Deshalb wurde zusätzlich zu der ersten modellunabhängigen Analyse eine „Step 2“ Auswertung ausgeführt, bei der das Versickerungsmodell PELMO mit georeferenzierten Daten verknüpft wurde, um das räumliche Schutzniveau des FOCUS Hamburg Szenarios für die ackerbaulich genutzte Fläche in Deutschland abhängig von Frühjahr-/Sommer- und Herbst-/Winterapplikationszeitpunkt und wichtigen Substanzeigenschaften wie Abbau und Sorption im Boden zu berechnen. Um PELMO mit geographischen Informationen aus unterschiedlichen thematischen Karten zu verknüpfen, wurde ein prozessbasierter Modellierungsansatz angewandt ähnlich der in GeoPEARL (Tiktak et al., 2013) und GeoPEARL_DE (Bangert, 2007) realisierten Methode. Die Neuentwicklung des Versickerungsmodells „GISPELMO“ für Deutschland resultierte in 3348 unterschiedlichen Kombinationen aus Bodenprofilen (BGR, 2007) und DWD Wetterstationen (DWD, 2012), für die die geographischen Daten basierend auf einem Raster mit $1km^2$ Auflösung zur Verfügung standen.

Um eine angemessene Bandbreite von typischen Eigenschaften von Pflanzenschutzmitteln abzudecken, wurden insgesamt 9 verschiedene fiktive Substanzen betrachtet und als Wirkstoffe simuliert. Deren Eigenschaften unterscheiden sich in deren Sorptionskonstante (Kf_{oc}) und deren Halbwertszeit ($DegT_{50}$), weil dies normalerweise die wichtigsten substanzbezogenen Einflussfaktoren für die Versickerung im Boden sind. Alle Simulationen wurden für die Kulturart Mais und Wintergetreide über eine Zeitspanne von 26 Jahren hinweg inklusive einer 6 jährigen Aufwärmphase und jährlichen Applikationen ein Tag vor Aufkommen der Kulturart ausgeführt. Mais und Wintergetreide wurden als typische Kulturarten ausgewählt, die sowohl Früjahr-/Sommer- als auch Herbst-/Winterapplikationszeitpunkt abdecken. Eine generelle Applikationsrate von 200 g/ha wurde festgelegt. Jedoch wurde die Rate für manche Substanzen angepasst, um eine Spanne von Versickerungskonzentrationen zu erreichen, die für Wirkstoffe den Grenzwert von 0.1 µg/l nicht mehr als eine Größenordnung über- oder unterschreitet. Während der Entwicklung von GISPELMO in diesem Projekt wurde entschieden, das 80. zeitliche Perzentil der PELMO Sickerwasserkonzentrationen in 1 m Bodentiefe aus 20 aufeinanderfolgenden Wetterjahren als relevanten PEC im Grundwasser für jede Rasterzelle zu nutzen, um damit sowohl mit dem FOCUS-Ansatz in der EU (FOCUS 2009/2014) als auch mit dem gegenwärtig angewendeten regulatorischen Grundwasserbewertungsschema in Deutschland (Holdt et all., 2011) im Einklang zu stehen.

Im Gegensatz zur regulatorisch akzeptierten FOCUS PELMO Standardsimulation wurde der Oberflächenabfluss (Runoff) als relevant für die Protektivitätsanalyse betrachtet, weil dies ein auf einer bedeutenden Fläche in Deutschland offensichtlich relevanter Prozess ist, der somit Einfluss auf die Ergebnisse der bundesweiten Versickerungsmengen und Versickerungskonzentrationen haben kann. Die über 20 Jahre gemittelten jährlichen Runoffmengen, die mit PELMO simuliert wurden, befanden sich im Bereich von 5 L/m^2 bis zu 250 L/m^2 mit deutlich höheren Runoffmengen in Mais als in Wintergetreide aufgrund von Brachebedingungen in der Herbst- und Winterzeit. Die Regionen mit den niedrigsten abgeschätzten Runoffmengen befinden sich hauptsächlich in Nordostdeutschland aufgrund des Vorkommens von sandigen Böden und niedrigen jährlichen Niederschlägen, während die höchsten Runoffmengen für Gebiete in Mittelgebirgen berechnet wurden, insbesondere im Sauerland in Nordrhein-Westfalen.

Die räumliche Verteilung der berechneten Versickerungsmengen zeugen davon, dass sich die Regionen mit den niedrigsten über 20 Jahre gemittelten jährlichen Versickerungsmengen aufgrund des niedrigen jährlichen Niederschlags hauptsächlich in Nordostdeutschland befinden, während die höchsten Versickerungsmengen für Mittelgebirge, wo normalerweise höhere Niederschläge auftreten, berechnet wurden.

Die Ergebnisse der Step 2 Simulationen mit 18 unterschiedlichen Kultur-/Substanzkombinationen zeigten generell höhere Versickerungskonzentrationen für Herbst-/Winterapplikationen (Wintergetreide) als für Frühjahr-/Sommerapplikationen (Mais). Desweiteren zeigten die GISPELMO Analysen, dass das FOCUS Hamburg Szenario nur ein räumliches Perzentil im Bereich 31 % bis 65 % für die ackerbauliche Fläche in Deutschland repräsentiert, wenn das 80. zeitliche Perzentil aus einer 20 jährigen Simulationsperiode vorausgewählt wurde. Der arithmetische Mittelwert für alle berechneten Kultur-/Substanzkombinationen lag letztlich bei 44 % für das FOCUS Hamburg Szenario. Daraus kann geschlussfolgert werden, dass das FOCUS Hamburg Szenario nicht ein erwartetes 80. räumliches Perzentil für die Ackerbaufläche in Deutschland repräsentiert, obwohl sich die simulierten Konzentrationen im Sickerwasser des FOCUS Hamburg Szenario nicht erheblich vom 80. räumlichen Perzentil, das mit GISPELMO berechnet wurde, unterscheiden. Das Verhältnis zwischen dem FOCUS Hamburg Szenario und dem 80. Perzentil aus GISPELMO kann mit einem mittleren Faktor von 3.23 beschrieben werden.

Unter der Annahme, dass die Sickerwassermenge in 1 m Bodentiefe einen wichtigen Summenparameter für den Pestizidtransport im Boden darstellt, weil sie bereits Bodenbedingungen und Niederschlagsmengen berücksichtigt, sind die Resultate bezüglich der Konzentrationen im Sickerwasser ziemlich gegensätzlich zu den Ergebnissen der berechneten Versickerungsmengen in 1 m Bodentiefe. Bezüglich letzterem Parameter wurde vom FOCUS Hamburg Szenario ein höheres räumliches Perzentil auf den ackerbaulich genutzten Böden in Deutschland eingenommen als für die Konzentrationen im Sickerwasser selbst.

Im Gegensatz zum Versickerungsvolumen in 1 m Bodentiefe sind die entsprechenden Pestizidkonzentrationen im hohen Maße durch den organischen Kohlenstoffgehalt im Bodenprofil beeinflusst. Mit 27.2 % zeigt das FOCUS Hamburg Szenario ein relativ niedriges räumliches Schutzniveau bezüglich des auf 1 m tiefengewichteten C_{org}-Gehaltes in deutschen Ackerböden. Dies ist wahrscheinlich der dominierende Faktor, der letztlich zu den gegensetzlichen Ergebnissen bezüglich der Protektivität der berechneten Sickerwassermengen und der Konzentrationen im Sickerwasser für das FOCUS Hamburg Szenario führt.

Mit den Analysen basierend auf dem 80. zeitlichen Perzentil wurden einige für Versickerung anfällige Flächen identifiziert, welche annähernd unabhängig von den gewählten Substanz- und Kultureigenschaften auftraten. Diese Feststellung war die Basis für die Auswahl und Bewertung von alternativen Szenarien, die das 80. räumliche Perzentil für die Ackerbaufläche in Deutschland besser repräsentieren als das FOCUS Hamburg Szenario.

Die folgenden Grundsätze wurden für die Auswahl von alternativen „realistic worst-case“ Szenarien für die Ackerbaufläche in Deutschland angewandt:

- GISPELMO Ergebnisse für alle ausgewählten Kultur-/Substanzkombinationen wurden betrachtet.
- Die Kombination des 80. räumlichen und des 80. zeitlichen Perzentils war, wie empfohlen durch FOCUS (2009/2014), das Ziel.
- Da das räumliche Zielperzentil genau genommen nur durch eine sehr kleine Fläche in Deutschland repräsentiert wäre (eine einzelne Rasterzelle des GISPELMO Modells) wurde eine breitere Spanne von 80 ± 5 % betrachtet, um angemessene Flächen für die Auswahl von Szenarien zu identifizieren.
- Die Auswahl eines Hauptszenarios basiert auf einer Überlappung von 18 Kultur-/Substanzkombinationen mit dem jeweils 80. räumlichen und zeitlichen Perzentil, wodurch die Unabhängigkeit des Szenarios von Kultur- und Substanzeigenschaften gegeben ist.
- Da die Gesamtüberlappung von allen 18 Kultur-/Substanzkombinationen nur für eine sehr kleine Fläche erreicht wurde, wurden weitere Szenarien basierend auf Unterklassen der 18 Kombinationen (z. B. nur Wintergetreide, zur Versickerung neigende Substanzen) vorgeschlagen.

Die Alternativszenarien, die im Zuge dieser Auswertung bestimmt wurden und die das 80. räumliche Perzentil für die eine Risikobewertung Grundwasser für Pflanzenschutzmittel für Ackerbauflächen in Deutschland besser repräsentieren würden, sind in Tabelle 3-45 zusammengefasst. Sie sind charakterisiert durch unterschiedliche saisonal mittlere Temperaturen und Niederschlagsmengen, die typische und geographisch bedingte Klima- und Wetterabweichungen in Deutschland widerspiegeln. Insgesamt sind die mittleren Temperaturen und Niederschläge an den meisten von diesen ausgewählten DWD-Stationen durchaus vergleichbar zum FOCUS Hamburg Wetter. Klare Abweichungen in Vergleich zum FOCUS Hamburg Wetter mögen für manche Klimaparameter an manchen Klimastationen vorhanden sein, wobei diese Unterschiede sowohl über als auch unter den Hamburg Wetterwerten liegen können. Indessen zeigt die Zusammenstellung deutlich, dass all diese Szenarien durch typische Bodenprofile mit niedrigeren gemittelten organischen Kohlenstoffgehalten bis zu einer Tiefe von 1 m (Spanne von 0.52 % bis 0.70 %) im Vergleich zum FOCUS Hamburg Boden (0.78 %) charakterisiert sind. Die Ergebnisse der Step 2 Analyse zeigten weiterhin, dass es problematisch sein kann, alle Entscheidungen auf ein einziges oder eine geringe Anzahl an Szenarien zu basieren, da es gemäß der GISPELMO Simulationen kein festes Szenario gibt, das immer ein bestimmtes räumliches Perzentil für die gesamte Ackerbaufläche in Deutschland garantiert.

Desweiteren betrachten die vorhandenen Simulationen nur wenige Applikationszeiträume und Kulturen. Nur ein bundesweites Werkzeug wie GISPELMO ist dazu in der Lage, immer ein exaktes räumliches Perzentil abhängig von den Substanzeigenschaften, der Kulturart und dem Applikationszeitpunkt zu berechnen. Zusätzlich könnte ein solches GIS-basiertes Werkzeug auch die reale

Ausbreitung der Kulturart oder bestimmte Bedingungen (wie zusätzliche geographische Informationen über Bodentypen, Klima oder Hangneigung) berücksichtigen, um eine Fall zu Fall Entscheidung zu ermöglichen. Insbesondere wenn eine Risikobewertung für bestimmte Situationen (z. B. Dauerkulturen wie Weinbau) durchgeführt werden muss und Simulationen für die gesamte Agrarfläche nicht sinnvoll erscheinen, ist GISPELMO eine geeignete Alternative.

Daher wird empfohlen, GISPELMO als eine zusätzliche „higher-tier" Option im Registrierungsprozess zu betrachten. Weitere Modellerweiterungen, die beispielsweise den Zwischenabfluss und den Makroporenabfluss als zusätzliche Prozesse in der Bodenwasserbilanz betrachten würden, benötigen weitere Untersuchungen und Bewertungen.

2 Summary

The assessment of potential leaching to groundwater of active substances from plant protection products and/or their relevant metabolites in the EU is based on nine FOCUS standard scenarios (Hamburg, Kremsmünster, Chateaudun, Okehampton, Sevilla, Piacenca, Thiva, Porto and Jokioinen) which have been first described in FOCUS (2000) and are advanced in FOCUS (2009/2014). The two scenarios Hamburg and Kremsmünster are those of the FOCUS standard scenarios with climatic and soil conditions which turned out to be most relevant for a conservative groundwater risk assessment in the German national authorisation procedure (Holdt et al, 2011).

Even though these two scenarios are obtained to be representative for the areas of arable land use type in Germany there's a lack of differentiated spatial analysis on national level regarding their protection level or their defined soil and climate properties respectively to confirm their "realistic worst-case" character for the agricultural area in Germany. Previous analyses conducted by FOCUS (2009) didn't have the aim to assess the protection level of single EU-scenarios for single member states. They rather should answer the question which areas of the EU are generally represented by FOCUS scenarios concerning their soil and climate properties. Correspondingly spatial datasets with a relatively low resolution and only information about the upper soil layer were used on the European level.

This "Part B" of the R & D (Research & Development) study aimed at the refinement of that lack of information. A GIS based analysis on national level was conducted using geodata with the nationwide highest possible resolution looking at the representativeness of the FOCUS-scenarios Hamburg and Kremsmünster, their soil and climate properties respectively. The analyses were separated into two parts ("STEP 1" and "STEP 2"). Topic of "STEP 1" was a substance independent examination of the occurrence of soil and climate properties on arable land in Germany compared to the corresponding properties of the two FOCUS scenarios. In course of that areas were identified which are more vulnerable than the scenarios according to special soil and climate properties which influence the leaching of plant protection products to groundwater.

Referring to the climate conditions it turned out that Hamburg doesn't seem to represent a realistic worst-case. About 60 % of the arable land is characterised by lower yearly precipitation than the FOCUS scenario. In winter the spatial protection level is a bit higher (around 65 %) than in summer (around 56 %). For the parameter "average temperature" the relevant area covered by the Hamburg scenario is even lower (around 45 %), whereat the summer temperature shows a higher spatial protection level (76 %) than the temperature in winter (25 %).

Concerning the soil parameters the Step 1 analysis showed that the FOCUS Hamburg soil profile with 1.5 % organic carbon content in the upper soil layer does represent a reasonable medium case scenario for the distribution of organic carbon contents in German agricultural soils. 44 % of the German soils show lower organic carbon contents in the upper soil layer compared to the FOCUS Hamburg scenario. Preliminary analysis further indicated, that in contrast to the FOCUS Hamburg scenario most of the agricultural soil profiles of the original BÜK 1000 N showed organic carbon contents of zero already in the second soil horizon. This conservative parametrisation in the BÜK 1000 N would have a significant impact on the estimated leaching behaviour. As it did not seem reasonable that the organic matter class h0 is widely found already at soil depths of about 50 cm the original C_{org}-contents were replaced by more recent results of Düwel et al. (2007) and Utermann et al. (2009). Finally,the results referring to the depth weighted organic carbon content

down to 1 m soil depth additionally confirm that the FOCUS Hamburg soil was found to be far away from being a realistic worst case. 73 % of agricultural soils in Germany according to Düwel et al. (2007) and Utermann et al. (2009) showed lower averaged organic carbon contents than the FOCUS Hamburg soil scenario and hence a lower potential for adsorption of plant protection products.

Finally, a quantitative protection level of the FOCUS Hamburg scenario for Germany can only be derived if other important model parameters beside climate and soil such as application pattern, substance properties or crop type are also taken into account. Therefore and in addition to the initial model independent analysis a Step 2 evaluation was performed where the leaching model PELMO was combined with geo-referenced data in order to calculate the spatial protection level of the FOCUS Hamburg scenario for the agricultural area in Germany dependent on spring/summer and autumn/winter application times and important pesticide parameters such as degradation and sorption in soil. In order to combine PELMO with geographic information from different thematic maps a process-based modelling approach was applied similar as the methodology realised in GeoPEARL (Tiktal et al., 2003) and GeoPEARL_DE (Bangert, 2007). The new development of the leaching model "GISPELMO" for Germany resulted in 3348 different combinations of soil profiles (BGR, 2007) and DWD weather stations (DWD, 2012) for which the geographic data was available based on a raster map with a resolution of 1 km^2

In order to cover a reasonable range of typical properties from plant protection products in total 9 different fictive compounds were considered and simulated as active substances. Their properties differed in their sorption constants (Kf_{oc}) and their degradation times in soil ($DegT_{50}$) because these are normally the most important substance related driving factors for leaching in soil. All simulations were performed in maize and winter cereals over a period of 26 years including a warming up period of 6 years and with annual applications one day before emergence of the crop. Maize and winter cereals were chosen as typical crops to cover both spring/summer and autumn/winter application dates. A general application rate of 200 g/ha was defined. However, for some compounds the rate was adapted to achieve a range of leaching concentrations which do not exceed one order of magnitude above or below the trigger value of 0.1 µg/L for active substances. During the development of the GISPELMO in this project it was decided to use the 80th temporal percentile of the PELMO percolate concentrations in 1 m soil depth from 20 sequent weather years as relevant PEC in groundwater for each raster cell and therefore to be consistent with the FOCUS scenario approach in the EU (FOCUS 2009/2014) and with the currently applied regulatory groundwater assessment scheme in Germany (Holdt et al., 2011).

In contrast to regulatory accepted standard FOCUS PELMO simulation the runoff process was considered as relevant for PEC calculation because it is obviously occurring as process on major areas in Germany and therefore may have an impact on the result of the evaluation of nationwide leachate amounts and leachate concentrations. The annual runoff amounts averaged over 20 years simulated with GISPELMO were in the range of 5 L/m^2 up to 250 L/m^2 with significantly higher amounts of runoff in maize than in winter cereals due to fallow conditions in the autumn and winter periods. The regions with the lowest estimated annual runoff amounts are located mainly in North-East-Germany due to a high occurrence of sandy soils and the low annual precipitation whereas maximum runoff amounts were calculated to be in areas of the low mountain range especially in the Sauerland in North Rhine-Westphalia.

The spatial distribution of the calculated percolate amounts in Germany gave evidence, that the regions with the lowest annual percolate averaged over 20 years are located mainly in North-East-

Germany due to the low annual precipitation whereas maximum percolate amounts were calculated to be in the low mountain range, where normally higher precipitation occurs.

The results of the step 2 simulations with 18 different crop-compound combinations generally showed higher leachate concentrations for autumn/winter applications (winter cereals) than for spring/summer applications (maize). Furthermore, the GISPELMO analysis showed that the FOCUS Hamburg scenario only represents a spatial percentile in the range of 31 % up to 65 % for the agricultural area in Germany when an 80th temporal percentile was pre-selected from a 20 years simulation period. The arithmetric mean of the spatial percentiles for all calculated crop-compound combinations was finally 44 % for the FOCUS Hamburg scenario. It was concluded that FOCUS Hamburg is not representing an 80th spatial percentile for the agricultural area in Germany although the simulated concentrations in the percolate of the FOCUS Hamburg scenario do often not extremely differ with the 80th spatial percentile as calculated with GISPELMO. An average factor of 3.23 would describe the averaged ratio between the FOCUS Hamburg scenario and the 80th percentile of GISPELMO, respectively.

Assuming that the percolate amount in 1 m soil depth represents an important sum parameter for pesticide transport in soil, because it considers already soil conditions and precipitations in a certain area, the results referring to the leachate concentrations seem to be quite contrary to the results of the calculated percolate amounts in 1 m soil depth. Concerning the latter parameter a higher spatial percentile of the agricultural area in Germany was met for the FOCUS Hamburg scenario than for the leachate concentration.

However, in contrast to the volume of the percolate at 1 m soil depth the related pesticide concentrations are highly influenced by the organic carbon content in the soil profile. With 27.2 % the FOCUS Hamburg scenario shows a relatively low level of spatial protection regarding the 1 m depth weighted C_{org}-content in German agricultural soils. That is probably the dominant factor which finally leads to the contrary results for the percolate amount and the concentrations in the percolate for the FOCUS Hamburg scenario.

With the analysis and based on the selected 80th temporal percentile some vulnerable areas for leaching were identified which appeared to be nearly independent on the chosen pesticide and crop properties. This observation was the base for the selection and evaluation of alternative scenarios which may better represent the 80th spatial percentile for the agricultural area in Germany than the FOCUS Hamburg scenario.

The following principles were applied for the selection of alternative realistic worst case scenarios for the agricultural area in Germany:

- GISPELMO results of all chosen crop-substance combinations were considered.
- The combination of the 80th spatial and the 80th temporal percentile was the target as recommended by FOCUS (2009/2014).
- As the target spatial percentile would technically speaking only be represented by a very small area (single raster cell relating to the GISPELMO model) in Germany a wider percentile range of 80 ± 5 % was considered to identify a reasonable area for the selection of scenarios.
- The selection of one main alternative scenario is based on an overlap of 18 crop-compound combination each with the 80th spatial and temporal percentile and therefore independent on the crops and pesticide properties.

- As the total overlap of all 18 crop-compound combinations was only reached for a very small area further scenarios were suggested based on subclasses of the 18 combinations (e.g. only winter crops, only major leaching substances).

The alternative scenarios determined in this evaluation, which would better represent an 80th spatial percentile for the risk assessment of pesticide leaching for the agricultural area in Germany, are summarised in Table 3-45. They are characterised by different seasonal averaged temperatures and precipitation amounts, which reflect typical and geographicly justified climate and weather deviations in Germany. Overall, the averaged temperatures and precipitations are in most of this selected DWD stations quite comparable to the FOCUS Hamburg weather. Clear distinctions compared to the FOCUS Hamburg weather may exist for some climate parameters in some stations, whereat those distinctions can be identified both below and above the typical FOCUS Hamburg weather values. However, the analysis also clearly demonstrated that all these alternative areas are characterised by typical soil profiles with lower averaged organic carbon contents until 1 m soil depth (range of 0.52 % to 0.70 %) compared to the FOCUS Hamburg soil (0.78 %). The results of the step 2 analysis further showed that it could be problematic to base all decisions on a single or a small number of scenarios because according to the GISPELMO simulations there is no fixed scenario which always guarantees a certain spatial percentile for the entire agricultural area in Germany.

Furthermore, the available simulations only consider few application pattern and crops. Only a spatially distributed tool like GISPELMO is able to always calculate an exact spatial percentile dependent on pesticide properties, crops and application time. Additionally, such a GIS based tool could also consider the real distribution of crop cover or specific conditions (e.g. additional geographic information about soil types, climate or slope) to enable case by case decisions. Especially when risk assessment has to be performed for special situations (e.g. permanent crops like vines) and simulations of the whole agricultural area don't seem meaningful, GISPELMO could be a suitable alternative.

It is therefore recommended to consider GISPELMO as an additional higher tier option in the registration procedure. Additional model extensions, which for example would consider interflow and preferential flow as additional processes in the soil water balance, need further investigations and validations.

3 Part B: GIS-based analysis of the protection level of the FOCUS-scenarios representative for Germany concerning climate and soil properties for the national risk assessment groundwater

3.1 Introduction

The assessment of potential leaching to groundwater of active substances from plant protection products and/or their relevant metabolites in the EU is based on nine FOCUS standard scenarios (Hamburg, Kremsmünster, Chateaudun, Okehampton, Sevilla, Piacenca, Thiva, Porto and Jokioinen) which first have been described in FOCUS (2000) and are advanced in FOCUS (2009/2014). The two scenarios Hamburg and Kremsmünster are the subset of the FOCUS standard scenarios with climatic and soil conditions found to be most relevant for a conservative groundwater risk assessment in the German national authorisation procedure (Holdt et al, 2011).

Even though these two scenarios are assumed to be representative for the areas of arable land use type in Germany there's a lack of differentiated spatial analysis on national level regarding their protection level or their defined soil and climate properties respectively to confirm their « realistic worst-case » character for the area of the Federal Republic of Germany (FRG). Previous analyses conducted by FOCUS (2009/2014) didn't have the aim to assess the protection level of single EU-scenarios for single member states. They rather should answer the question which areas of the EU are generally represented by FOCUS-scenarios concerning their soil and climate properties. Correspondingly spatial datasets with a relatively low resolution were used on the European level.

This part of the Research and Development (R &. D.) study was aimed at the refinement of that lack of information. A GIS based analysis with the greatest possible resolution of geodata on national level looking at the representativeness of the FOCUS scenarios Hamburg and Kremsmünster, their soil and climate properties respectively, was conducted. The analyses were separated into two parts ("STEP 1" and "STEP 2"). Topic of "STEP 1" was a substance independent examination of the occurrence of soil and climate properties on arable land in Germany compared to the corresponding properties of the FOCUS-scenarios. In course of that areas could be identified which are more vulnerable than the scenarios according to special soil and climate properties which influence the leaching of plant protection products to groundwater.

In the subsequent "STEP 2" analysis concrete substance properties along with soil/climate properties occurring in reality were integrated. Thereby PEC groundwater could be calculated for a lot of different geo-referenced combinations of soil and climate data. The modelling tool PELMO (Pesticide leaching model) was used therefor. PELMO is recommended to be used to calculate the PEC_{gw} of active substances and their relevant metabolites for national assessment in Germany (Holdt et al, 2011). A similar approach to GeoPEARL_DE (Bangert, 2007) was therefore implemented in "GISPELMO". In the GeoPEARL_DE approach combinations of MARS-weather data and soil properties (from the BÜK 1000) were implemented to calculate PEC_{gw} for Germany with the model Pearl.

The model based assessment of the leaching potential is carried out with the assumption that the chromatographic flow of soil water in a homogeneous volume of pores in the different soil layers is the most important process for the transport and relocation of chemical substances in soil. The leaching is thereby mostly inhibited by the adsorption of the substances to the organic matter in soil.

3.2 Step 1 Analysis

3.2.1 Methodology

In the context of "Step 1" a GIS based analysis regarding the spatial representativity of the FOCUS groundwater scenarios "Hamburg" and "Kremsmünster" for Germany was conducted. Therefore different climate and soil parameters were evaluated quantitatively regarding their areal occurrence and were compared with the corresponding values integrated in the mentioned FOCUS GW-scenarios Hamburg and Kremsmünster. "Step 1" did not consider specific substance properties of plant protection products and therefore enabled only a relative view on the climate and soil properties influencing the chromatographic leaching of the substances in soil. But first indications of areas/regions which are probably more vulnerable in comparison to the FOCUS scenarios could be derived.

3.2.1.1 Methodology of the spatial representativity analysis of climate parameters

For "climate" as influencing factor precipitation and temperature parameters were analysed. For the analysis concerning precipitation raster datasets with a temporal resolution of 1 day and concerning temperature of 1 month together with a spatial resolution of each 1 x 1 km were available (DWD, 2012 and 2011, see Table 3-1). Regarding these climatic parameters this represents the highest available nationwide spatial and temporal resolution.

Table 3-1: Overview of applied climatic geodata

	Parameter	Spatial resolution	Source
REGNIE-raster data (clipped on ATKIS land use type "arable land" and "permanent crops")	daily precipitation thereof calculated: yearly precipitation precipitation summer half year precipitation winter half year	1 x 1 km	DWD (2011)
DWD-raster data	monthly temperature thereof calculated: yearly average temperature average temperature summer half year average temperature winter half year	1 x 1 km	DWD (2012)

Separate precipitation and temperature information was determined for summer and winter half-year (summer half-year: beginning of April until end of September, winter half-year: beginning of October until end of March) to take into account the different risk potential (due to different groundwater production rates) of the two main cultivation dependent crop growing seasons of agriculture. Additionally the average annual precipitation and temperature were calculated. For all the parameters a period of 30 years was considered (1980 – 2009), since they represent the most recent climatic relevant time period. For the spatial analysis the nationwide climate raster data was using the ATKIS object classes "arable land" and "permanent crops" (BKG, 2012) in order to perform the analysis only for the potential area of use. The size of the reference area was about 132000 km^2.

For each of these parameters cumulative distribution functions and maps were produced. In order to estimate their vulnerability identical average values were also calculated for the FOCUS-scenarios "Hamburg" and "Kremsmünster" (20 years). The scenario properties could thereby be ranked into the overall distribution and be characterized regarding their vulnerability.

It was assumed that the cumulative areal percentage which is covered by a scenario property directly corresponds to the spatial protection level. Higher precipitation would lead to more leaching of plant protection products (but not necessarily to higher concentrations in the leachate). Concerning the temperature parameters the spatial protection level is conducted from the difference 100 %-"cumulative areal percentage of temperature x". Since the degradation of a substance is going on slower at lower temperatures, a cold scenario shows a high protection level. The curve of the spatial protection level for temperature parameters has thus an inverse run compared to the curve of the cumulative areal distribution.

For reasons of clarity in the results section concerning temperature (see chapter 3.2.2.2) parameters only the spatial protection level is illustrated and the cumulative areal distribution function is left out.

The subsequent chapters start with separate presentations of the analyses of the factors precipitation and temperature. Then different combinations concerning climate properties ("wetter and colder than Hamburg/Kremsmünster", "wetter and warmer than Hamburg/Kremsmünster", …) are illustrated in maps and presented in tables.

3.2.1.2 Methodology of the spatial representativity analysis of soil parameters

The database for the representativity analysis concerning soil was the Land Use Differentiated Soil map of the FRG, scale 1: 1000000 (BÜK 1000 N; BGR, 2007). For parts of Germany there already exists a map with a higher resolution, the Soil map 1: 200000. Since that map series is not finalized for the whole area of Germany yet, the Soil map BÜK 1000 N was used in this project.

In the BÜK 1000 N 432 reference profiles for different land use types (arable land, pasture, agricultural areas with heterogeneous structure and forests) are available. For arable land 129 reference profiles are provided. Those were used in the analyses carried out. The geometries of the BÜK can be linked with profile data of soils with arable land use. In GIS they take an area of about 164000 km^2. Within a single geometry the assigned reference profile does only represent a certain part of the full area. However it generally stands for the most dominant soil type of the area. Therefore the properties of the reference profile are assumed to be valid for 100 % of the single geometry. The spatial extents of the geo-datasets of the reference data on the one hand and climate data on the other differ by about 32000 km^2. This is due to the smaller scale of the soil map (in comparison the ATKIS Basis DLM has a scale of 1: 25000) and the hereby higher level of generalization. Hence the evaluations regarding climate has a higher spatial accuracy.

Concerning soil the properties relevant for the leaching of PPP to groundwater namely C_{org}-content, pH-value, saturated water conductivity (Kf-value) and field capacity were analysed. The values of the parameters pH- and Kf-value are provided in a classified way according to the "Bodenkundliche Kartieranleitung" (BKA; BGR, 2005), for the parameters C_{org}-content and field capacity specific values are given. Since the property classes of the BKA always include a certain range, the average value of the class was used for the analysis (including the lowest Kf-class ($<1.2*10^{-7}$ m/s) ranging between 0 and the upper class limit). PH-values in the lowest class (<3.3) and values in the range of the topmost class for Kf- ($>=3.5*10^{-5}$m/s) and pH-values (>=10.7) didn't occur. The evaluations were made for each parameter based on a depth weighted average over 1 m in soil. In case of a C-horizon where the soil properties are only stated for a depth of 60 cm for example, the depth weighted average was calculated over 60 cm only. For the property "C_{org}-content" there was additionally made an analysis related on the first soil horizon, since the leaching behaviour is significantly influenced by the organic carbon content of the top soil.

Table 3-2: Overview of applied soil geodata

	Parameter	Spatial resolution	Source
BÜK 1000 N vector data	geometries of the 129 reference profiles for arable land joined attributes: C_{org}-content pH-value Kf-value field capacity	1: 1 000 000	BGR (2007)

3.2.1.3 Adaption of the organic carbon content of the BÜK 1000 N soil profiles

In contrast to the FOCUS Hamburg scenario most of the soil profiles of the original BÜK 1000 N show organic matter contents of 0 already in the second soil horizon. That has a significant impact on the estimated leaching behaviour by modelling. As it did not seem reasonable that the organic matter class h0 is widely found already at soil depth of about 50 cm the original C_{org}-contents were replaced by more recent results of Düwel et al. (2007).

The C_{org}-contents of Düwel et al. (2007) are listed according to different soil parent rock groups (BAG). Within these groups there is particularly distinguished according to the land use type (arable land, pasture and forest). Furthermore for every climate region in Germany there's a table with combinations from BAG and land use type (see Table 3-4). Latter differentiation only exists for top soils, in subsoils it's not differentiated referring to climate regions.

On the basis of the legend unit of the BÜK a BAG could be assigned to every soil of the BÜK (see Table 3-3.). Thereby the particular C_{org}-contents could be assigned to the map geometries.

Table 3-3: Overview of the legend units of the BÜK 1000 N summarised according to soil parent rock groups (according to Düwel et al., 2007)

Legend unit (LU)	Soil parent rock group	LU of the BÜK 1000
without	without denotation	2, 72
1	sediments in tides area	3, 4, 5
2	sediments in flood plains	8, 9, 10, 11
3	terraces and gravel deposition	13, 14, 15, 16
4	sands	1, 12, 17, 22, 25, 28, 29, 31, 32, 33, 34
5	till with sandy overlay/cap	26
6	till	19, 20, 21, 23, 24, 27, 30
7	loess	18, 25, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 48
8	sand loess	46
9	carbonate rocks	49, 50, 66, 68, 69
10	argillite	51, 52, 59, 60, 65, 67
11	sandstones	58, 61, 62, 63, 64
12	base igneous rocks and metamorphits	47, 53
13	bimstuff	54
14	acid igneous rocks and metamorphits	55, 56, 57
15	peat (including cultivated peat)	6, 7
(16)	without denotation	70, 71

Table 3-4: Extract from the table „Statistical parameters of the C_{org}-contents (mass-%) in the climate region 33 (North-western climate region), differentiated according to soil parent rock groups and land use type“ (Düwel et al., 2007)

Climate region	Soil parent rock group	Land use type	n	min	P 25	Median	Average
north-western climate region (no 33)	sediments in tides area	arable land	117	0.5	1.4	1.9	2.3
		pasture land	497	0.5	3.5	6	8.1
		forestry	12	2.3	3.3	4.3	4.4
	floodplain sediments	arable land	95	0.5	1.3	1.6	1.9
		pasture land	181	0.4	2.7	4.5	6.4
		forestry	113	0.4	1.8	3.7	5.8
	river and gravel deposits	forestry	52	0.3	1.4	2.7	3.1
	sands	arable land	377	0.3	1.2	1.9	2.1
		pasture land	292	0.3	2.4	3.8	7
		forestry	491	0.1	1.4	2.5	4
	cap over till	arable land	40	0.5	0.6	0.7	0.9
	till	arable land	122	0.2	0.9	1.3	2
		pasture land	34	0.5	1.7	3.4	5.5
	loess	arable land	86	0.6	0.9	1.3	1.7
		pasture land	19	0.7	2	3.9	3.5
		forestry	107	0.5	1.6	2.8	4.5
	sand loess	arable land	91	0.5	1	1.2	1.3
		pasture land	10	0.7	1.1	1.6	2.3
		forestry	77	0.5	1.4	2.2	2.5
	carbonate rocks	pasture land	17	1.3	7.9	10.6	10.5
		forestry	43	0.7	2.1	3	4
	organic and mineral soils in the area of peats	arable land	45	0.3	1.3	2.5	3.7
		pasture land	158	0.7	3.7	7.1	16.6
		forestry	56	0.2	1.7	2.8	6.2

From the tabulated values of the organic carbon contents in soil the median was used in each case. The values for topsoil (Düwel et al., 2007) are valid for 0 – 30 cm, the values for subsoil (Utermann et al., 2009) for 30 – 60 cm. For the comparison the corresponding depth weighted averages for the BÜK were calculated.

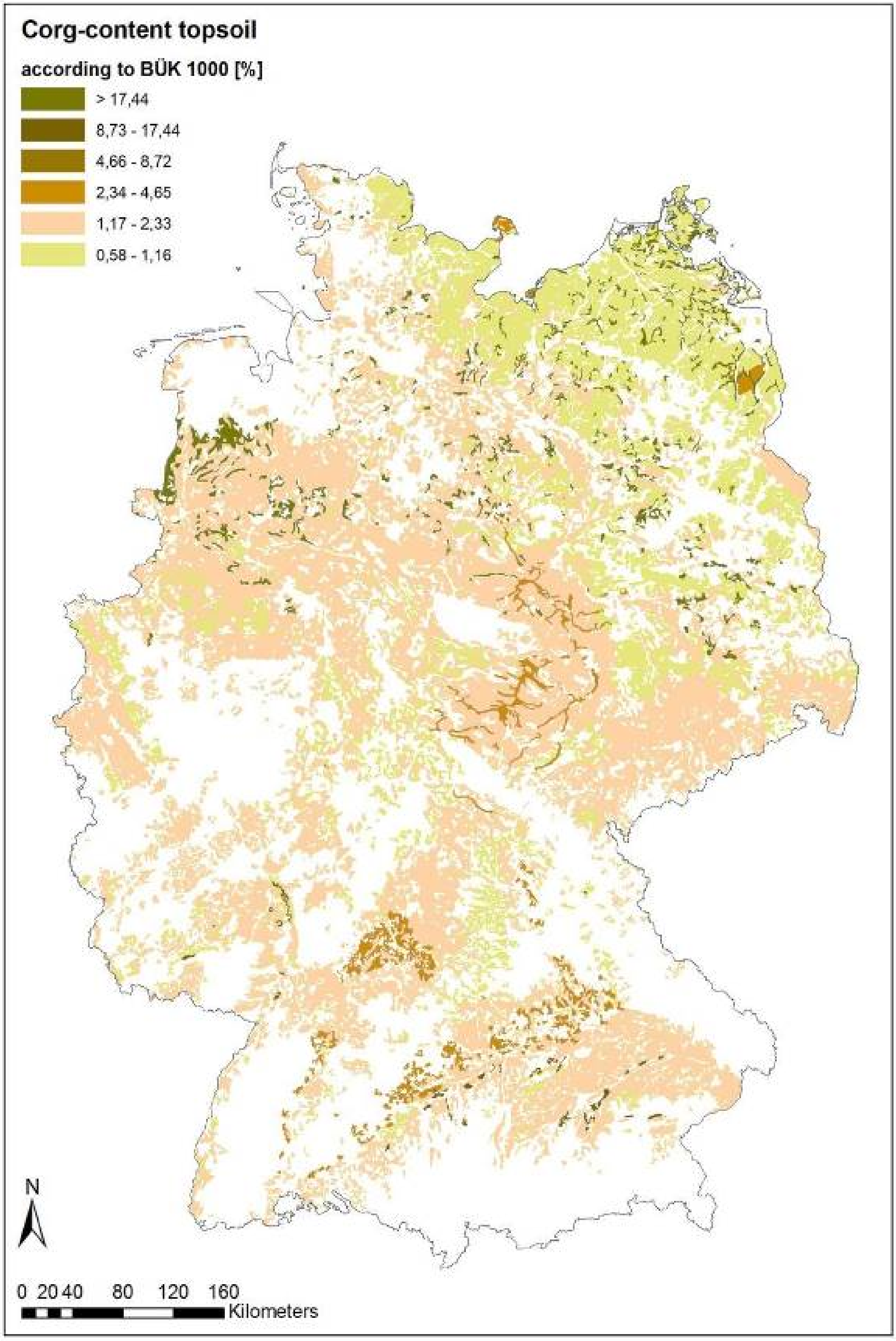


Figure 3-1: C_{org}-contents of the soils with arable land use type in top soil according to the BÜK 1000 N

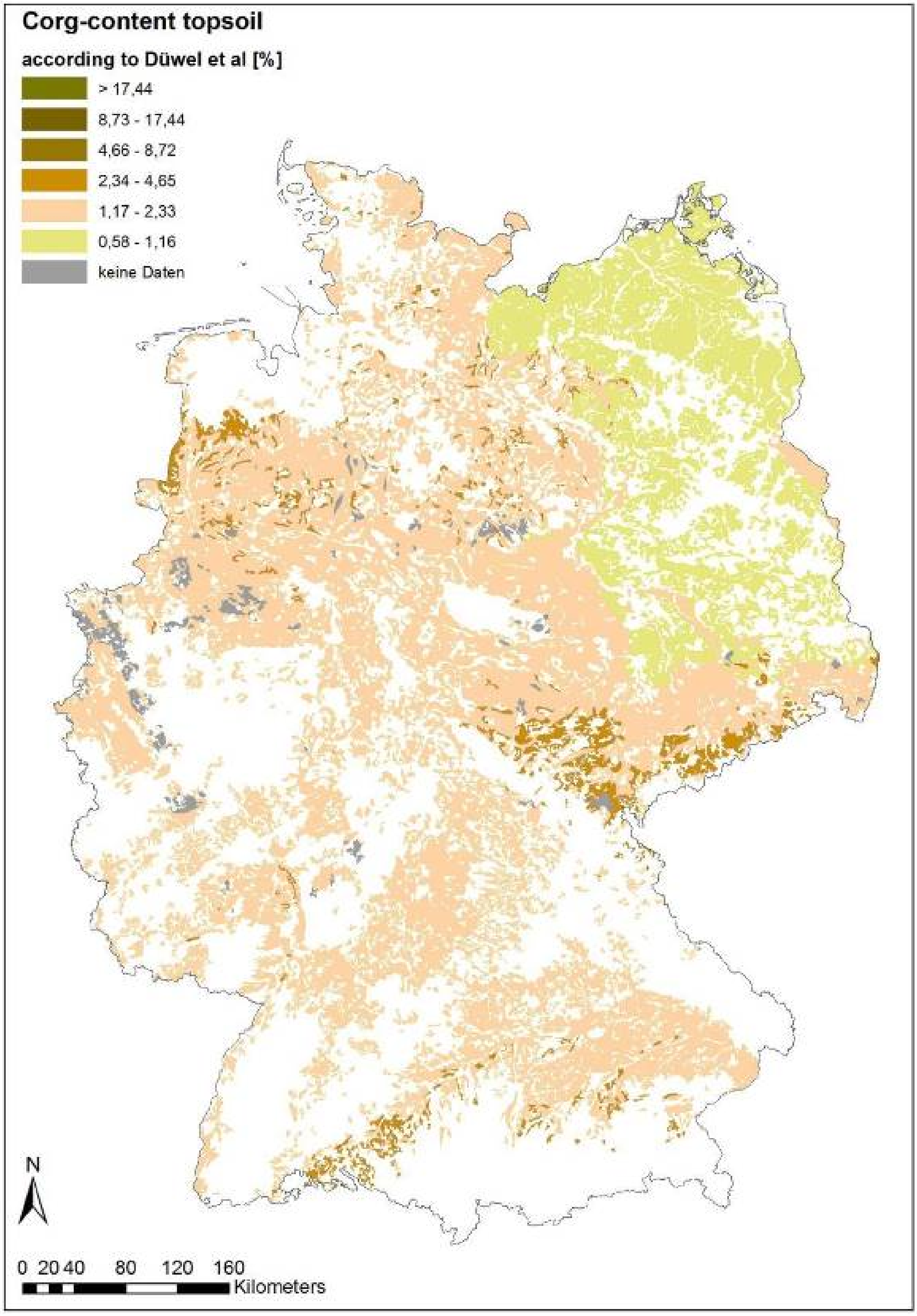


Figure 3-2: C_{org}-contents of the soils with arable land use type in top soil according to Düwel et al. (2007)

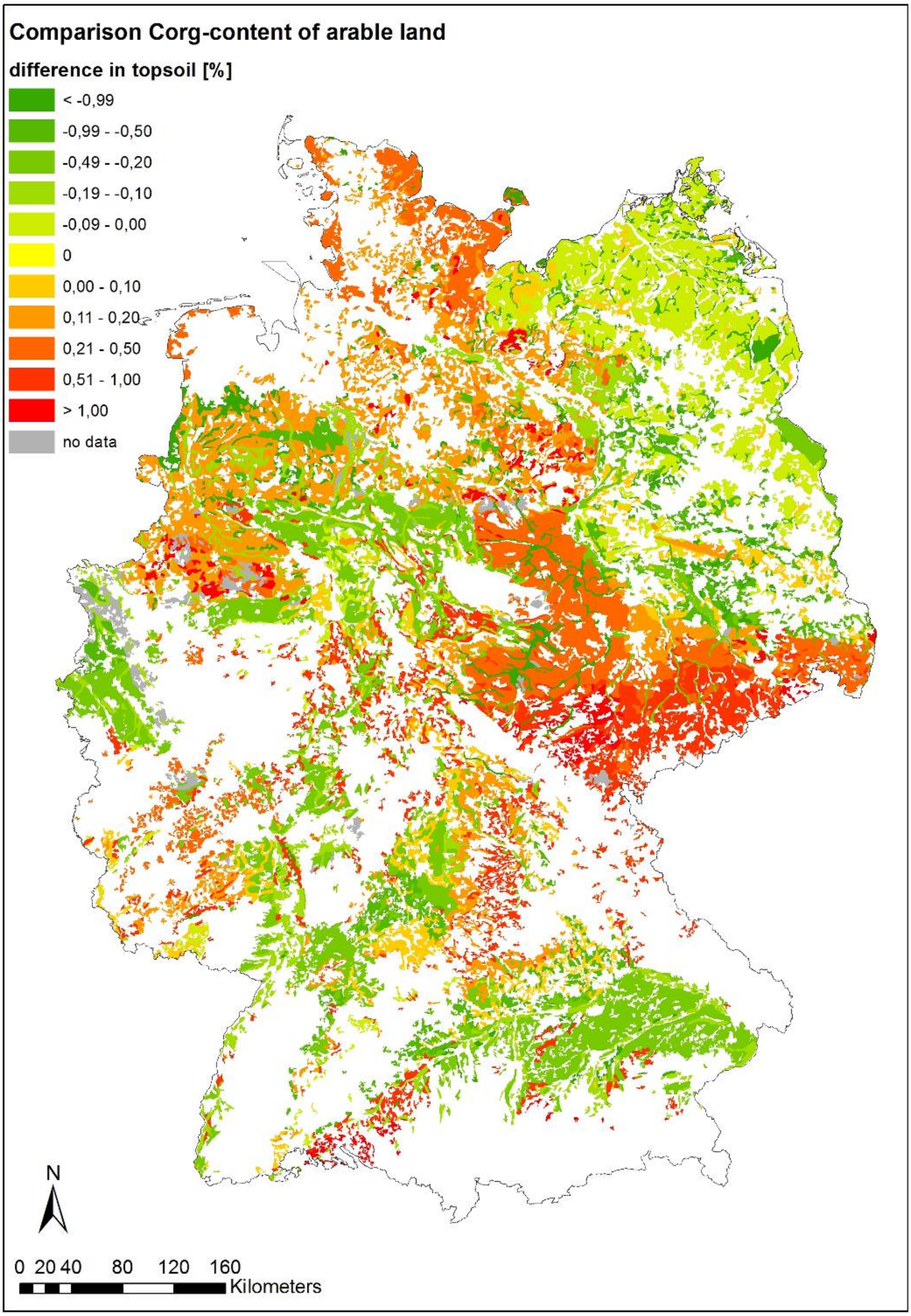


Figure 3-3: Difference of the C_{org}-contents in topsoil from the BÜK 1000 N and Düwel et al. (2007) (shades of red: BÜK 1000 N lower than Düwel et al., 2007; shades of green: BÜK 1000 N higher than Düwel et al., 2007)

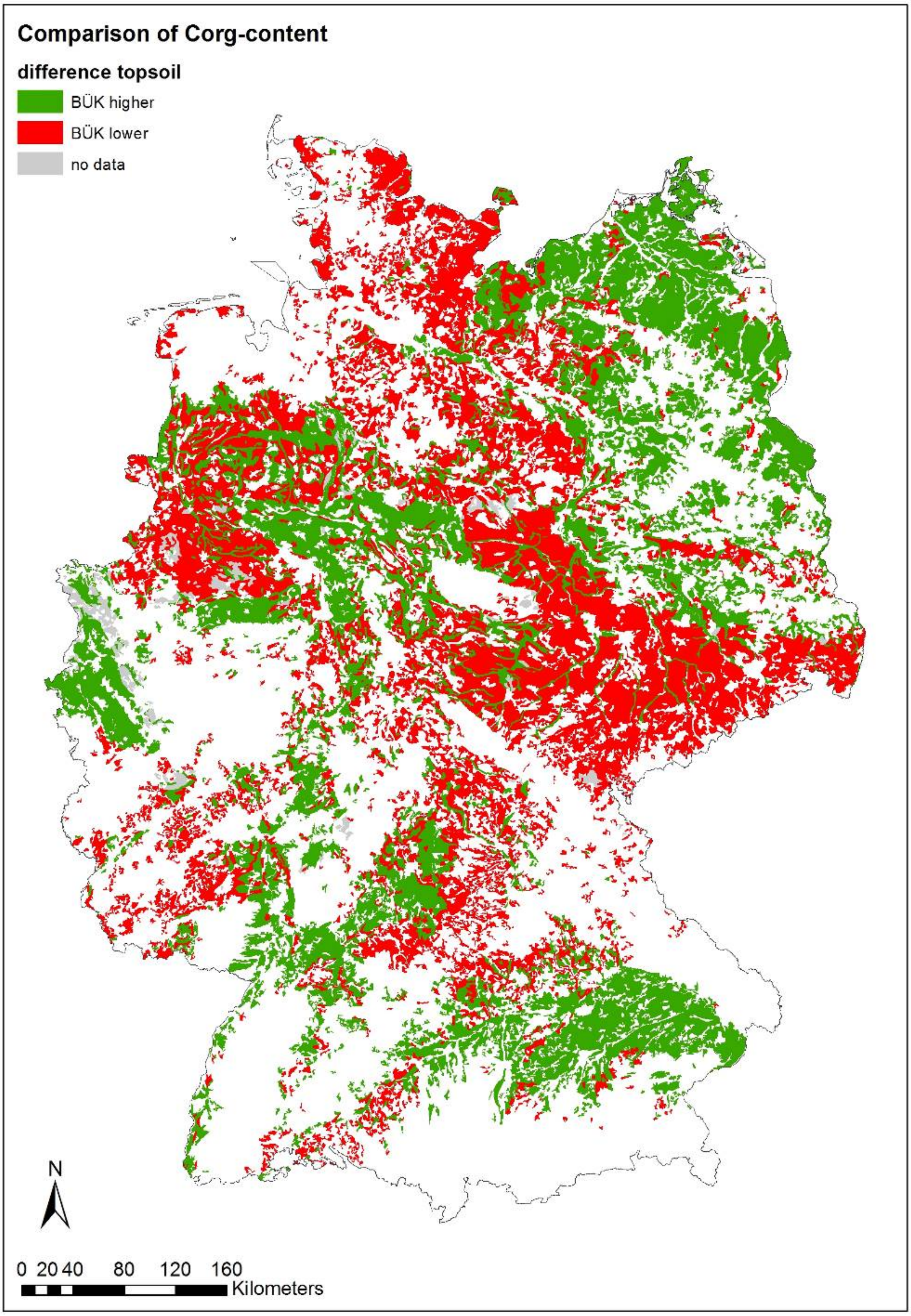


Figure 3-4: Difference of the C_{org}-contents in topsoil from the BÜK 1000 N and Düwel et al. (2007) (red: BÜK 1000 N lower than Düwel et al., 2007; green: BÜK 1000 N higher than Düwel et al., 2007)

In topsoil 49.7 % of the BÜK-area show higher C_{org}-values than Düwel et al. (2007), 50.3 % show lower C_{org}-values.

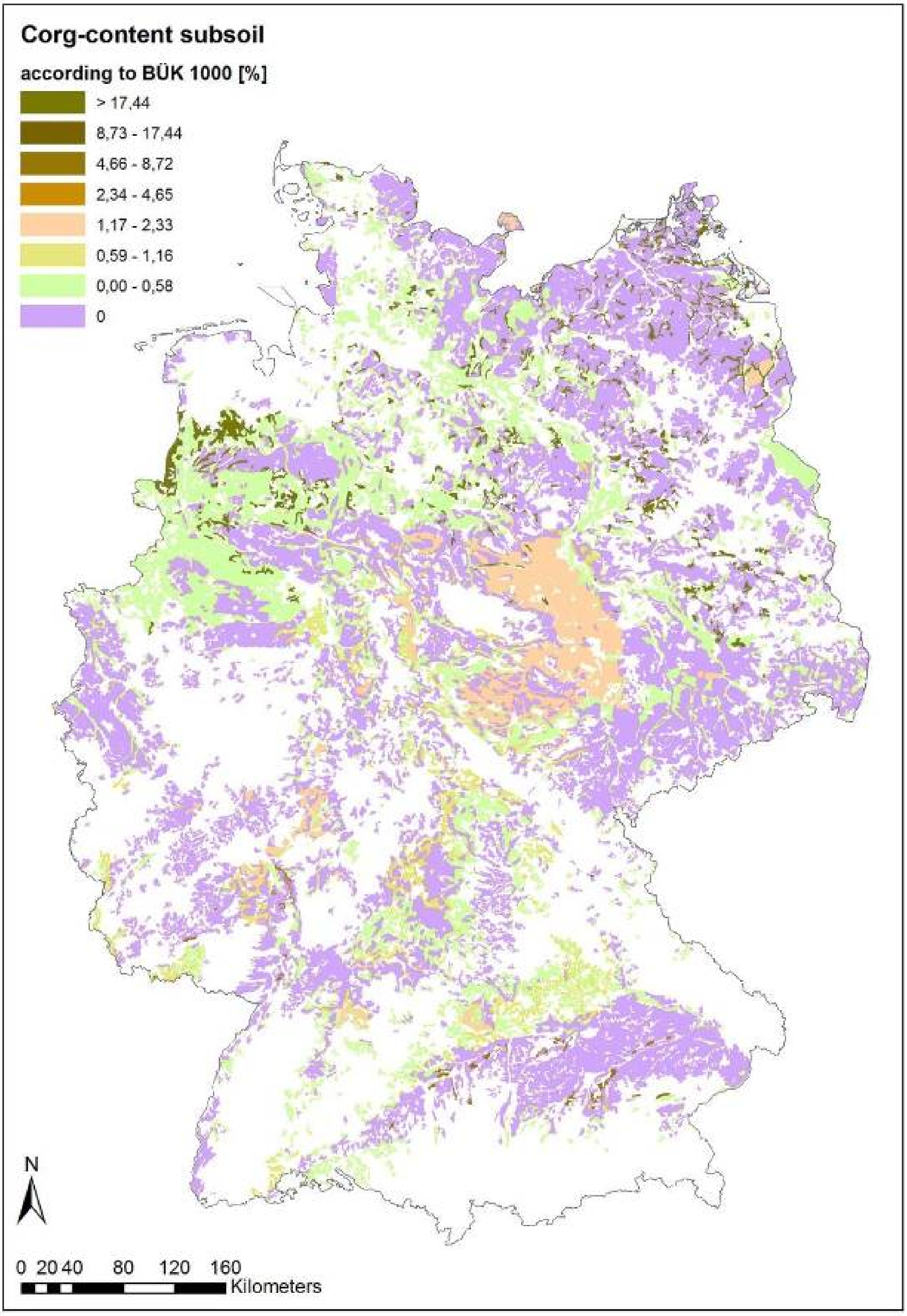


Figure 3-5: Corg-contents of soils with arable land use type in subsoil according to BÜK 1000 N

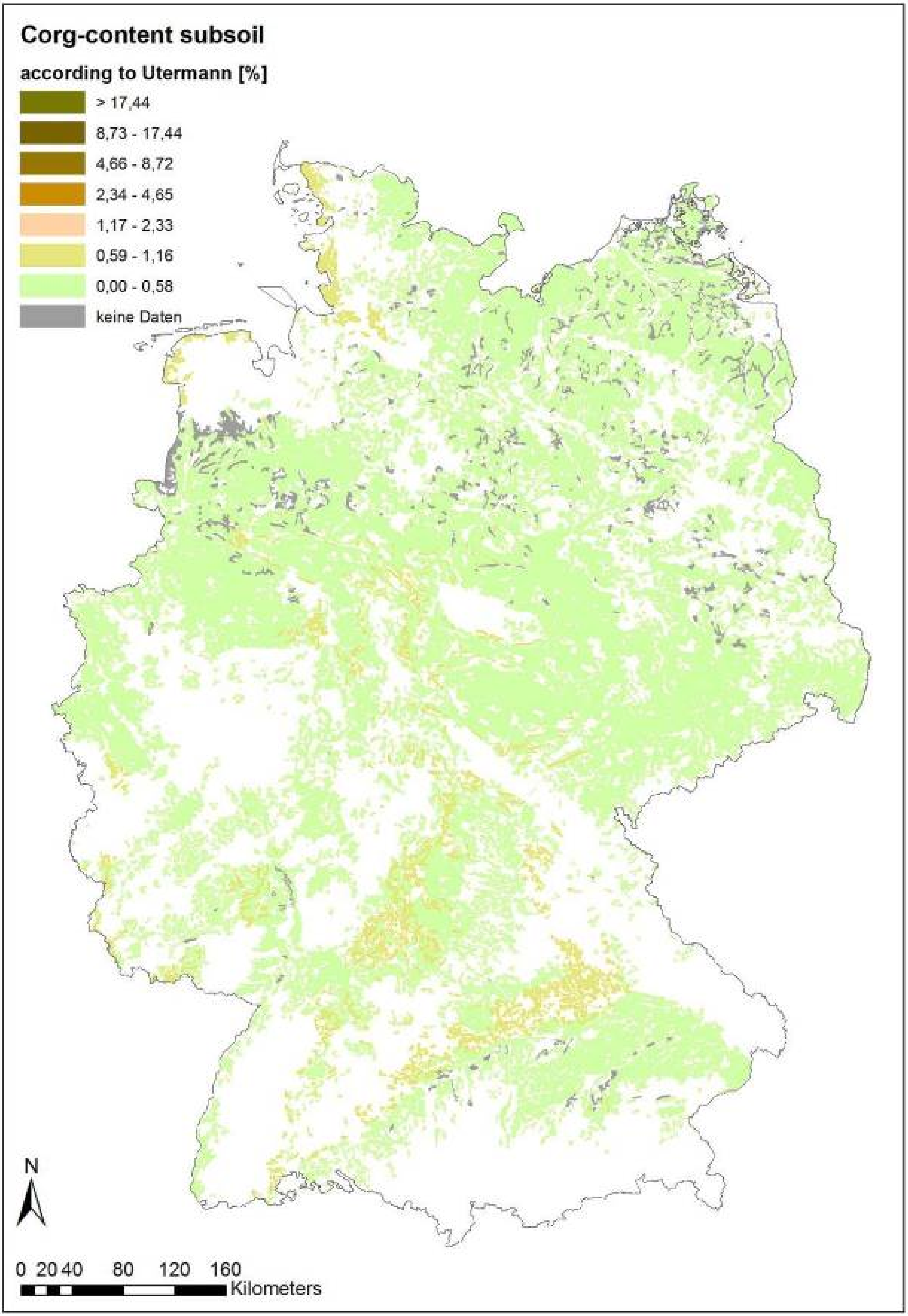


Figure 3-6: C_{org}-contents of soils with arable land use type in subsoil according to Utermann et al. (2009)

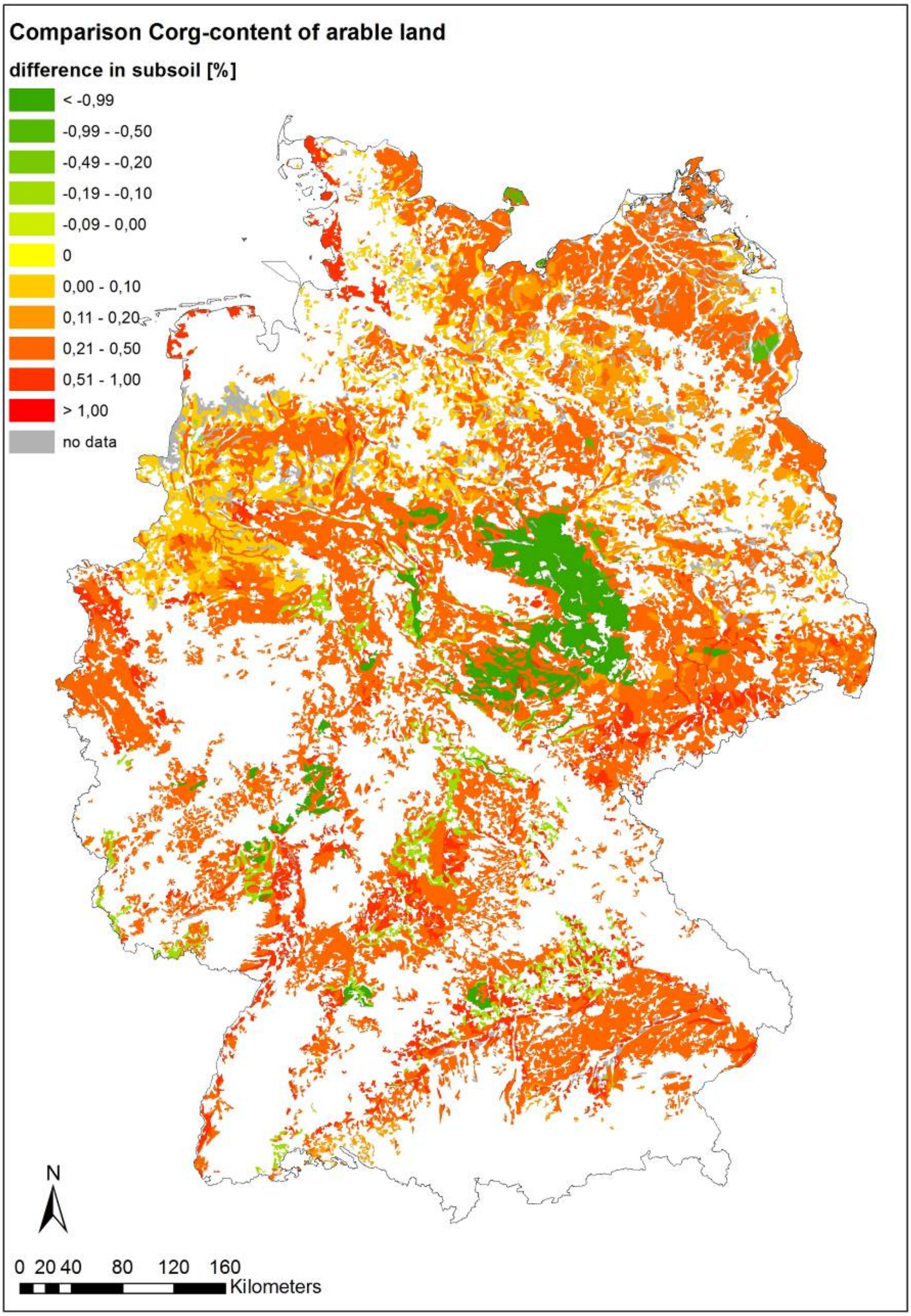


Figure 3-7: Difference of the C_{org}-contents in subsoil from BÜK 1000 N and Utermann et al. (2009) (shades of red: BÜK 1000 N lower than Utermann et al., 2009; shades of green: BÜK 1000 N higher than Utermann et al., 2009)

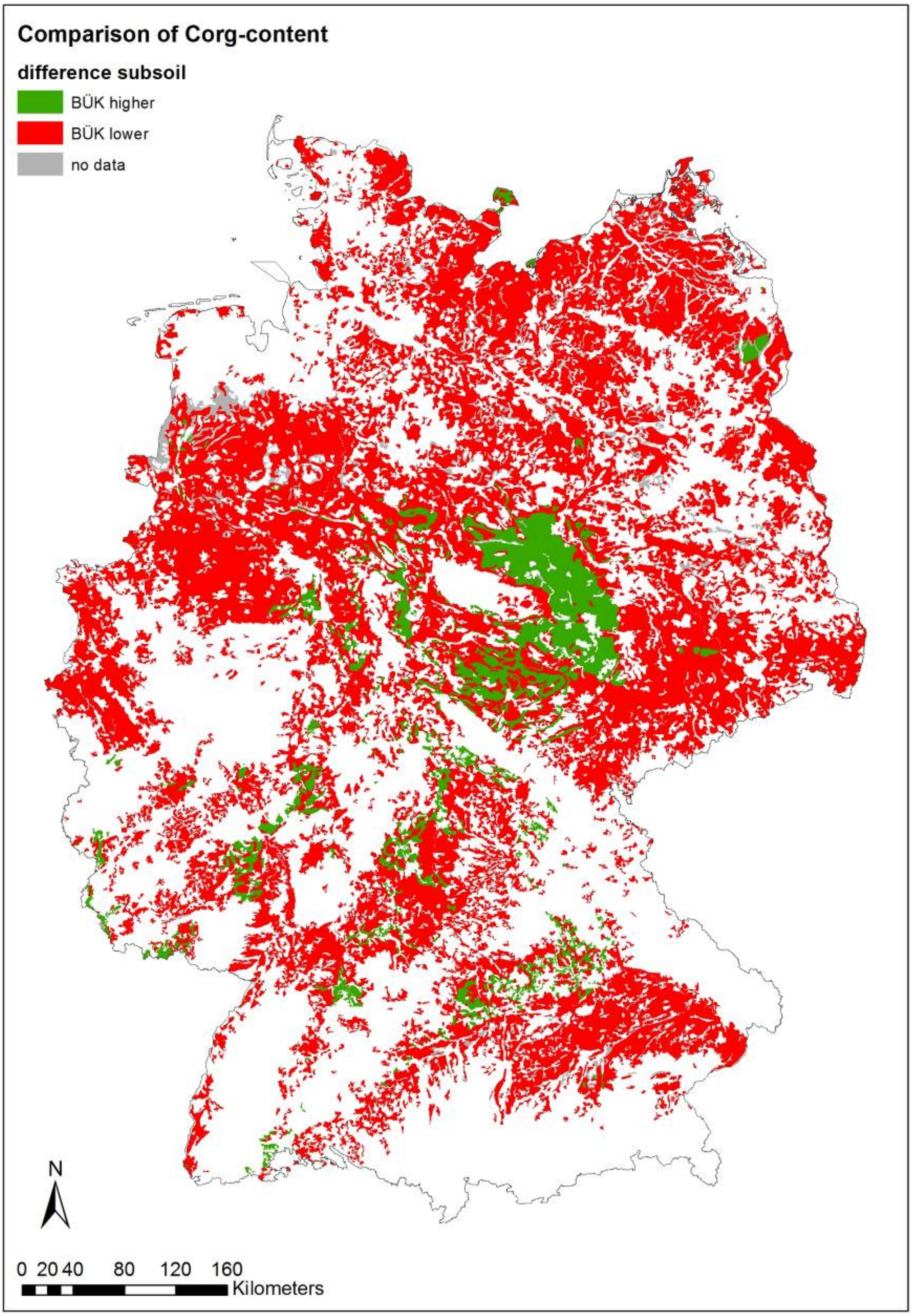
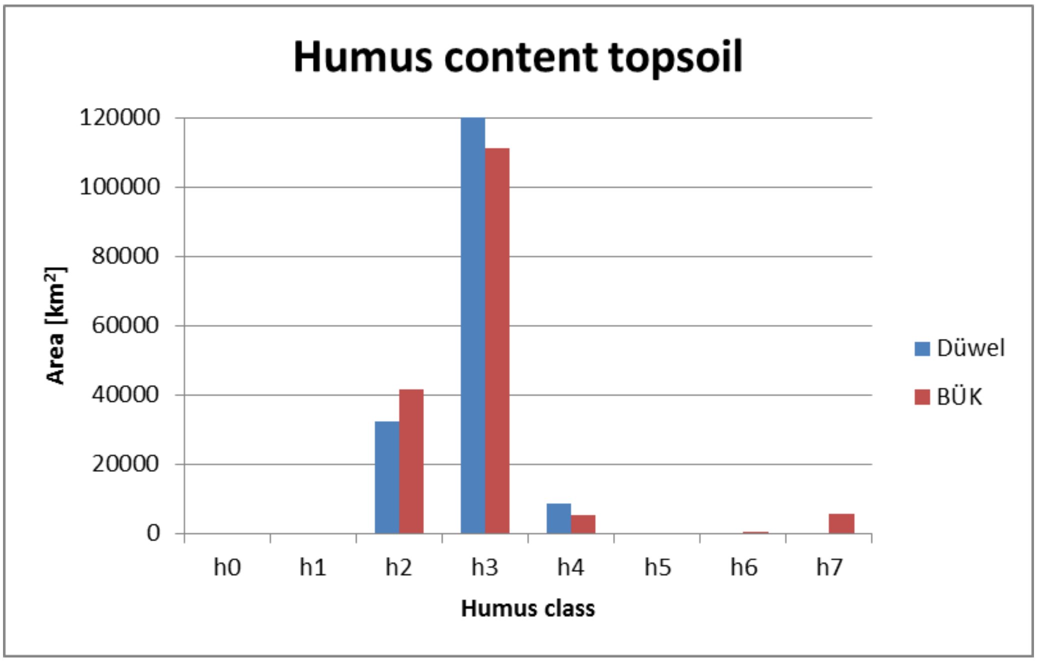


Figure 3-8: Difference of the C_{org} contents in subsoil from BÜK 1000 N and Utermann et al. (2009) (red: BÜK 1000N lower than Utermann et al., 2009; green: BÜK 1000N higher than Utermann et al., 2009)

In subsoil 14.1 % of the BÜK-area show higher C_{org}-values than Utermann et al. (2009), 85.9 % show lower C_{org}-values.



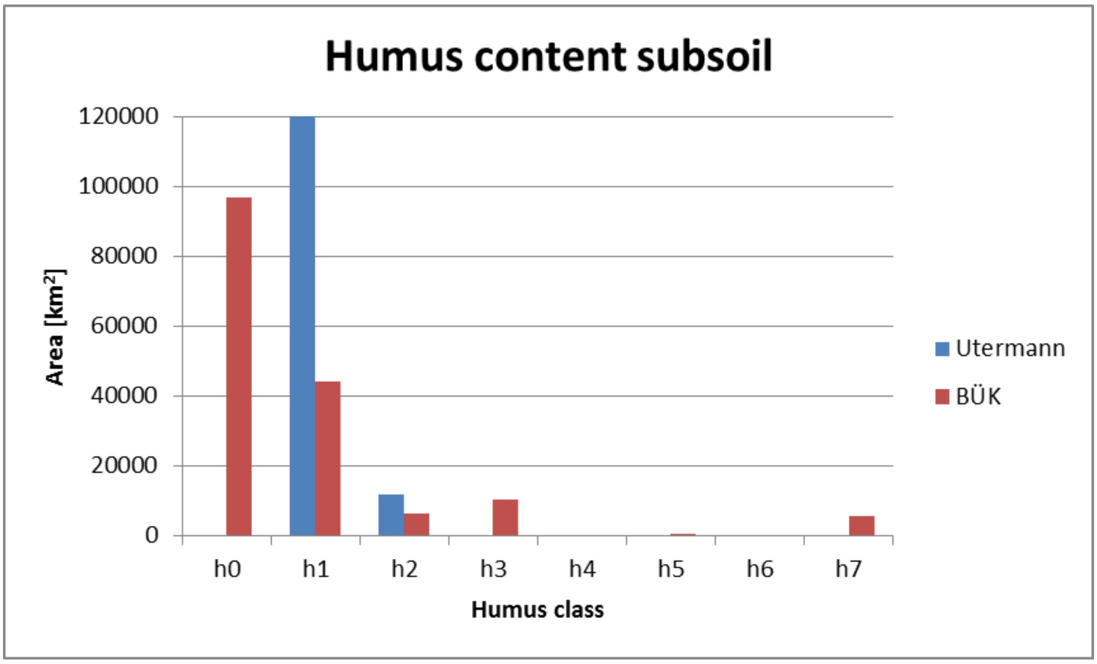


Figure 3-9: Spatial comparison of the C_{org}-contents from the BÜK 1000 and Düwel et al. (2007)/Utermann et al. (2009) in top- and subsoil

The C_{org}-contents after Düwel et al. (2007) /Utermann et al. (2009) only exist as summarized values for 0-30 cm and 30-60 cm soil depth. For PECgw-calculation in the Step 2 analysis several assumptions had to be made for the assignment of the C_{org}-contents after Düwel et al. (2007) /Utermann et al. (2009) to the profiles of the BÜK 1000:

- The median organic carbon content after Düwel et al. (2007) was assigned to the 1st horizon of the corresponding BÜK 1000 profiles (independent of the thickness of the 1st horizon in the BÜK profile)
- All further horizons until a depth of 60 cm get the value Utermann et al. (2009) subsoil. If the 60 cm boundary does not lie directly on a boundary of a horizon the horizon which includes the 60 cm boundary still gets this value.
- Differing from the "60 cm-rule" also deeper horizons get the value of Utermann et al. (2009) subsoil if the "C_{org} BÜK" of the corresponding horizons is not 0.

Table 3-5: Three examples of the assignment of the C_{org}-contents of Düwel et al. (2007) /Utermann et al. (2009) on the BÜK-profiles

Soil No.	HOR-No	Thick-ness	Corg (Düwel et al., 2007/ Utermann et al., 2009)	Corg BÜK
3301211	1	35	1.9	1.74
3301211	2	15	0.31	0.29
3301211	3	30	0.31	0
3301211	4	30	0	0
3301211	5	90	0	0
3303211	1	25	1.9	1.74
3303211	2	25	0.85	0
3303211	3	50	0.85	0
3303211	4	100	0	0
3304211	1	25	1.9	1.74
3304211	2	25	0.85	0.29
3304211	3	50	0.85	0.29
3304211	4	50	0	0

3.2.2 Results of the spatial representativity analysis of climate parameters

3.2.2.1 Results of the analysis of the climate factor precipitation

Average precipitation summer half-year

Figure 3-10 shows the cumulative spatial distribution function for the average precipitation in the summer half-year (April until September; reference period: 1980 – 2009; reference area: ATKIS "arable land" and "permanent crops"). From the function curve certain percentiles can be derived (see Table 3-7) and the representativeness with respect to the spatial protection level of the FOCUS GW-scenarios "Hamburg" and "Kremsmünster" concerning the precipitation in the summer half-year can directly be seen. Higher precipitation in general leads to an increase of the leaching potential of PPP. Concerning this precipitation parameter the scenario "Kremsmünster" therefore states a worst-case with a spatial protection level of 97.3 %, whereas "Hamburg" can be considered as a medium case.

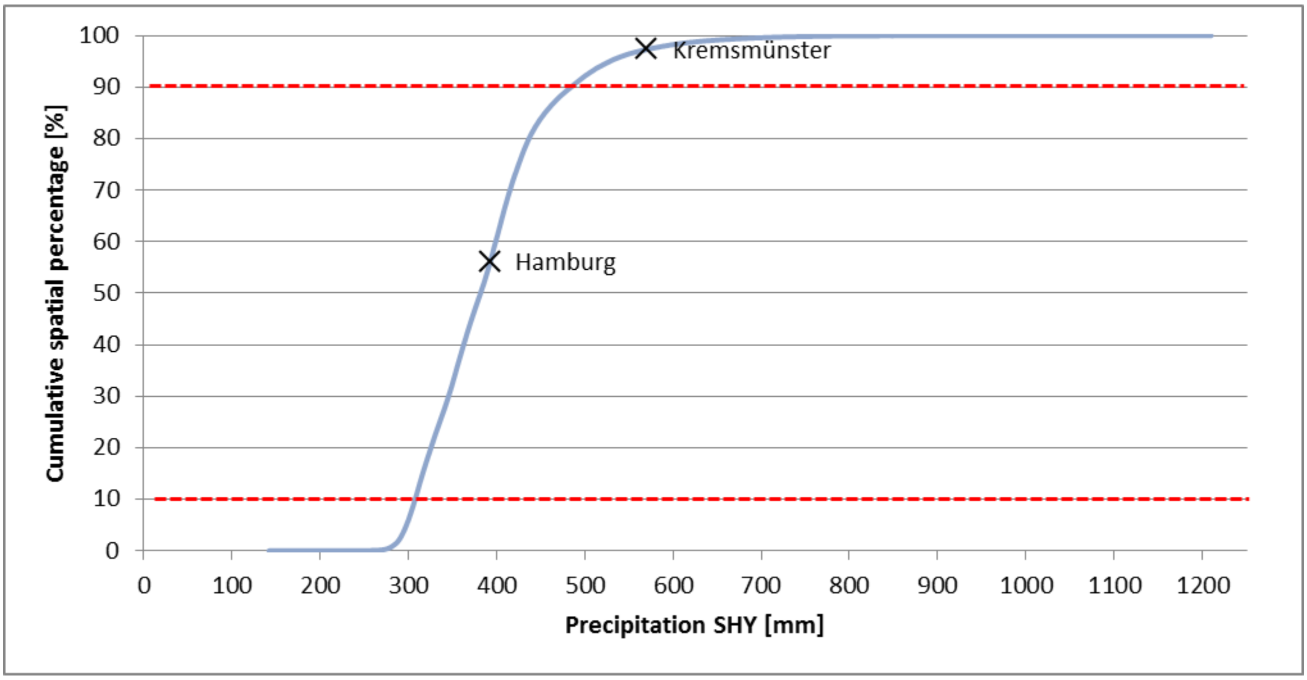


Figure 3-10: Cumulative distribution function of average precipitation of the summer half-year (DWD, 2011).

Table 3-6: Placement of the FOCUS GW-scenarios Hamburg and Kremsmünster on the total spatial distribution function concerning the average precipitation of the summer half-year (DWD, 2011)

Scenario	Prec SHY [mm]	Cum area percentage [%]
Hamburg	393	56.2
Kremsmünster	570	97.3

Table 3-7: 10th percentile, median and 90th percentile from the cumulative spatial distribution function concerning the average precipitation of the summer half-year (DWD, 2011)

Total area	10th percentile [mm]	Median [mm]	90th percentile [mm]
	308	382	485

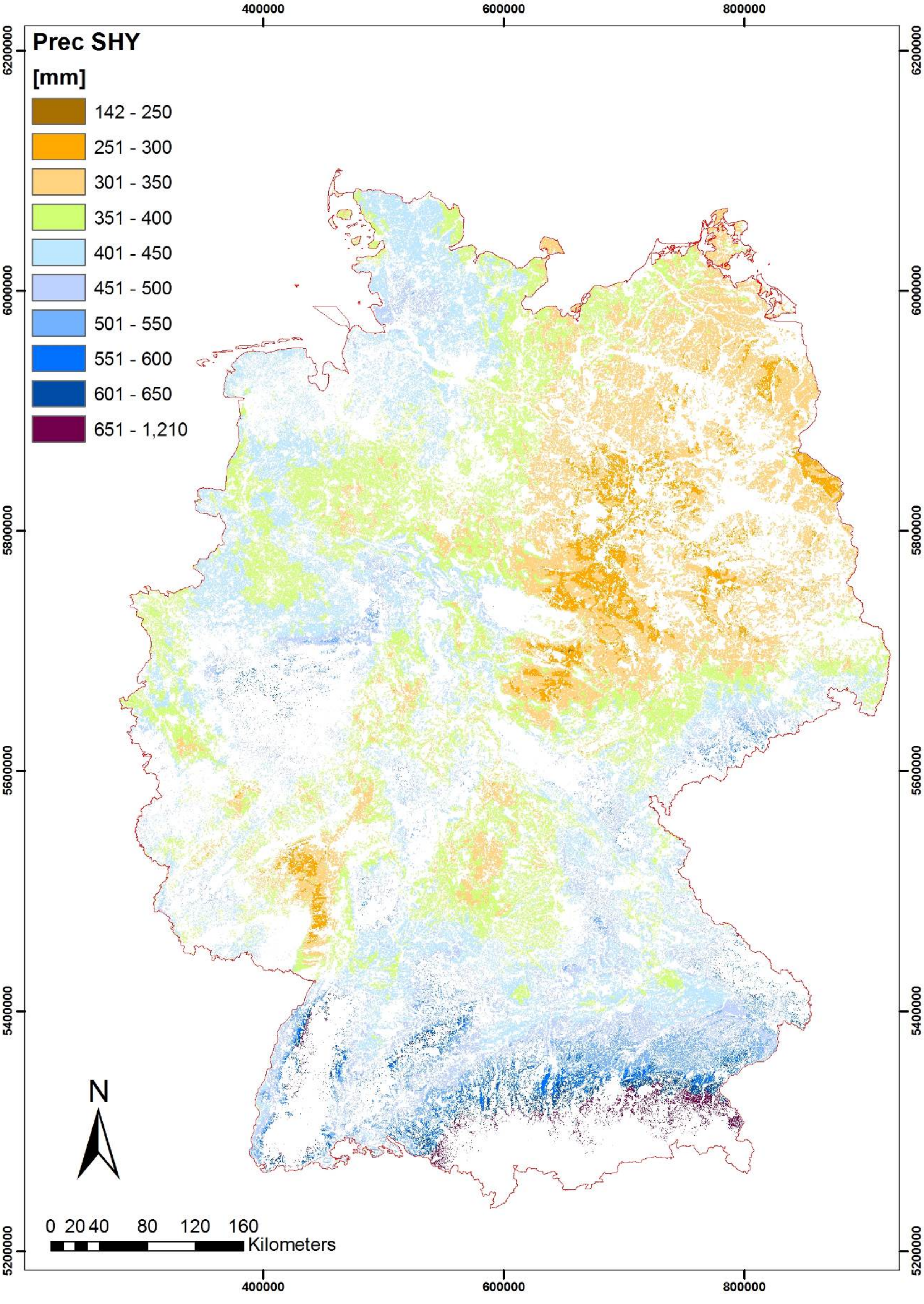


Figure 3-11: Average precipitation of the summer half-year (DWD, 2011) for the time period 1980-2009 (reference area: ATKIS „arable land“ and „permanent crops“; BKG, 2012)

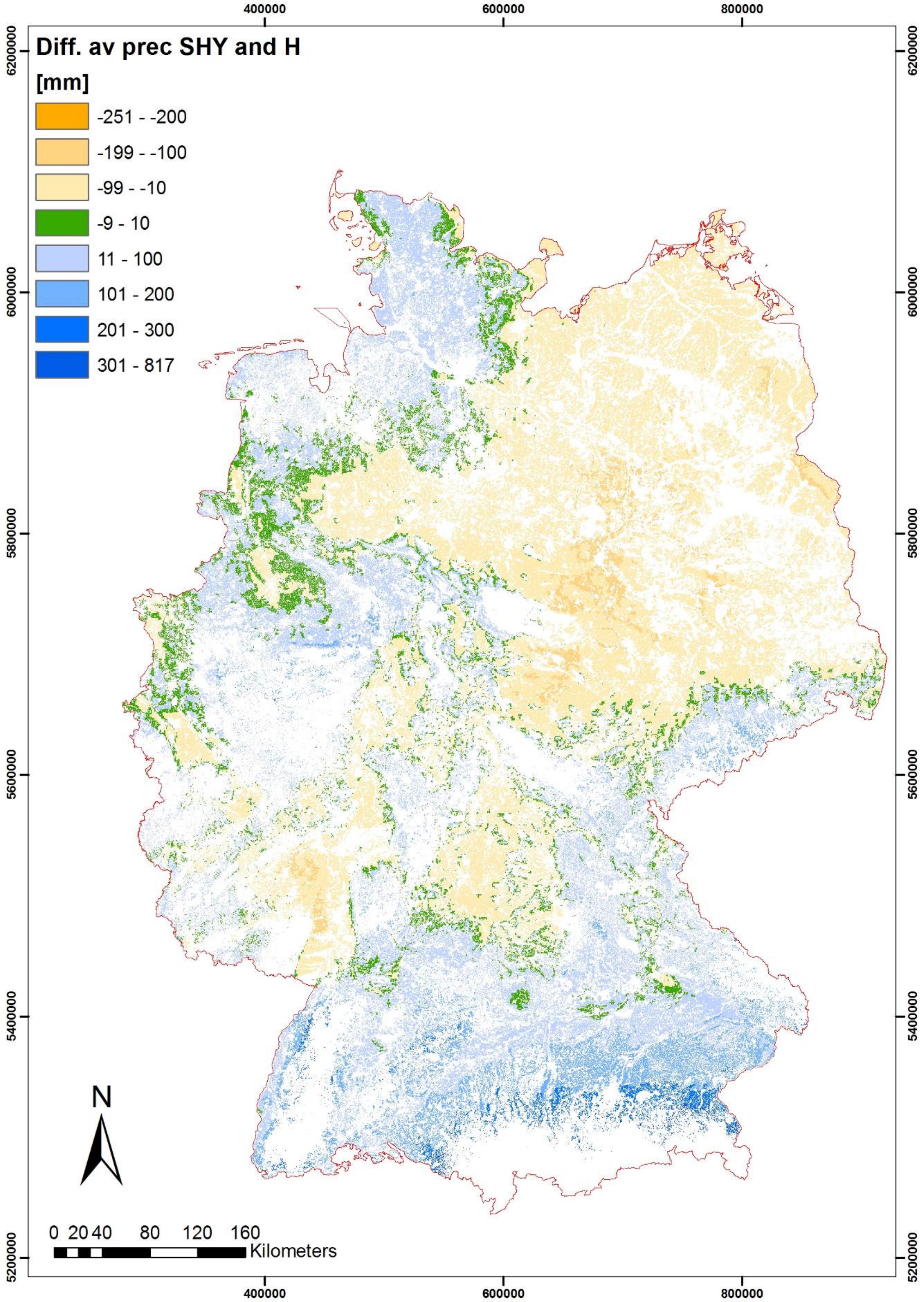


Figure 3-12: Difference of the average precipitation in the summer half-year (DWD, 2011) to the FOCUS GW-scenario „Hamburg“

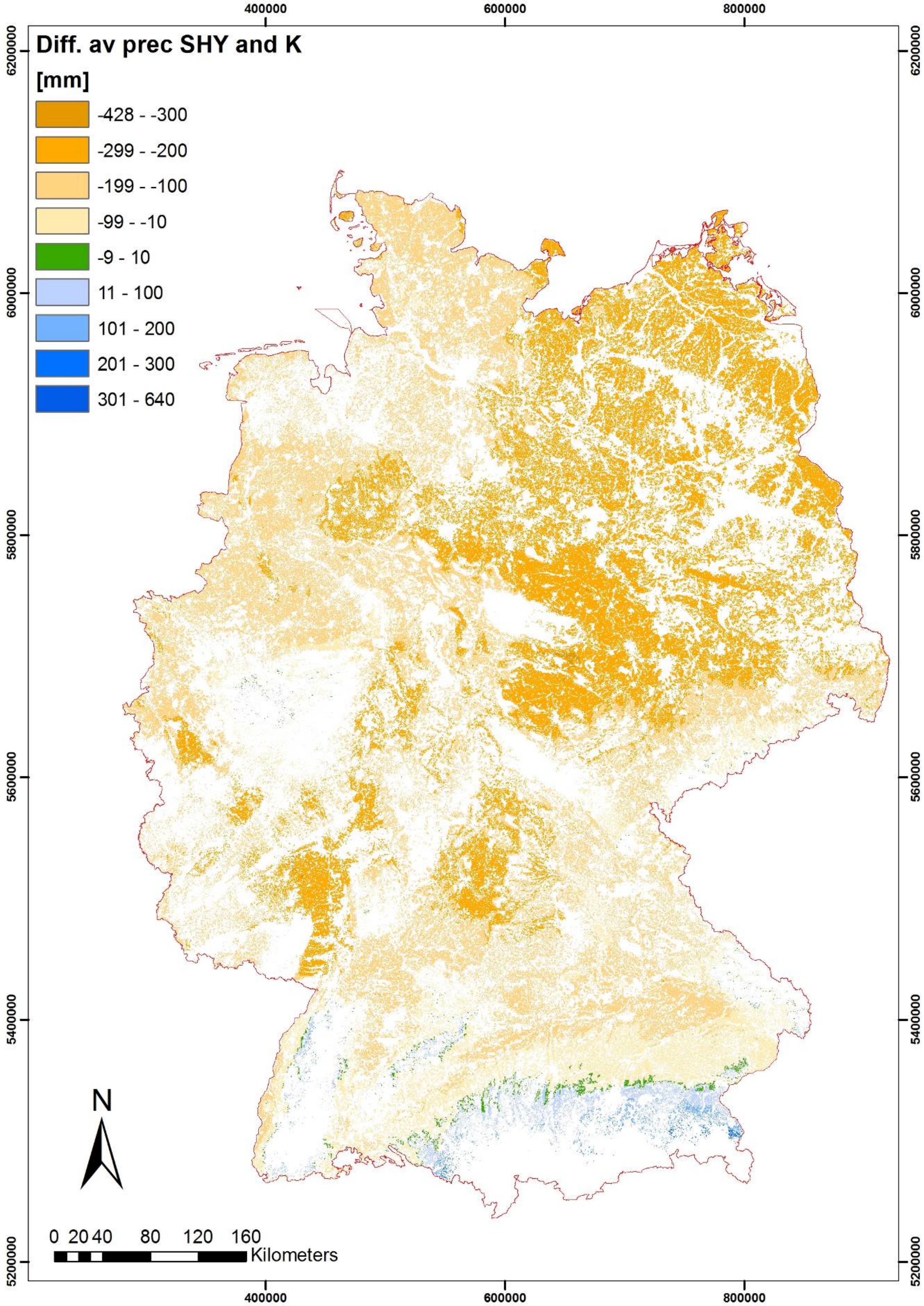


Figure 3-13: Difference of the average precipitation in the summer half-year (DWD, 2011) to the FOCUS GW-scenario „Kremsmünster“

Figure 3-11 shows the map of the summer conditions for precipitation of “arable land” and “permanent crops” (ATKIS). The remarkably driest and coherent areas in summer are Brandenburg, Saxony-Anhalt, parts of Thuringia, parts of Mecklenburg-Western Pomerania and the northern part of the Rhine rift valley. The wettest areas are located in the Alpine foreland, the Black Forest, parts of the Swabian Alps, the Sauerland and the Erzgebirge.

In Figure 3-12 and Figure 3-13 the precipitation difference to the scenarios “Hamburg” and “Kremsmünster” is shown as the result of the subtraction of the value of the particular scenario from every raster cell of the summer precipitation raster. Negative values indicate drier conditions than the scenario (shades of orange in the map), positive values indicate wetter conditions (shades of blue in the map). The green colored areas in the map show a very similar level of precipitation in the summer half-year compared to the scenario (+/- 10mm). Figure 3-12 illustrates the medium-case character of the scenario “Hamburg” concerning the summer rainfall. A bit more than the half of the area is drier, around the other half wetter and a transient area shows rainfalls +/- 10mm. Figure 3-13 points out the worst-case character of the scenario “Kremsmünster”: with exception of a small areal fraction in the south of Germany all areas are drier than Kremsmünster in the summer.

Average precipitation winter half-year

Figure 1-14 shows the cumulative spatial distribution function of the precipitation in the winter half-year (October until March; reference time period: 1980 – 2009; reference area: ATKIS “arable land” and “permanent crops”). Table 3-9 shows the 10th percentile, the median and the 90th percentile of the cumulative spatial distribution function. With a protection level of 65.4 % the scenario “Hamburg” represents a medium case, whereas its worst-case character is a bit higher compared to “Kremsmünster” with only 40 % spatial representativity.

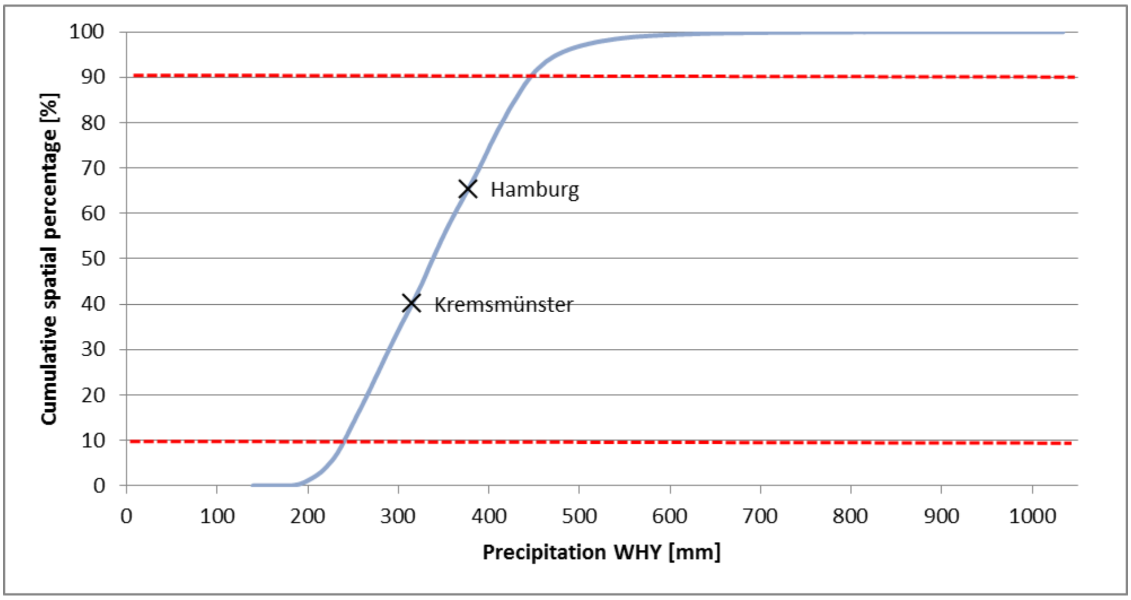


Figure 3-14: Cumulative distribution function of the average precipitation of the winter half-year (DWD, 2011)

Table 3-8: Placement of the FOCUS GW-scenarios Hamburg and Kremsmünster on the total spatial distribution function concerning the average precipitation of the winter half-year (DWD, 2011)

Scenario	Prec WHY [mm]	Cum area percentage [%]
Hamburg	377	65.4
Kremsmünster	315	40.1

Table 3-9: 10th percentile, median and 90th percentile from the cumulative spatial distribution function concerning the average precipitation of the winter half-year (DWD, 2011)

Total area	10th percentile [mm]	Median [mm]	90th percentile [mm]
	241	338	446

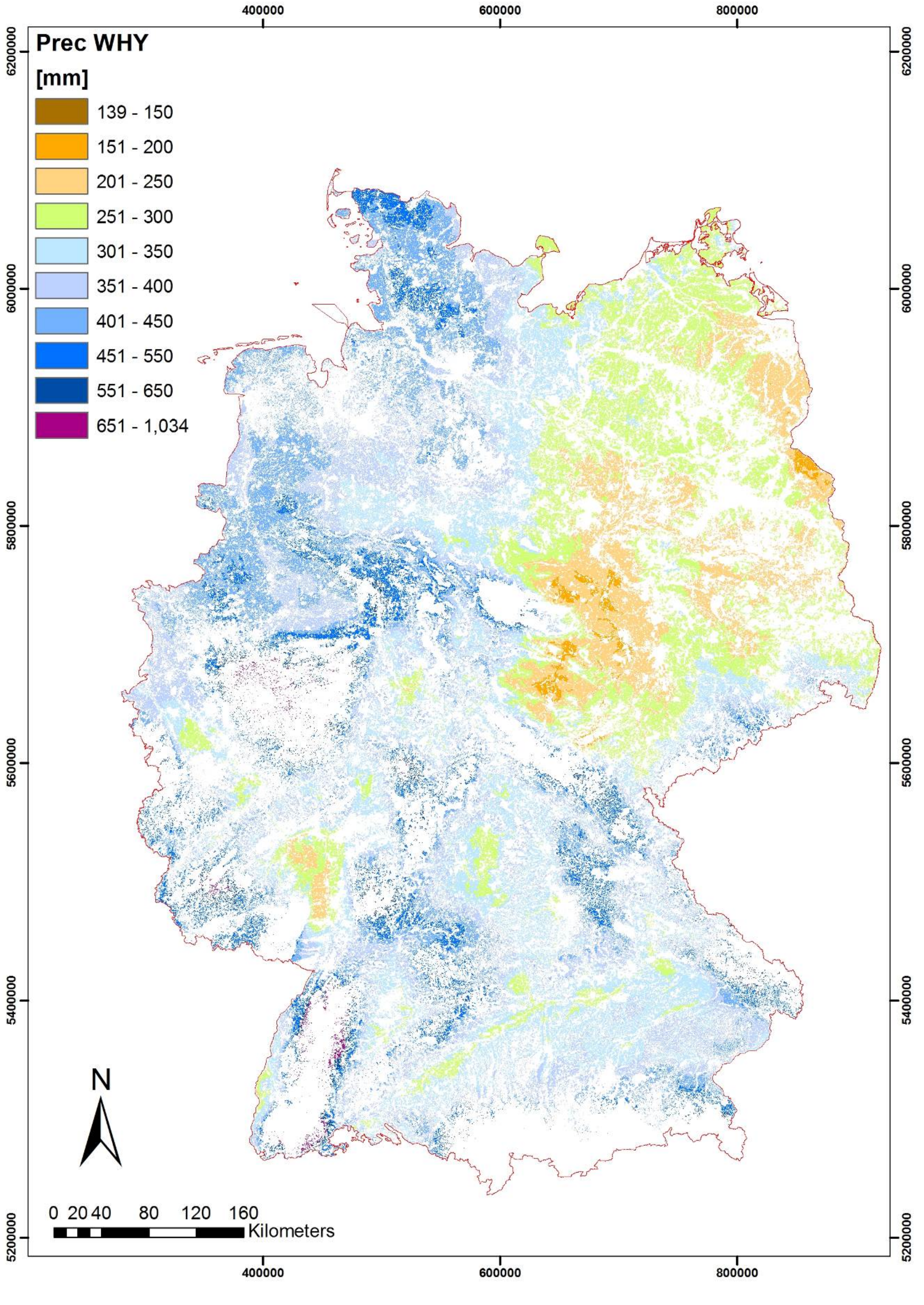


Figure 3-15: Average Precipitation of the winter half-year (DWD, 2011) for the time period 1980 – 2009 (reference area: ATKIS „arable land“ and „permanent crops“; BKG, 2012)

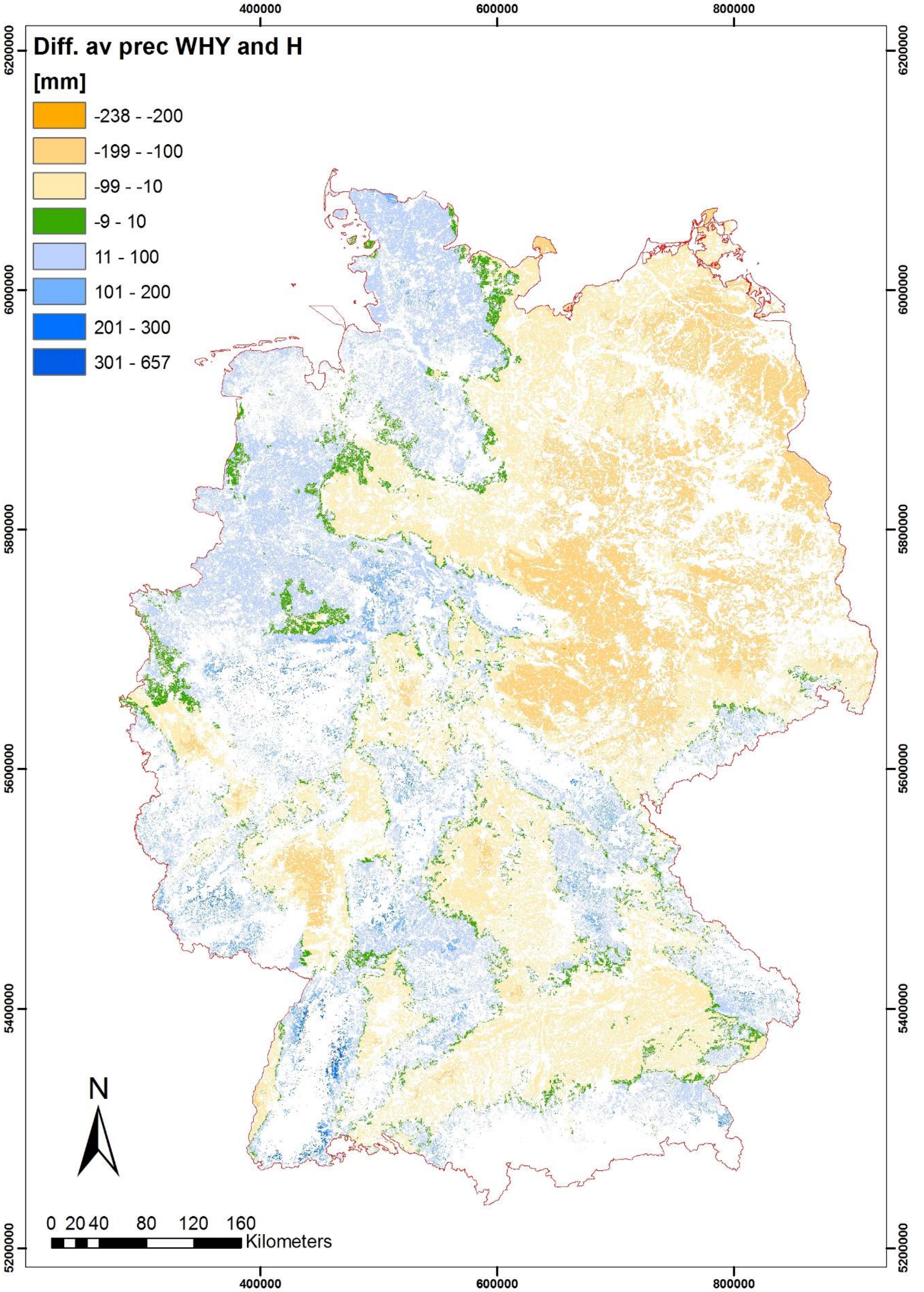


Figure 3-16: Difference of the average precipitation in the winter half-year (DWD, 2011) to the FOCUS GW-scenario „Hamburg“

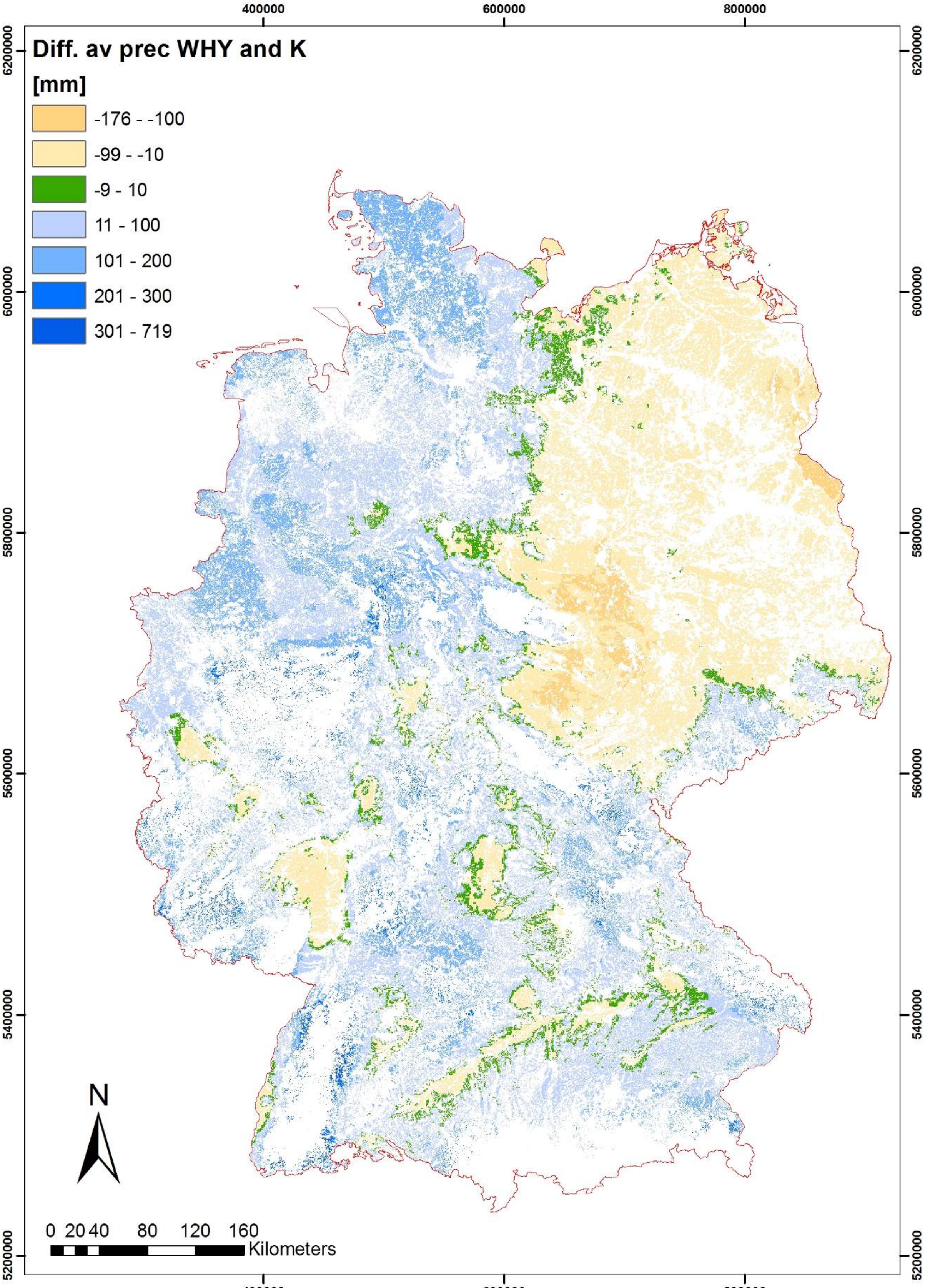


Figure 3-17: Difference of the average precipitation in the winter half-year (DWD, 2011) to the FOCUS GW-scenario „Kremsmünster“

Figure 3-15 shows the winter conditions of precipitation for "arable land" and "permanent crops" (ATKIS). In general precipitation in winter is lower than in summer. This is also reflected in the spatial percentiles in Table 3-9. Locally, summer precipitation amounts may exceed winter precipitation (Nahe-Saar Bergland or the Lower Saxon Hills). The driest areas can be found in the eastern states and the northern part of the Rhine rift valley. As in summer the wettest areas are located in parts of the Black Forest, of the Nahe-Saar Bergland and of the Sauerland.

In Figure 3-16 and Figure 3-17 the difference of precipitation of the winter half-year and the scenarios „Hamburg" and "Kremsmünster" is illustrated. Figure 3-16 shows that around two thirds of the total area are drier than "Hamburg" in winter. Figure 3-17 shows, that around two thirds of the area are more humid than "Kremsmünster" in winter.

Average annual precipitation

Figure 3-18 presents the cumulative spatial distribution function for the average annual precipitation (reference time period 1980 – 2009; reference area: ATKIS „arable land" and „permanent crops"). Table 3-11 shows the 10th percentile, the median and the 90th percentile from the cumulative spatial distribution function. Concerning the annual rainfall the scenario "Kremsmünster" shows a protection level of around 90 % and therefore can be seen as a worst-case. With a protection level of 62.3 % around two thirds of the area are covered by the scenario "Hamburg" in terms of the annual precipitation.

In Table 3-12 the results concerning precipitation in summer, winter and over the whole year are summarized.

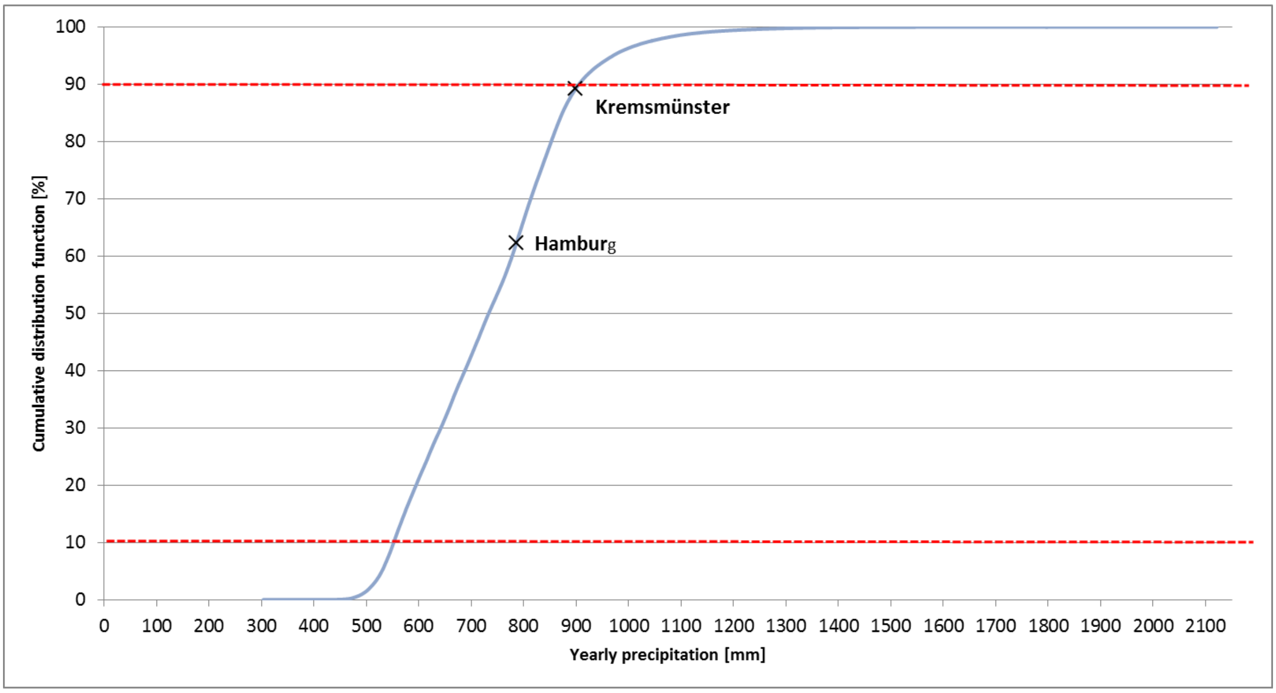


Figure 3-18: Cumulative spatial distribution function of the average annual precipitation (DWD, 2011)

Table 3-10: Placement of the FOCUS GW-scenarios Hamburg and Kremsmünster on the total spatial distribution function concerning the average annual precipitation (DWD, 2011)

Scenario	An prec [mm]	Cum area percentage [%]
Hamburg	786	62.3
Kremsmünster	899	89.2

Table 3-11: 10th percentile, median and 90th percentile from the cumulative spatial distribution function concerning average yearly precipitation (DWD, 2011)

Total area	10th percentile [mm]	Median [mm]	90th percentile [mm]
	552	773	905

Table 3-12: Summary of the spatial analysis concerning the climatic factor precipitation (DWD, 2011)

Total area				Hamburg		Kremsmünster	
	10th percentile [mm]	Median [mm]	90th percentile [mm]	[mm]	Cum. area percentage [%]	[mm]	Cum. area percentage [%]
Prec SHY	308	382	485	393	56.2	570	97.3
Prec WHY	241	338	446	377	65.4	315	40.1
An prec	552	773	905	786	62.3	899	89.2

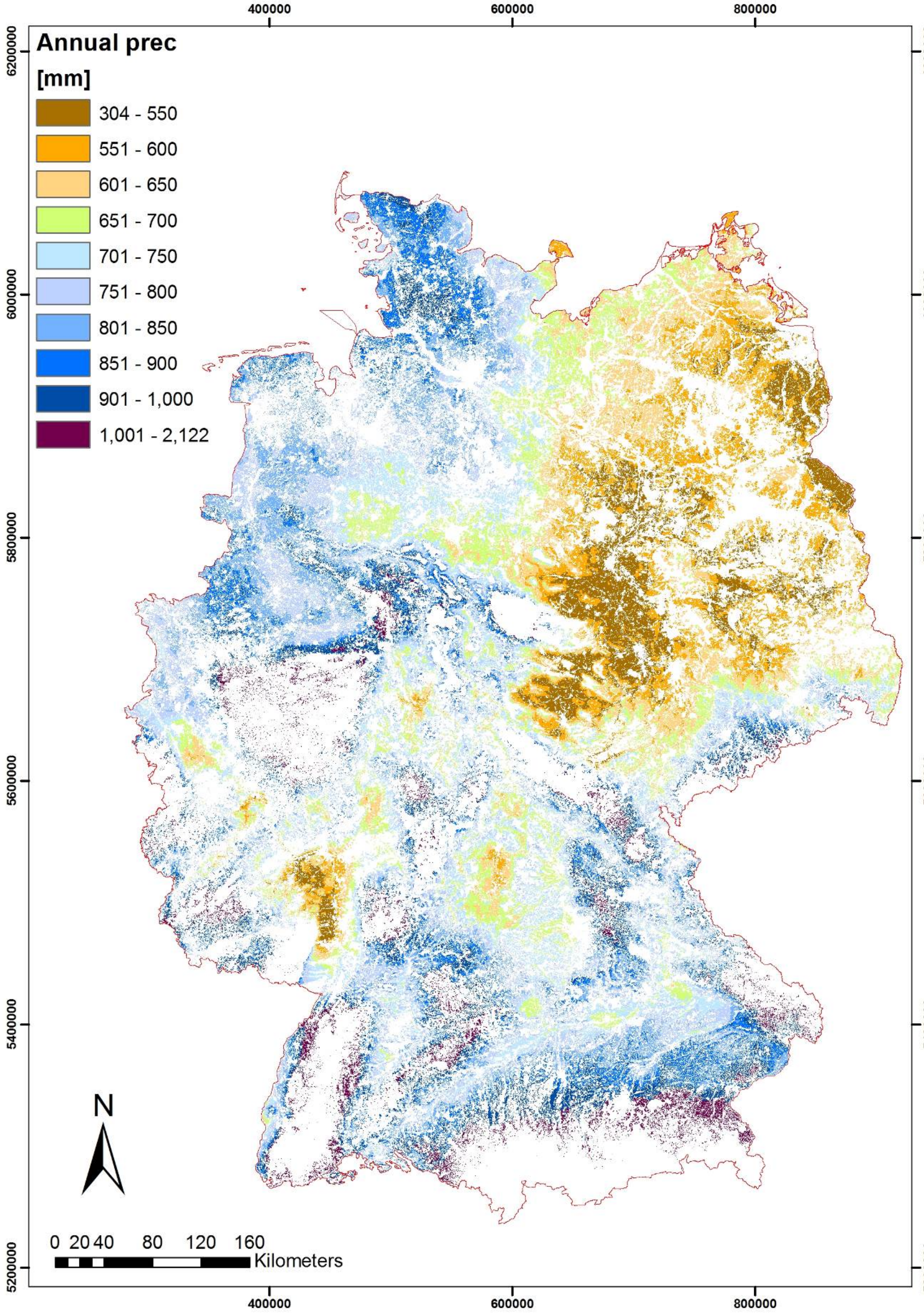


Figure 3-19: Average annual precipitation (DWD, 2011) for the time period 1980 – 2009 (reference area: ATKIS „arable land“ and „permanent crops“; BGK, 2012)

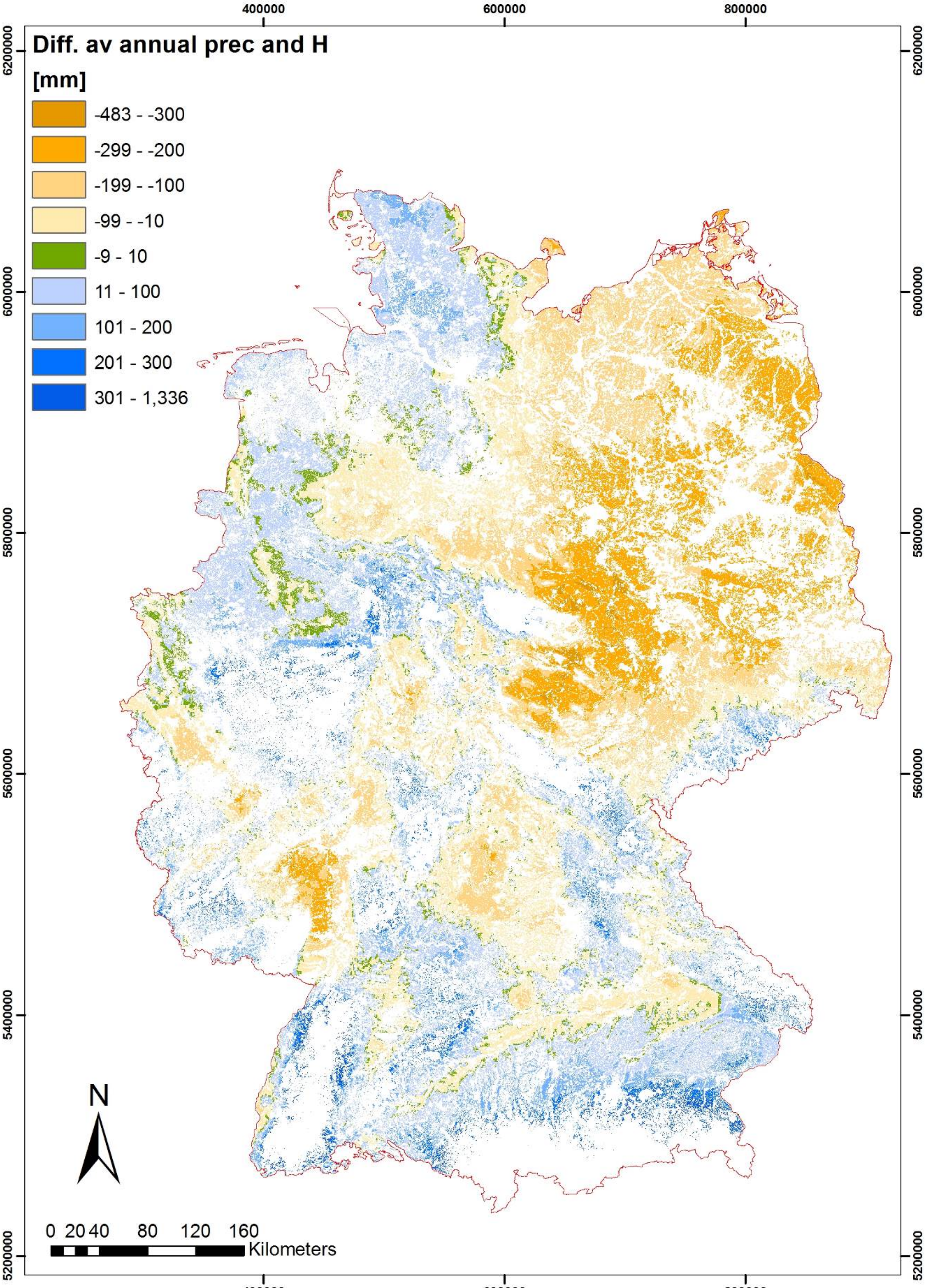


Figure 3-20: Difference of the average annual precipitation (DWD, 2011) and the FOCUS GW-scenario „Hamburg“

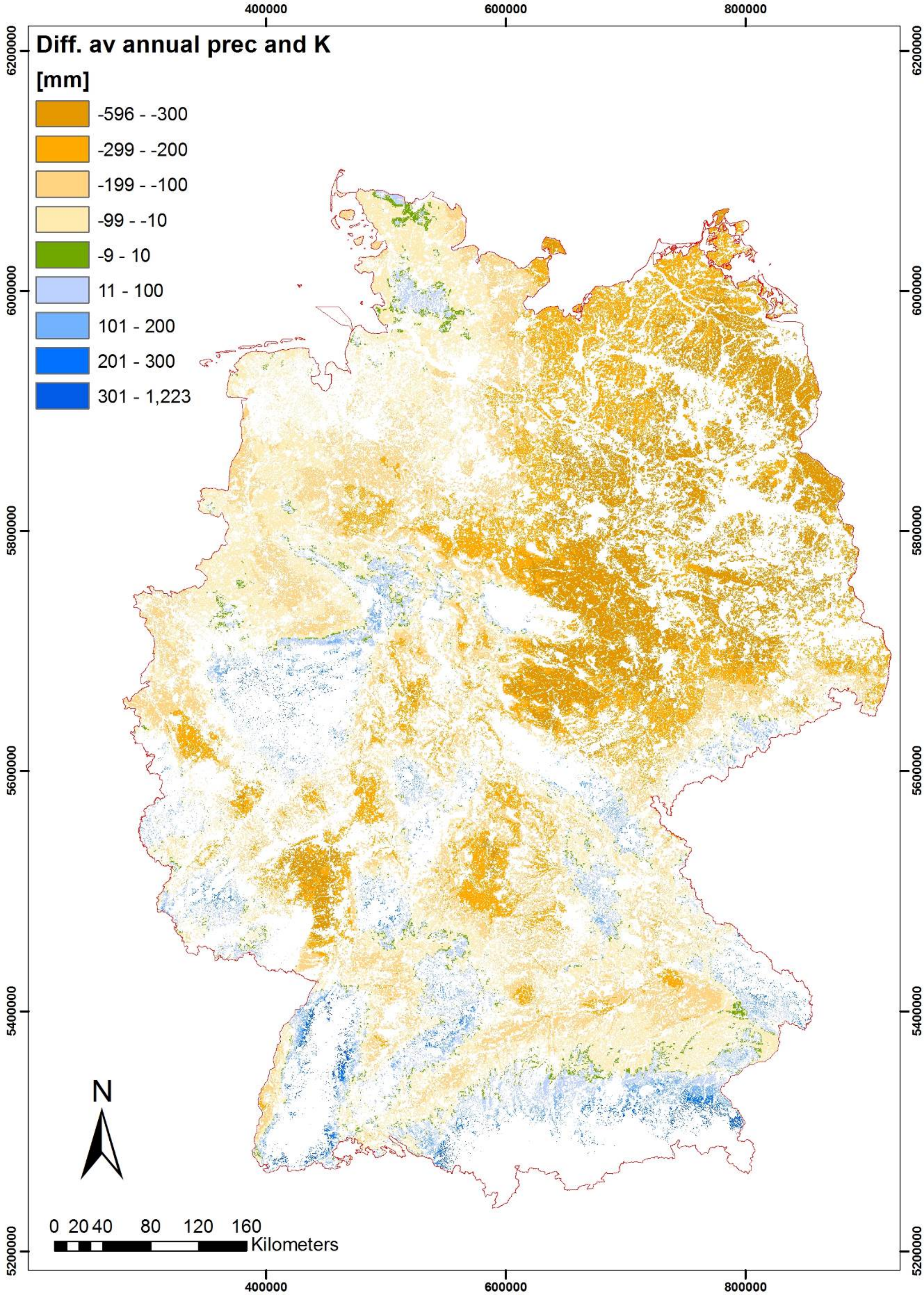


Figure 3-21: Difference of the average annual precipitation (DWD, 2011) and the FOCUS GW-scenario „Kremsmünster“

Figure 3-19 shows the map of the annual rainfall for “arable land” and “permanent crops” (ATKIS). Regarding the whole year the driest regions are Saxony-Anhalt, Brandenburg, parts of Mecklenburg-Western Pomerania, parts of Thuringia and the northern part of the Rhine rift valley. Some of the most humid regions are the Alpine foreland, the Black Forest, the Sauerland and other regions of minor size.

In Figure 3-20 and Figure 3-21 the difference of the annual precipitation and the scenarios „Hamburg“ and „Kremsmünster“ is mapped. Figure 3-20 illustrates that around two thirds of the total area are drier over the year than the scenario “Hamburg”. Figure 3-21 underlines the worst-case character of the scenario “Kremsmünster” concerning the annual precipitation. Only about 10 percent of the areas are more humid over the whole year.

3.2.2.2 Results of the analysis of the climate factor temperature

Average temperature summer half-year

Figure 3-22 shows the spatial protection level concerning the average temperature in the summer half-year (April until September; reference period 1980 – 2009; reference area: ATKIS “arable land” and “permanent crops”). Since the spatial protection level cannot be derived directly from the cumulative spatial distribution function concerning the temperature parameters but only can be deduced from the difference 100 %-“cumulative spatial percentage of temperature x”, the cumulative distribution function was not illustrated here. From the curve regarding the spatial protection level certain percentage levels can be read off (see Table 3-14) and the representativeness with respect to the spatial protection level of the FOCUS GW-scenarios “Hamburg” and “Kremsmünster” concerning the temperature can directly be seen. The degradation of a substance is slower at especially low soil temperatures. A cold scenario covers a large area fraction and therefore shows a high spatial protection level. Hence the scenario “Hamburg” tends to be conservative concerning this temperature parameter with a protection level of 75.8 %, whereas “Kremsmünster” can be considered as a medium-case only.

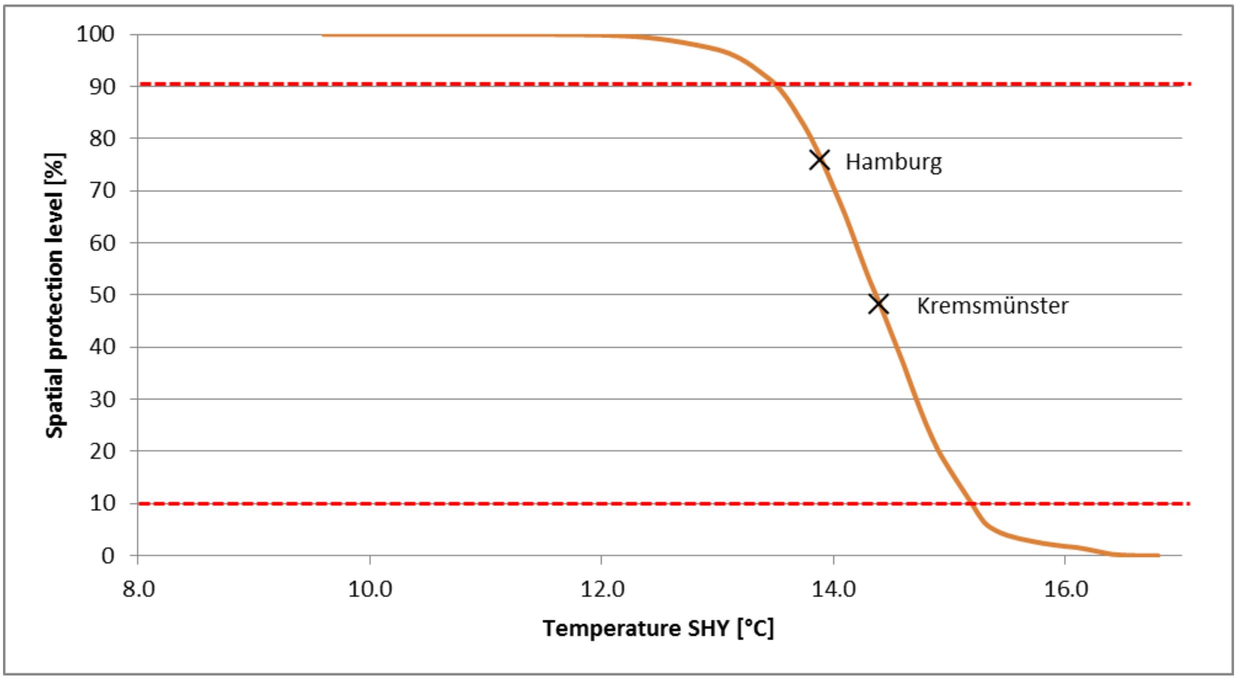


Figure 3-22: Spatial protection level concerning the average temperature of the summer half-year (DWD, 2012)

Table 3-13: Placement of the FOCUS GW-scenarios Hamburg and Kremsmünster on the total spatial distribution function concerning the average temperature of the summer half-year (DWD, 2012)

Scenario	T_SHY [°C]	Cum area percentage [%]	Spatial protection level [%]
Hamburg	13.9	24.2	75.8
Kremsmünster	14.4	51.8	48.2

Table 3-14: Different spatial protection levels of the total area concerning the average temperature of the summer half-year (DWD, 2012)

Protection level total area	90th percentile [°C]	Median [°C]	10th percentile [°C]
	13.6	14.4	15.2

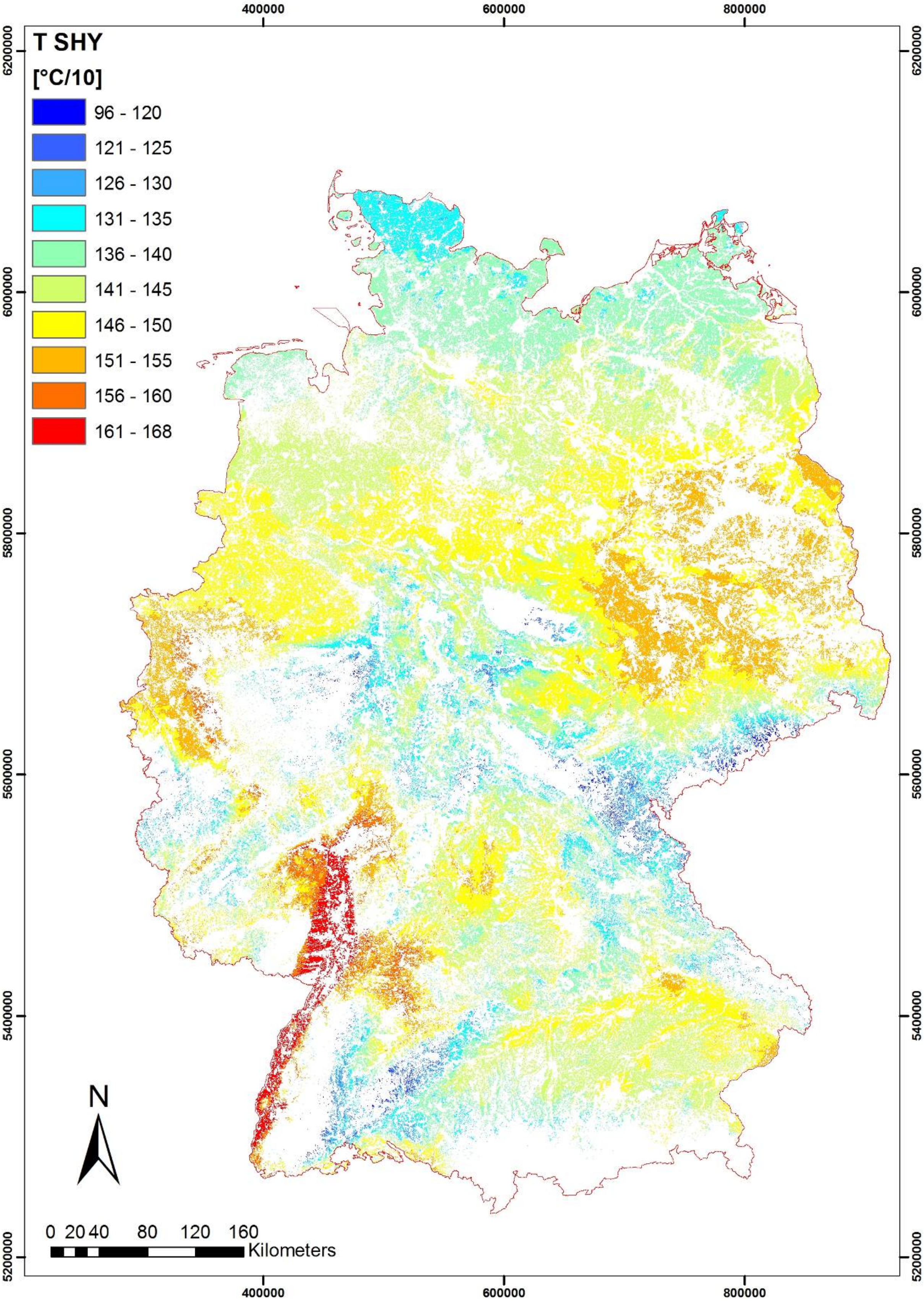


Figure 3-23: Average temperature of the summer half-year (DWD, 2012) for the time period 1980 – 2009 (reference area: ATKIS „arable land“ and „permanent crops“; BKG, 2012)

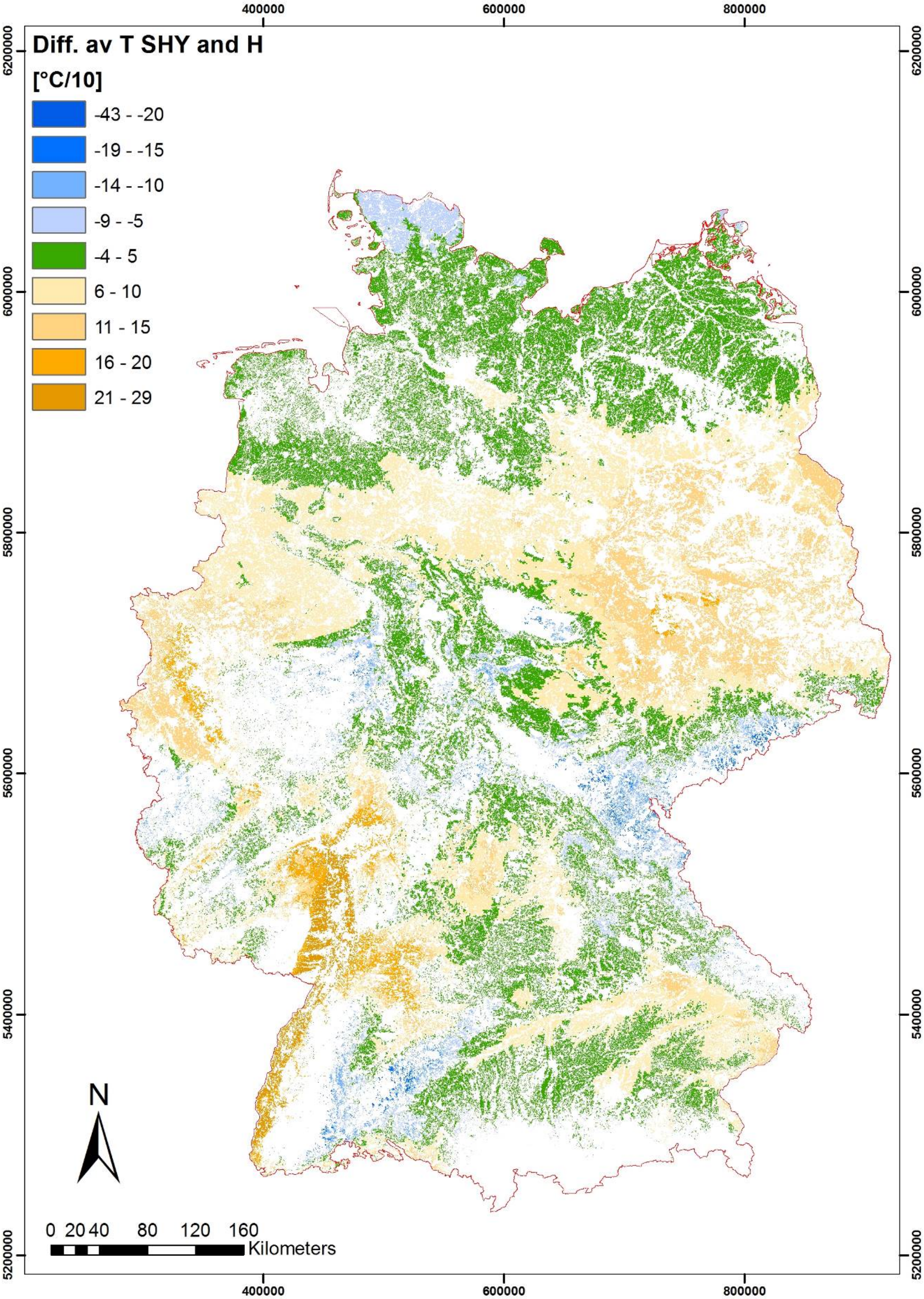


Figure 3-24: Difference of the average temperature in the summer half-year (DWD, 2012) and the FOCUS GW-scenario „Hamburg“

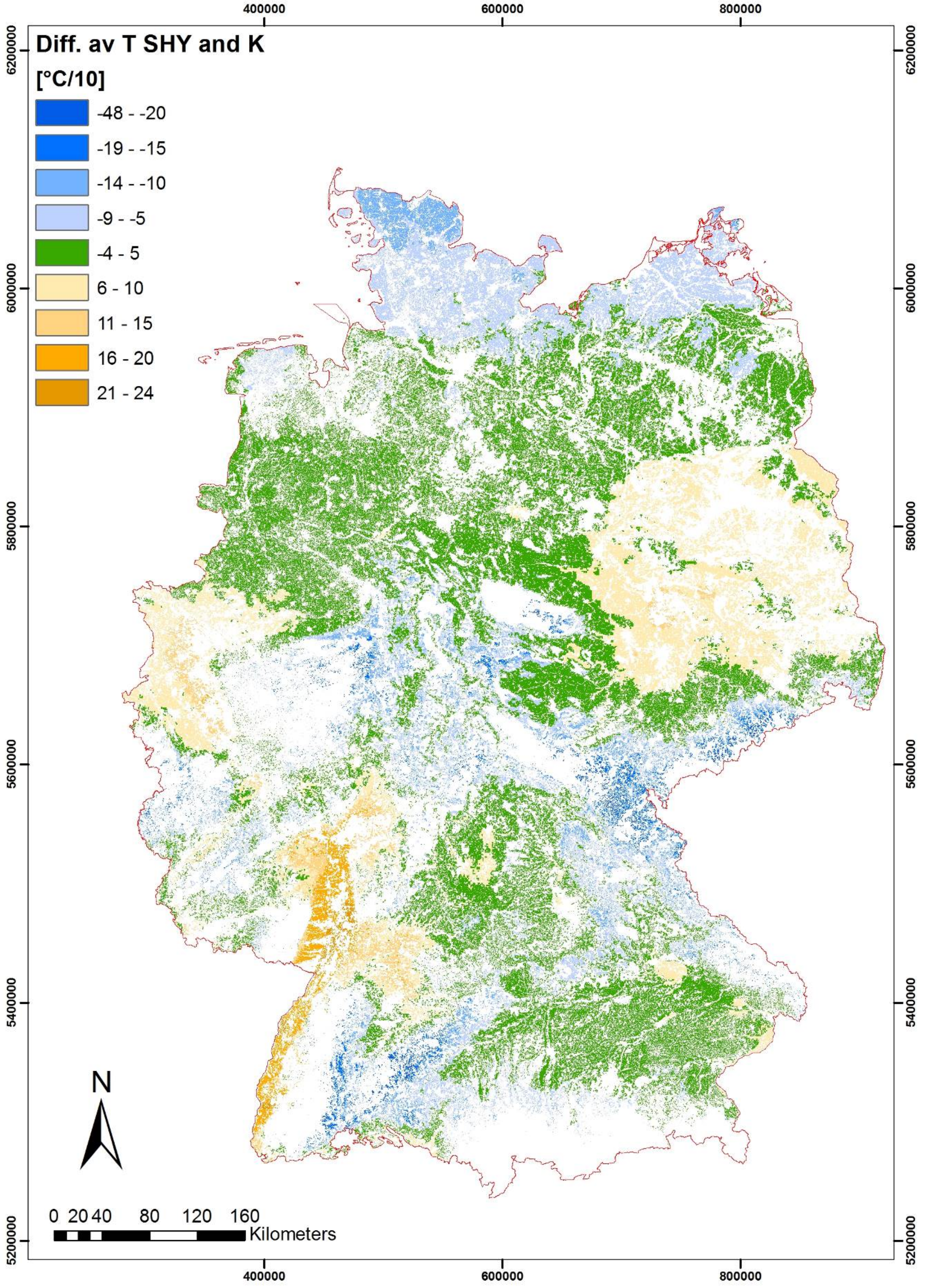


Figure 3-25: Difference of the average temperature in the summer half-year (DWD, 2012) and the FOCUS GW-scenario „Kremsmünster“

Figure 3-23 shows the map of the temperature in summer for „arable land“ and „permanent crops“ (ATKIS). The whole area of the Rhine rift valley, the Kraichgau, the Cologne Bay (respectively the Lower Rhine area) and Brandenburg belong to the remarkably warmest and coherent areas in summer. The coldest areas are located in the Erzgebirge, the Fichtelgebirge, the southwestern Swabian Alps and other regions of smaller size. In Figure 3-24 and Figure 3-25 the difference of temperature in the summer half-year and the scenarios „Hamburg“ and „Kremsmünster“ is shown as the result of the subtraction of the value of the particular scenario from each raster cell of the summer temperature raster. Negative values indicate colder conditions than the scenario (shades of blue in the map), positive values indicate warmer conditions than the scenario (shades of orange in the map). The green colored areas in the map show a very similar temperature in summer to the scenario (+/- 0.5 °C). Figure 3-24 shows the conservative character of the scenario “Hamburg” concerning the summer temperature. A large area fraction shows higher temperatures than this scenario. Also a large area is located in the “transient area” of +/- 0.5 °C. Only a relatively small area fraction is more than 0.5 °C colder than “Hamburg” in the summer half-year. Figure 3-25 illustrates the medium-case character of the scenario “Kremsmünster”. Almost equal area fractions are more than 0.5 °C warmer or colder than this scenario. A relatively large area fraction is located in the “transient area” of +/-0.5 °C.

Average temperature winter half-year

Figure 3-26 shows the spatial protection level concerning the average temperature in the winter half-year (October until March; reference time period: 1980 – 2009; reference area: ATKIS “arable land” and “permanent crops”). In Table 3-16 the 90th percentile, the median and the 10th percentile spatial protection level concerning the winter temperature is shown. The “Hamburg” scenario tends to represent a best-case concerning this temperature parameter with a protection level of 24.9 %, whereas “Kremsmünster” tends to be a worst-case.

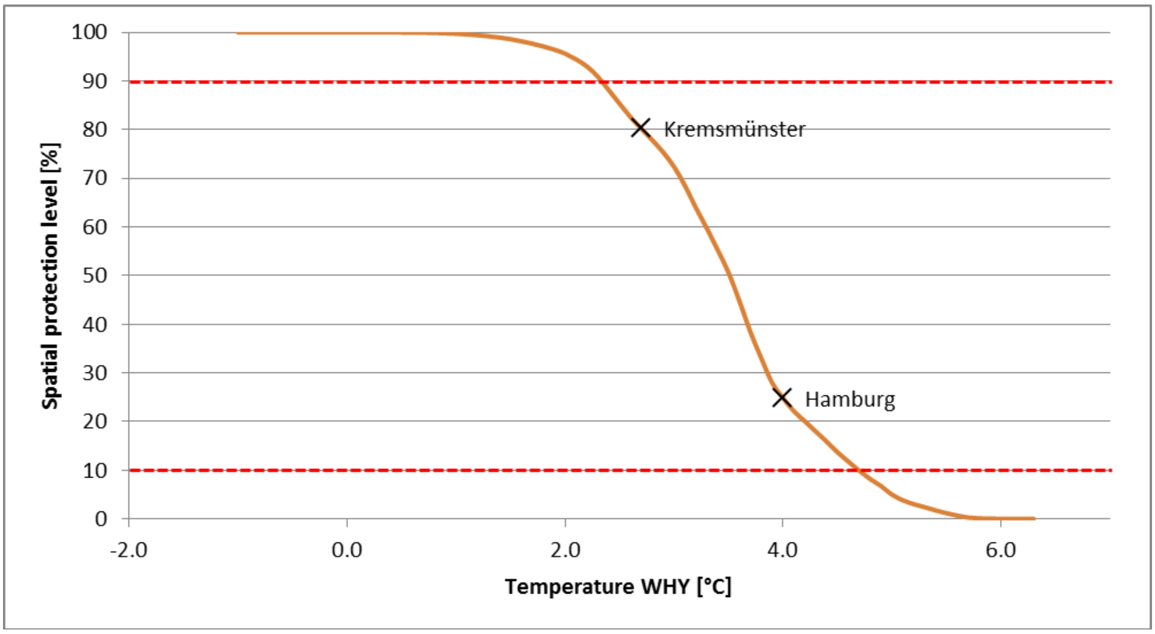


Figure 3-26: Spatial protection level concerning the temperature in the winter half-year (DWD, 2012)

Table 3-15: Placement of the FOCUS GW-scenarios Hamburg and Kremsmünster on the total spatial distribution function concerning the average temperature of the winter half-year (DWD, 2012)

Scenario	T_WHY [°C]	Cum area percentage [%]	Spatial protection level [%]
Hamburg	4.0	75.1	24.9
Kremsmünster	2.7	19.8	80.2

Table 3-16: Spatial protection level of the total area concerning the average temperature in the winter half-year (DWD, 2012)

Protection level total area	90th percentile [°C]	Median [°C]	10th percentile [°C]
	2.4	3.6	4.7

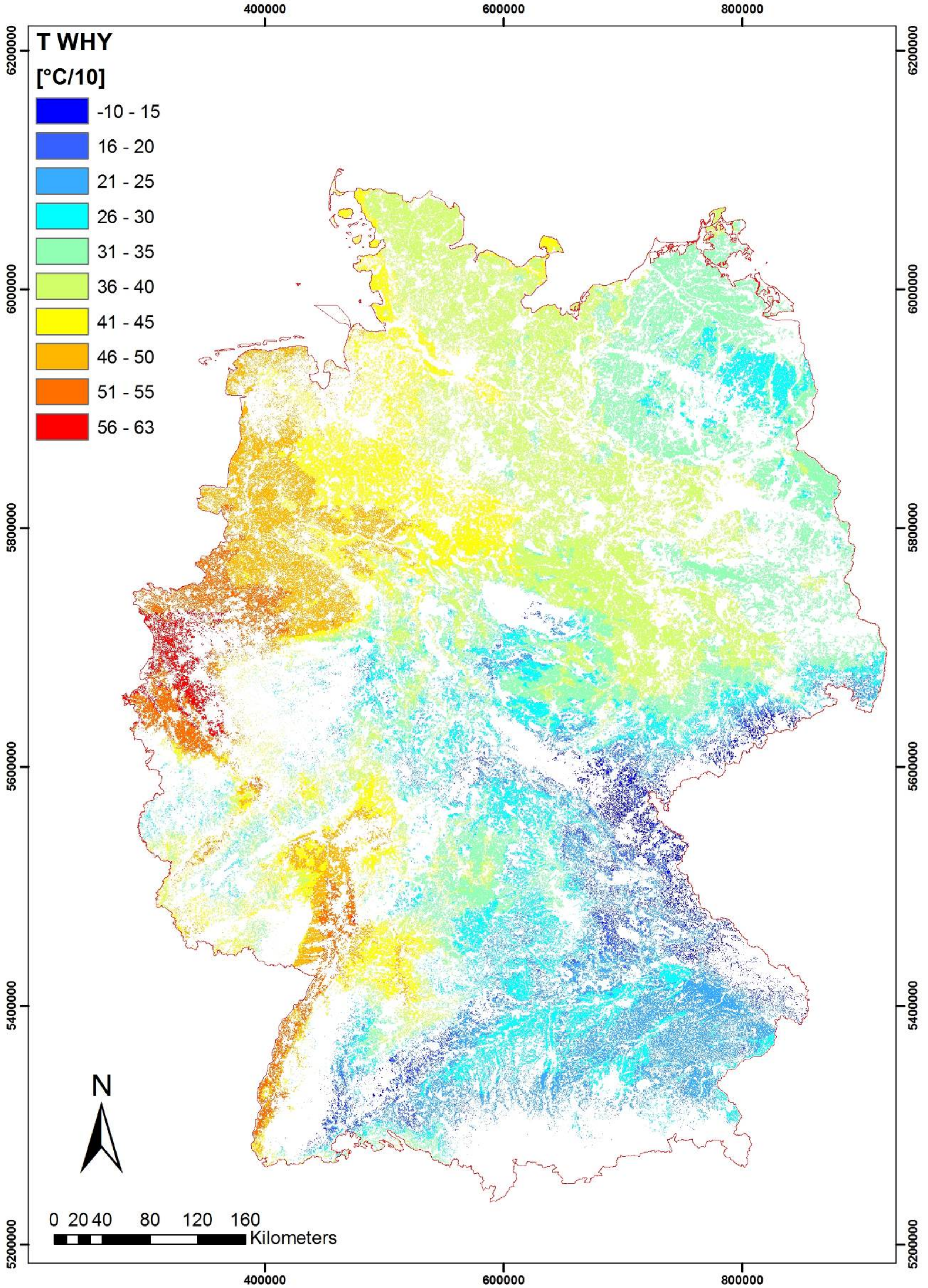


Figure 3-27: Average temperature in the winter half-year (DWD, 2012) for the time period 1980 – 2009 (reference area: ATKIS „arable land“ and „permanent crops“; BKG, 2012)

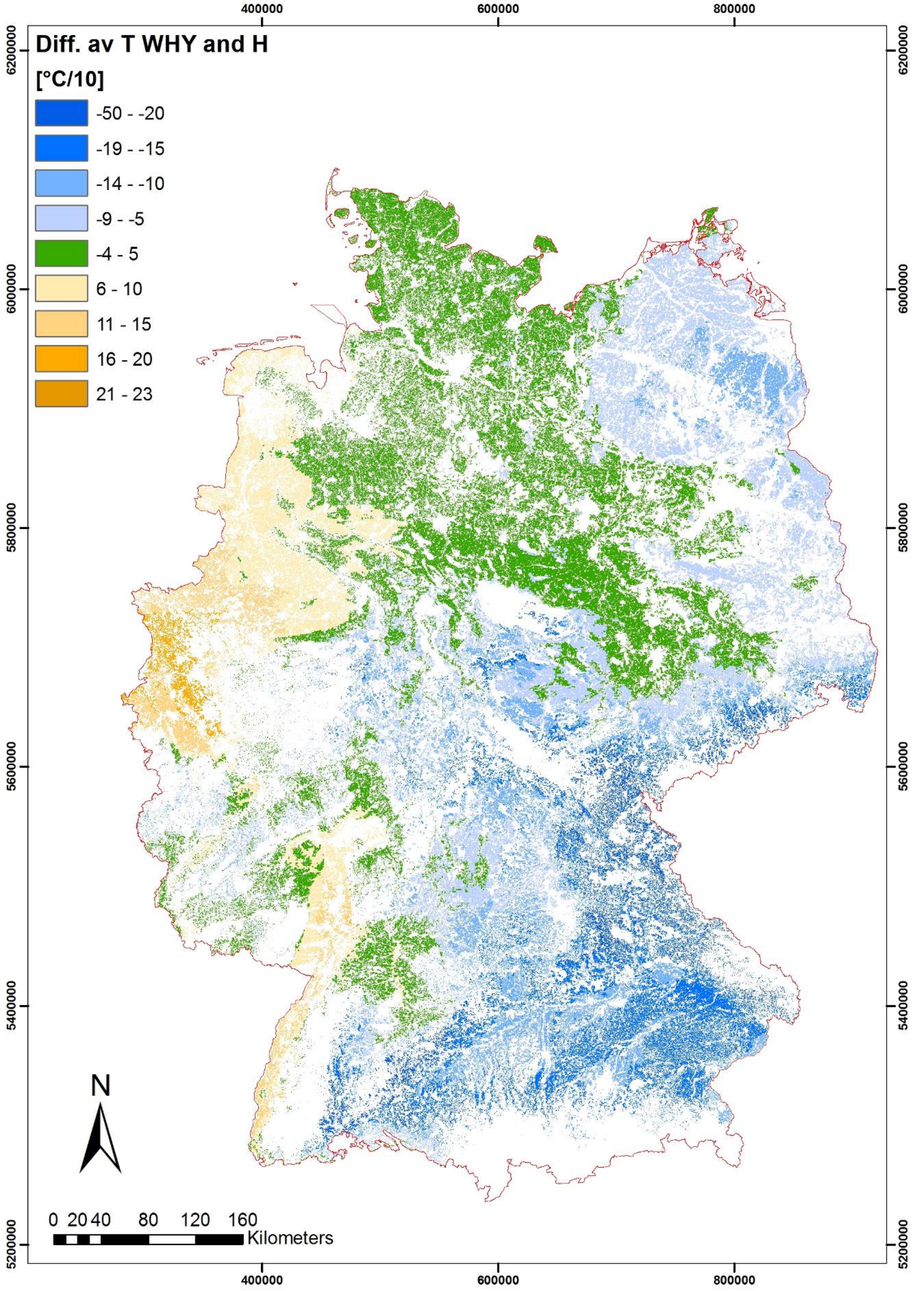


Figure 3-28: Difference of the average temperature in the winter half-year (DWD, 2012) and the FOCUS GW-scenario „Hamburg“

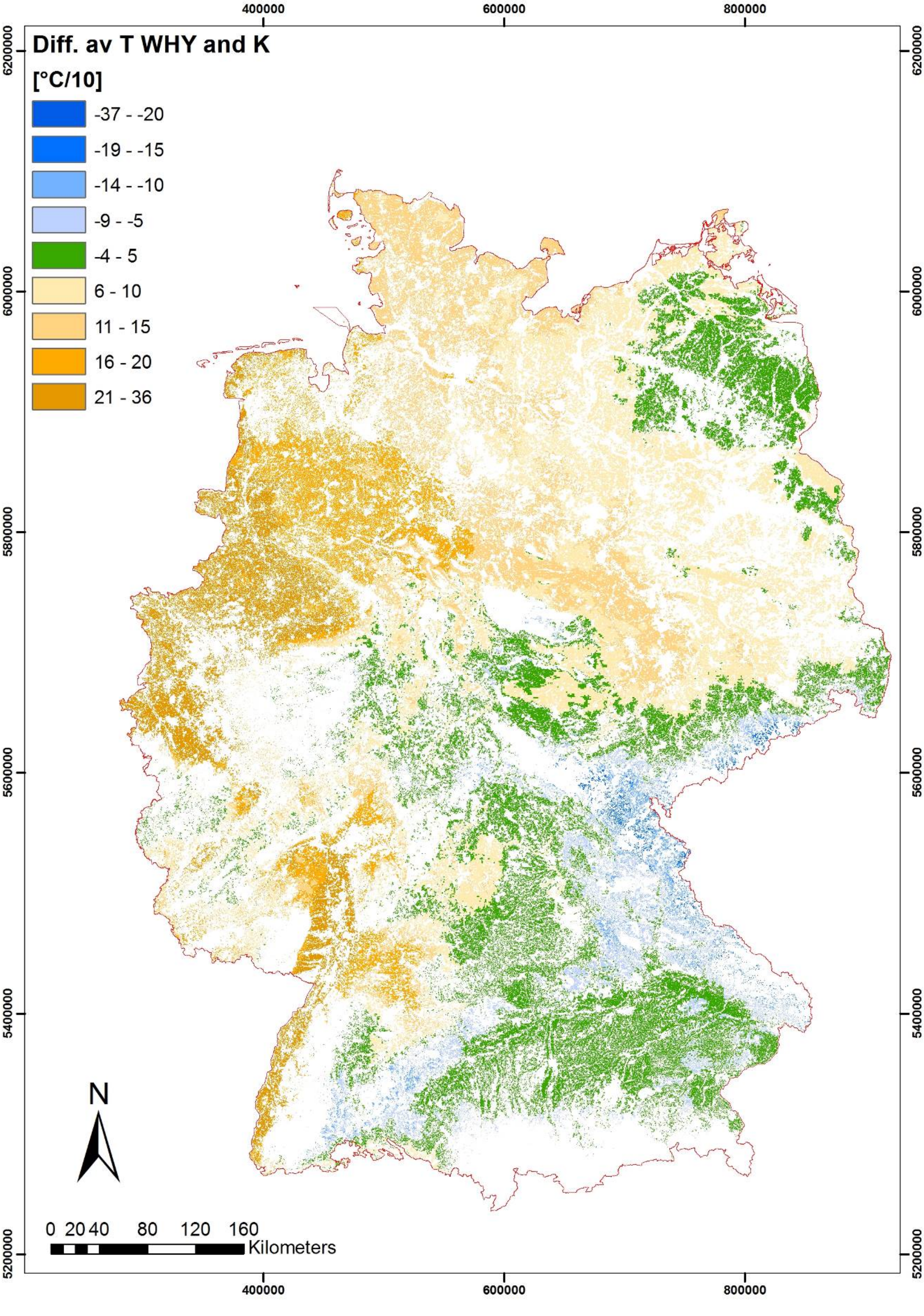


Figure 3-29: Difference of the average temperature in the winter half-year (DWD, 2012) and the FOCUS GW-scenario „Kremsmünster“

Figure 3-27 shows the map of the temperature in winter for „arable land“ and „permanent crops“ (ATKIS). To the remarkably warmest and coherent regions in the winter half-year belong the Lower Rhine region with the Cologne Bay, the Westfalian Basin and the whole area of the Rhine rift valley. The coldest areas are located in the northwestern Bavaria, South Saxony, the southwestern Swabian Alps and the Black Forest.

In Figure 3-28 and Figure 3-29 the difference of the temperature in the winter half-year and the scenarios „Hamburg“ and „Kremsmünster is mapped. Figure 3-28 illustrates the tendential best-case character (low spatial protection level) of the scenario “Hamburg” concerning the temperature in winter. A large area fraction is 0.5 °C warmer than Hamburg in winter. Figure 3-29 illustrates the tendential worst-case character of the scenario “Kremsmünster”. A large portion of the reference area is more than 0.5 °C warmer than “Kremsmünster” in winter, only a small area fraction more than 0.5 °C colder.

Average annual temperature

Figure 3-30 shows the spatial protection level concerning the yearly average temperature (reference time period: 1980 – 2009; reference area: ATKIS „arable land“ and „permanent crops“). In Table 3-18 the 90th percentile, the median and the 10th percentile spatial protection level concerning the annual temperature is shown. The scenario “Hamburg” represents a medium-case concerning this temperature parameter with a protection level of 44.5 %, “Kremsmünster” is not clearly a medium or worst-case with a 68 % protection level.

In Table 3-19 the results of the analyses concerning the temperature in the summer half-year, the winter half-year and in the whole year are summarized.

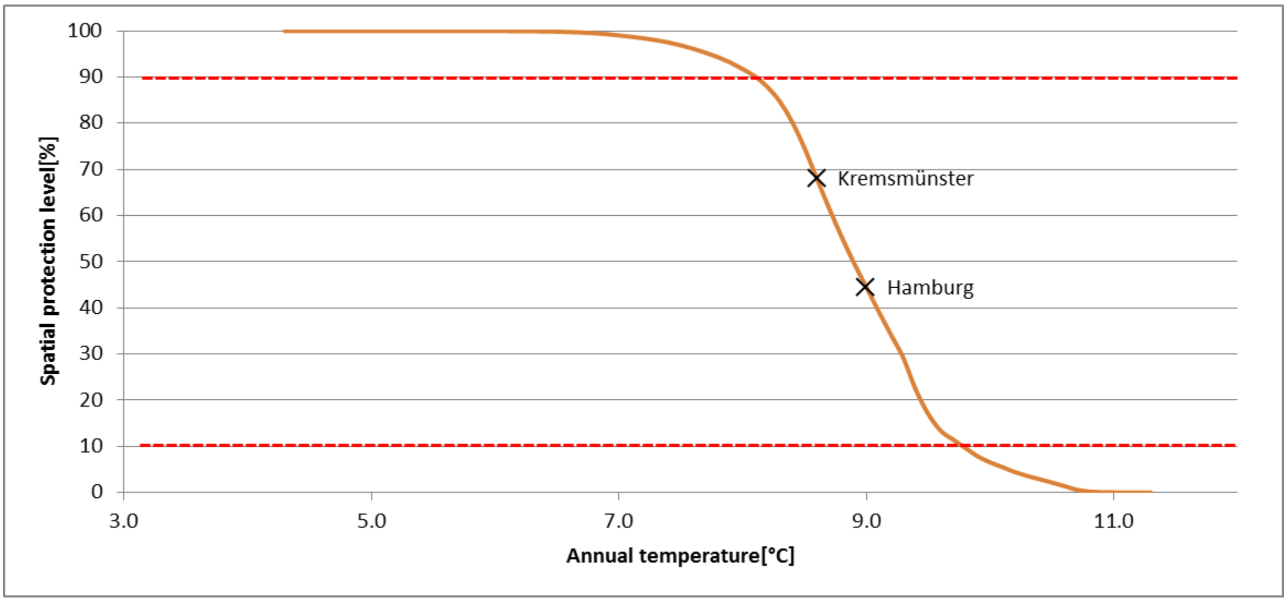


Figure 3-30: Spatial protection level concerning the average annual temperature (DWD, 2012)

Table 3-17: Placement of the FOCUS GW-scenarios „Hamburg“ and „Kremsmünster“ on the total spatial distribution function concerning the annual average temperature (DWD, 2012)

Scenario	An. T [°C]	Cum area percentage [%]	Spatial protection level [%]
Hamburg	9.0	55.5	44.5
Kremsmünster	8.6	32	68

Table 3-18: Different spatial protection levels of the total area concerning the annual average temperature (DWD, 2012)

Protection level total area	90th percentile [°C]	Median [°C]	10th percentile [°C]
	8.2	8.9	9.8

Table 3-19: Summary of the spatial analyses (protection level) concerning the climatic factor temperature (DWD, 2012)

Protection level total area				Hamburg		Kremsmünster	
	90th percentile [°C]	50th percentile [°C]	10th percentile [°C]	[°C]	Spatial protection level [%]	[°C]	Spatial protection level [%]
T SHY	13.6	14.4	15.2	13.9	75.8	14.4	48.2
T WHY	2.4	3.6	4.7	4	24.9	2.7	80.2
An. T	8.2	8.9	9.8	9	44.5	8.6	68

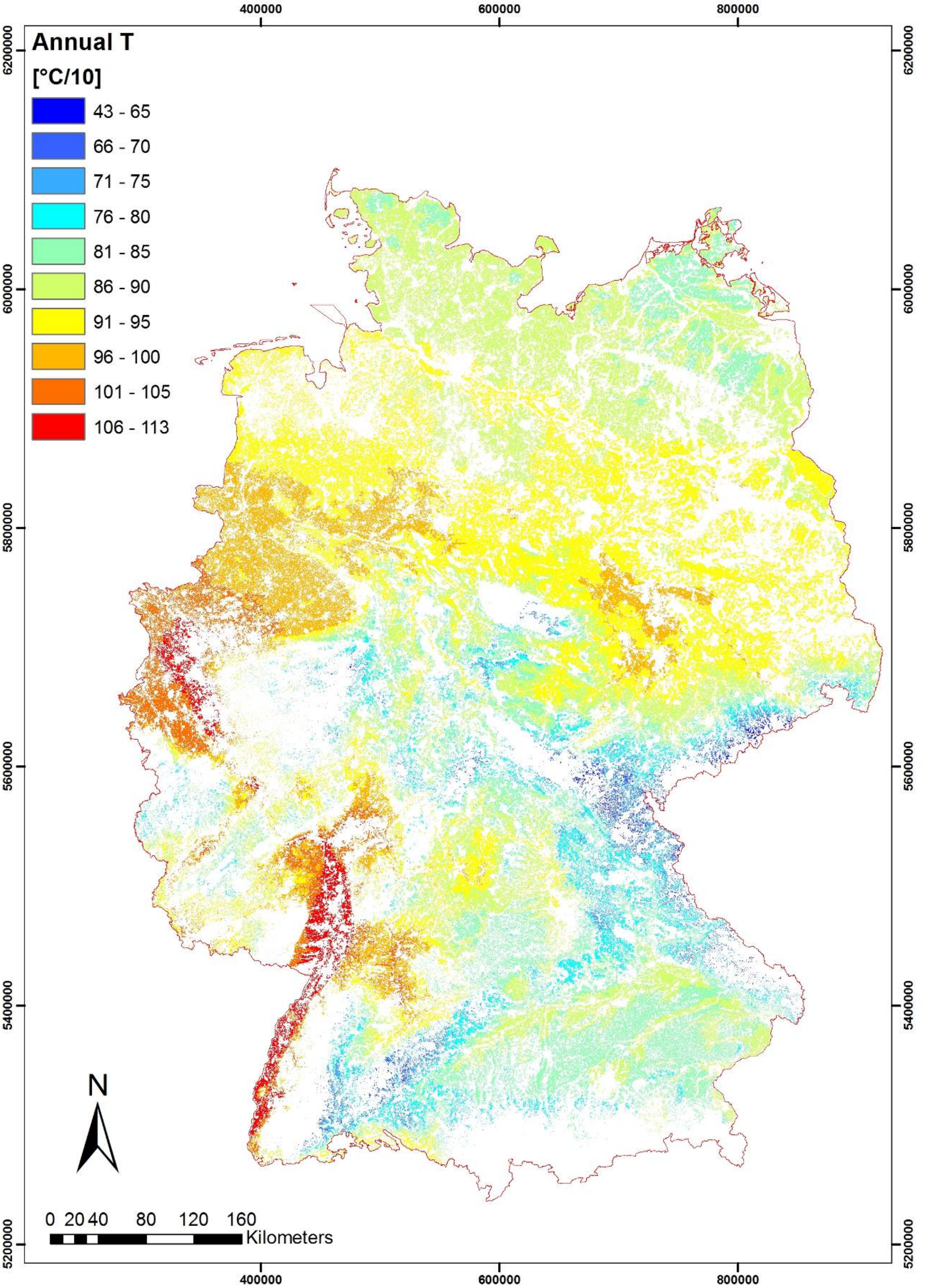


Figure 3-31: Average annual temperature (DWD, 2012) for the time period 1980 – 2009 (reference area: ATKIS „arable land“ and „permanent crops“; BKG, 2012)

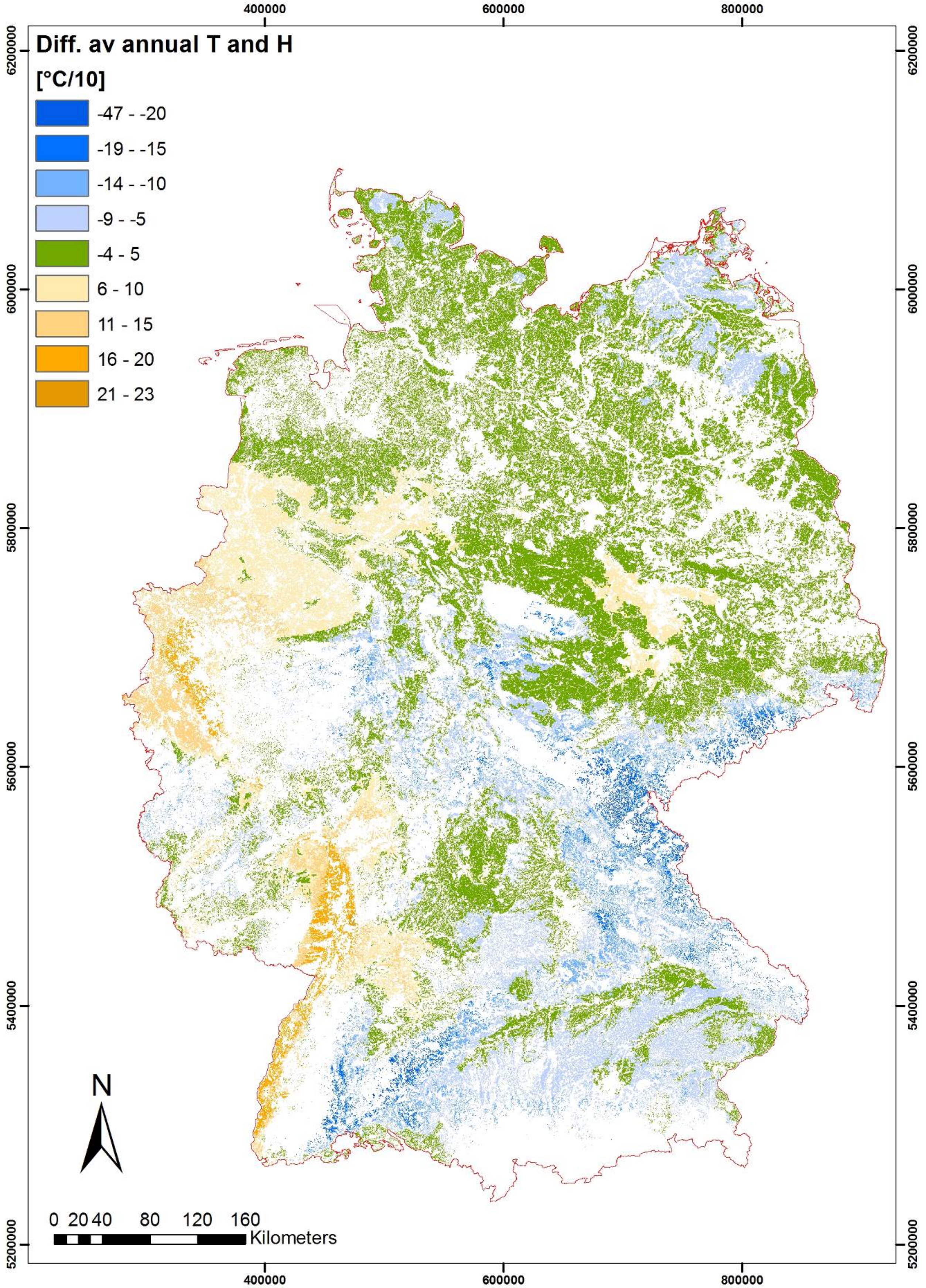


Figure 3-32: Difference of the average annual temperature (DWD, 2012) and the FOCUS GW-scenario „Hamburg“

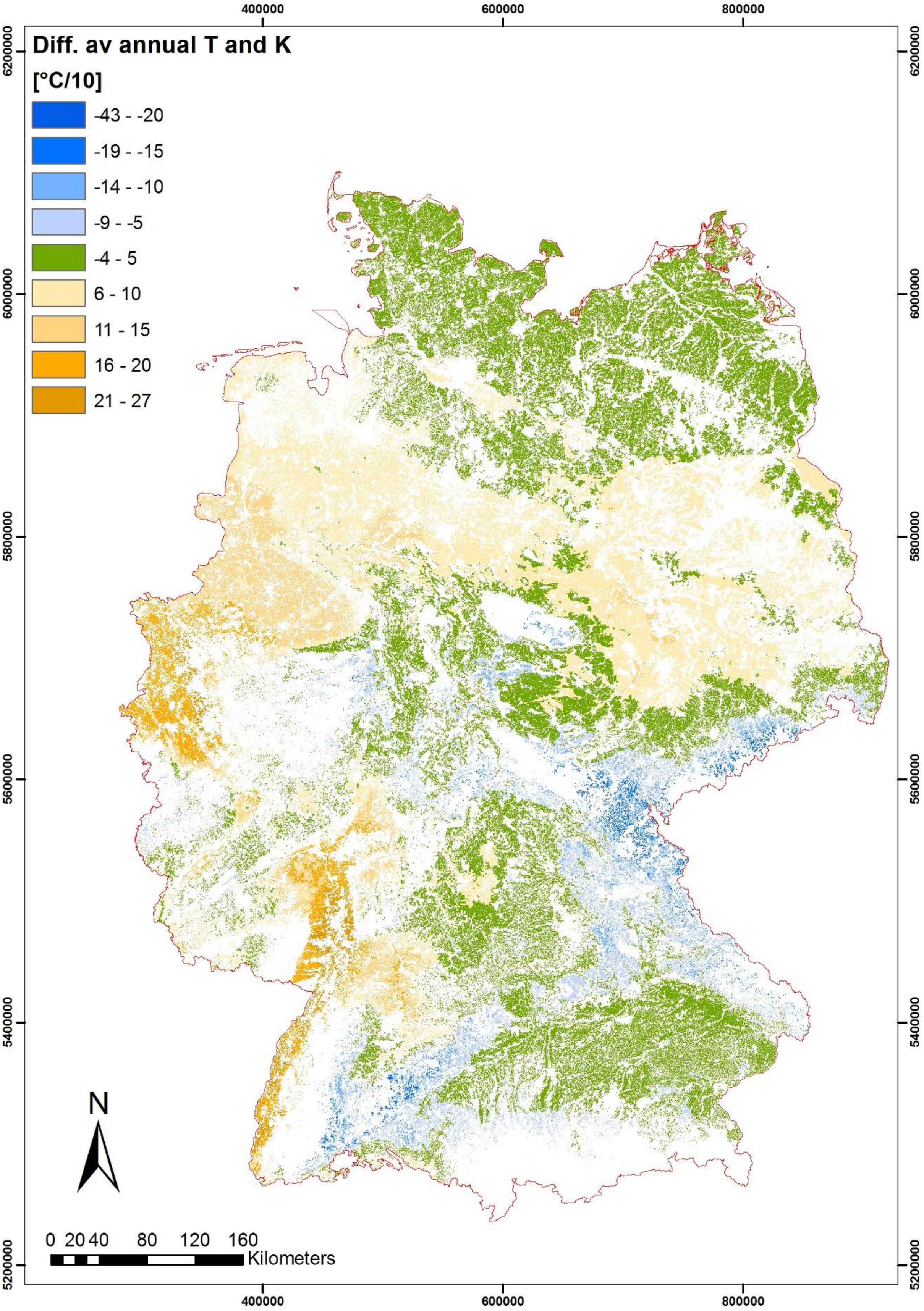


Figure 3-33: Difference of the average annual temperature (DWD, 2012) and the FOCUS GW-scenario „Kremsmünster“

Figure 3-31 shows the map of the average annual temperature for „arable land“ and „permanent crops“ (ATKIS). To the remarkably warmest and coherent areas over the whole year belong the Lower Rhine region with the Cologne Bay, the Westphalian Basin, the whole area of the Rhine rift valley, the area between the Forest of Odes and the Black Forest and parts of Thuringia. The coldest areas are located in the northeastern Bavaria, South Saxony, the southwestern Swabian Alps and the Black Forest.

In Figure 3-32 and Figure 3-33 the difference of the temperature in the whole year and the scenarios “Hamburg” and “Kremsmünster” is mapped. Figure 3-32 illustrates the medium-case character of the scenario “Hamburg” concerning the average annual temperature. Almost equally sized area fractions are more than 0.5 °C warmer or colder than “Hamburg”. A relatively large area fraction shows temperatures in the range +/- 0.5 °C. Figure 3-33 shows that more than half of the reference area is warmer than 0.5 °C than the scenario “Kremsmünster”. Only a relatively small part of the reference area is more than 0.5 °C colder than “Kremsmünster” over the year. Also in this case the area fraction with temperatures +/- 0.5 °C is relatively large.

3.2.2.3 Results concerning the combinations of precipitation and temperature

In the previous chapters the spatial analyses of the temperature and precipitation conditions have been pointed out separately. The following chapter analyses the two parameters in a combined way to identify areas with relevant property combinations in comparison with the two scenarios (e.g. wetter and colder or dryer and warmer than “Hamburg”).

These combinations were particularly analysed for the summer and the winter half-year. Additionally the areas with the characteristics “winter half-year wetter & year colder” than Hamburg/Kremsmünster were identified.

Figure 3-34 to Figure 3-43 show the occurrence of the different combinations for annual climate conditions. The exact area fractions can be seen in Table 3-20. In Table 3-21 the results of the combination query concerning the winter and summer half-year are presented.

In Figure 3-44 to Figure 3-49 the property combinations are mapped summarizing separately after summer half-year, winter half-year and the whole year and the scenarios „Hamburg“ and „Kremsmünster“.

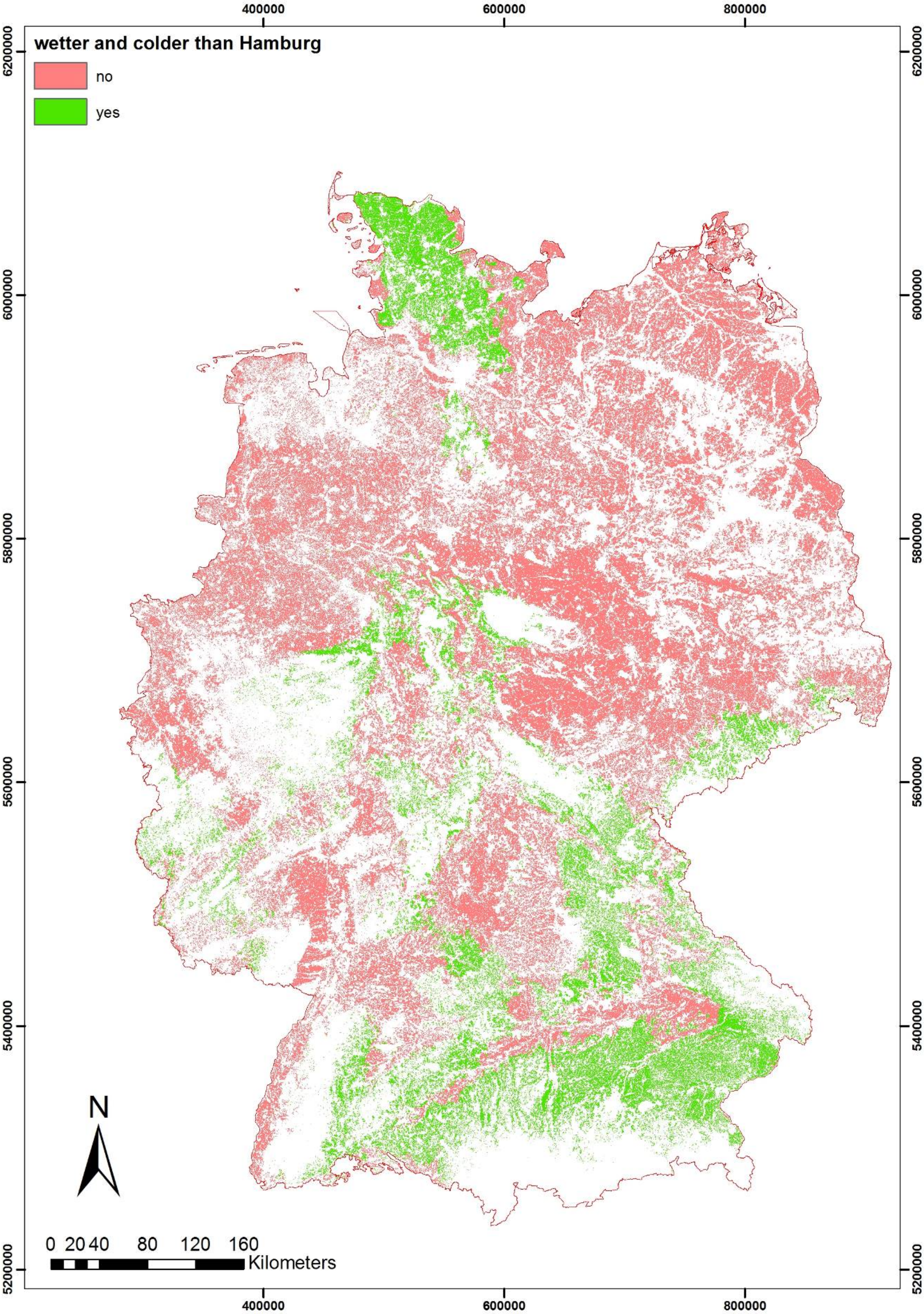


Figure 3-34: Annual climate conditions of FOCUS GW-scenario „Hamburg“ compared to DWD-climate data: wetter and colder areas (green)

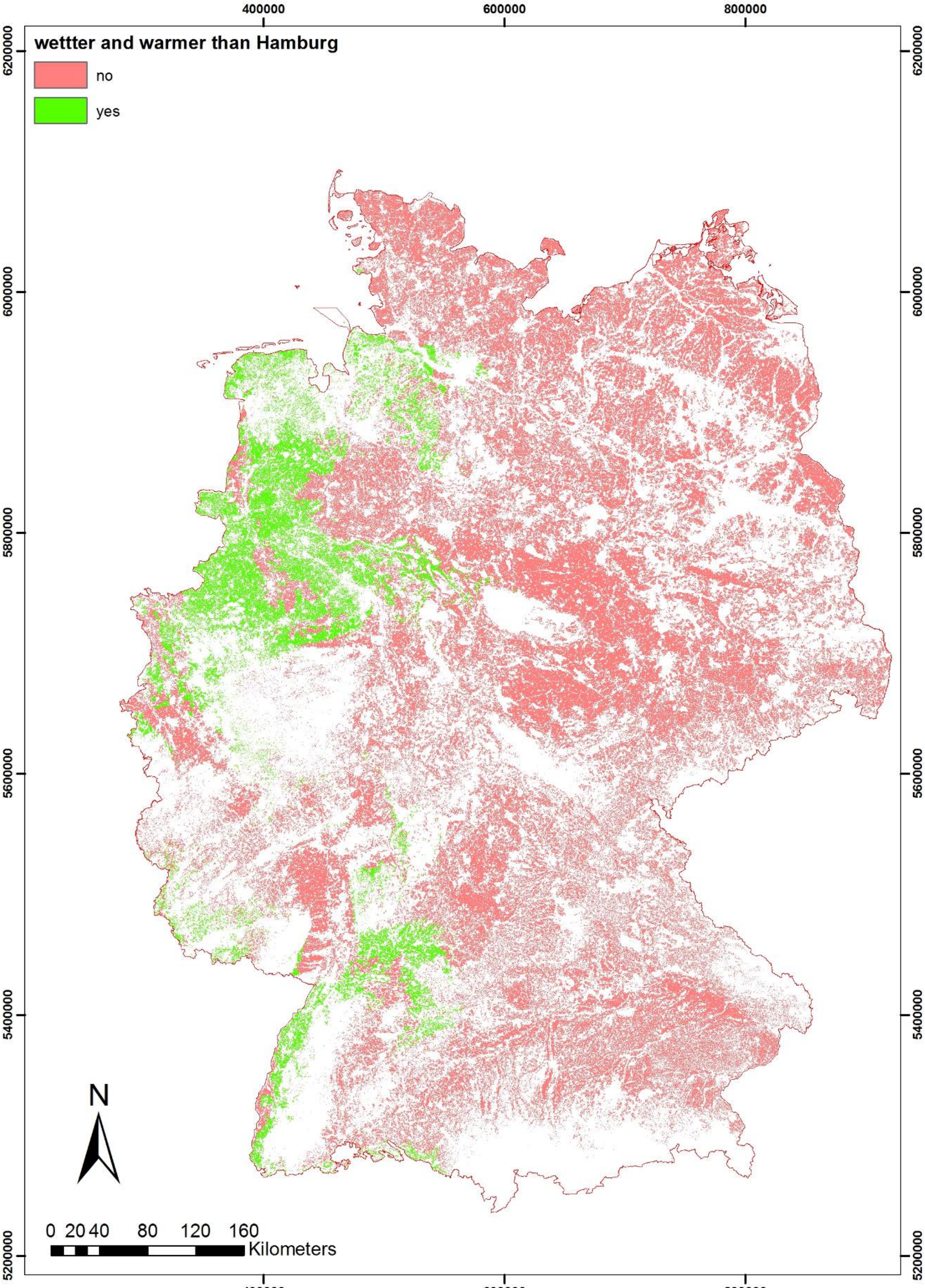


Figure 3-35: Annual climate conditions of FOCUS GW-scenario „Hamburg“ compared to DWD-climate data: wetter and warmer areas (green)

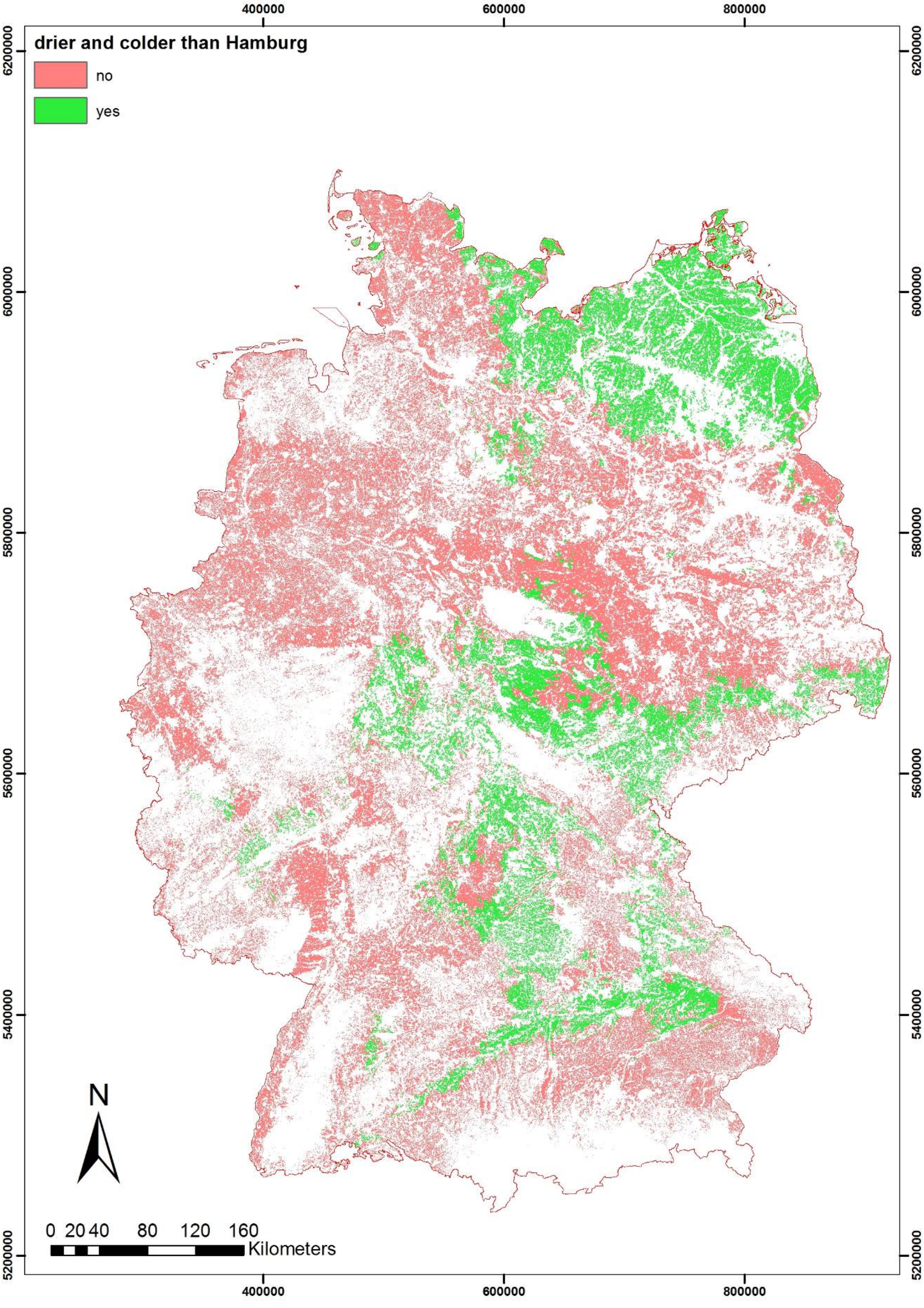


Figure 3-36: Annual climate conditions of FOCUS GW-scenario „Hamburg“ compared to DWD-climate data: drier and colder areas (green)

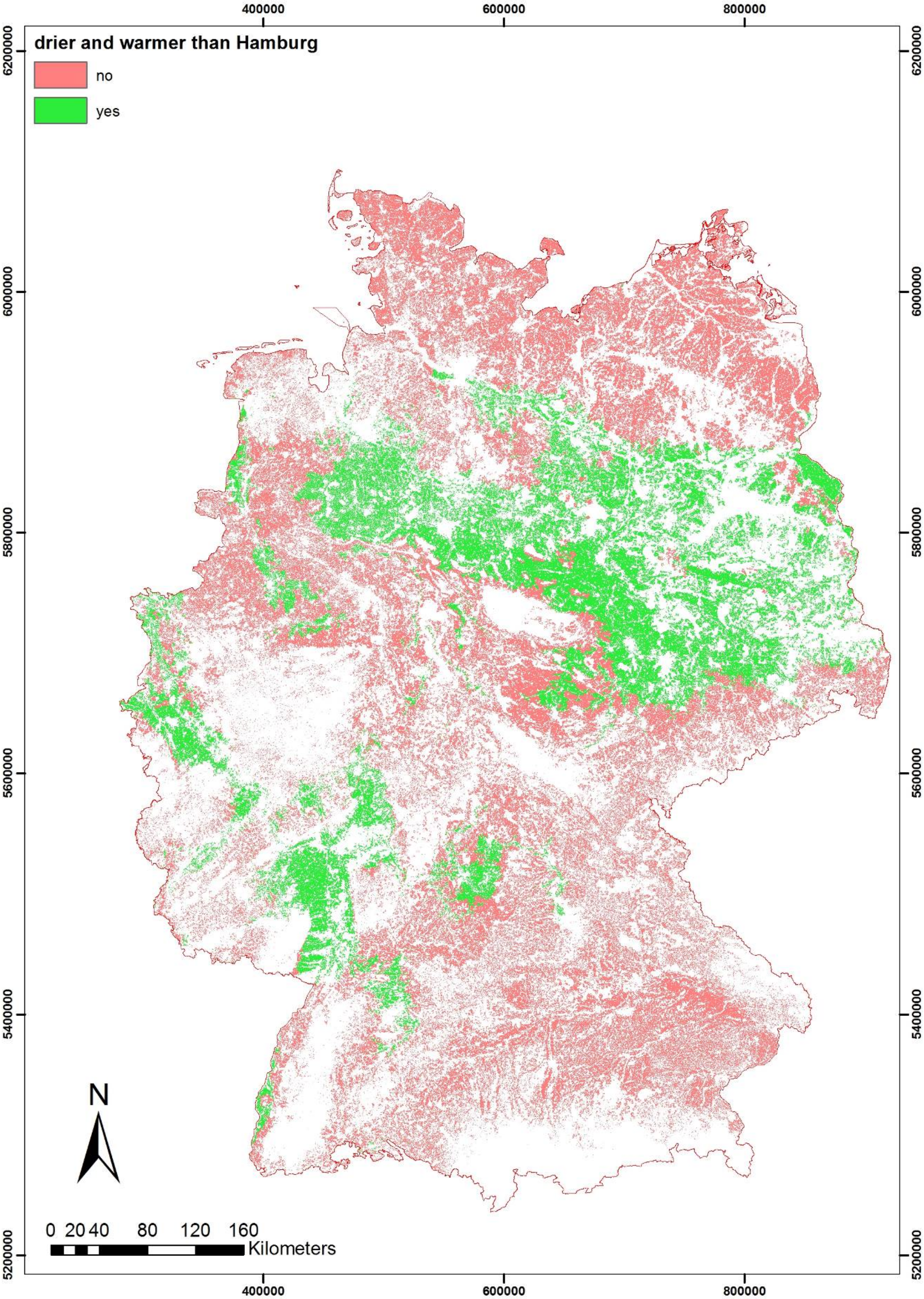


Figure 3-37: Annual climate conditions of FOCUS GW-scenario „Hamburg“ compared to DWD-climate data: drier and warmer areas (green)

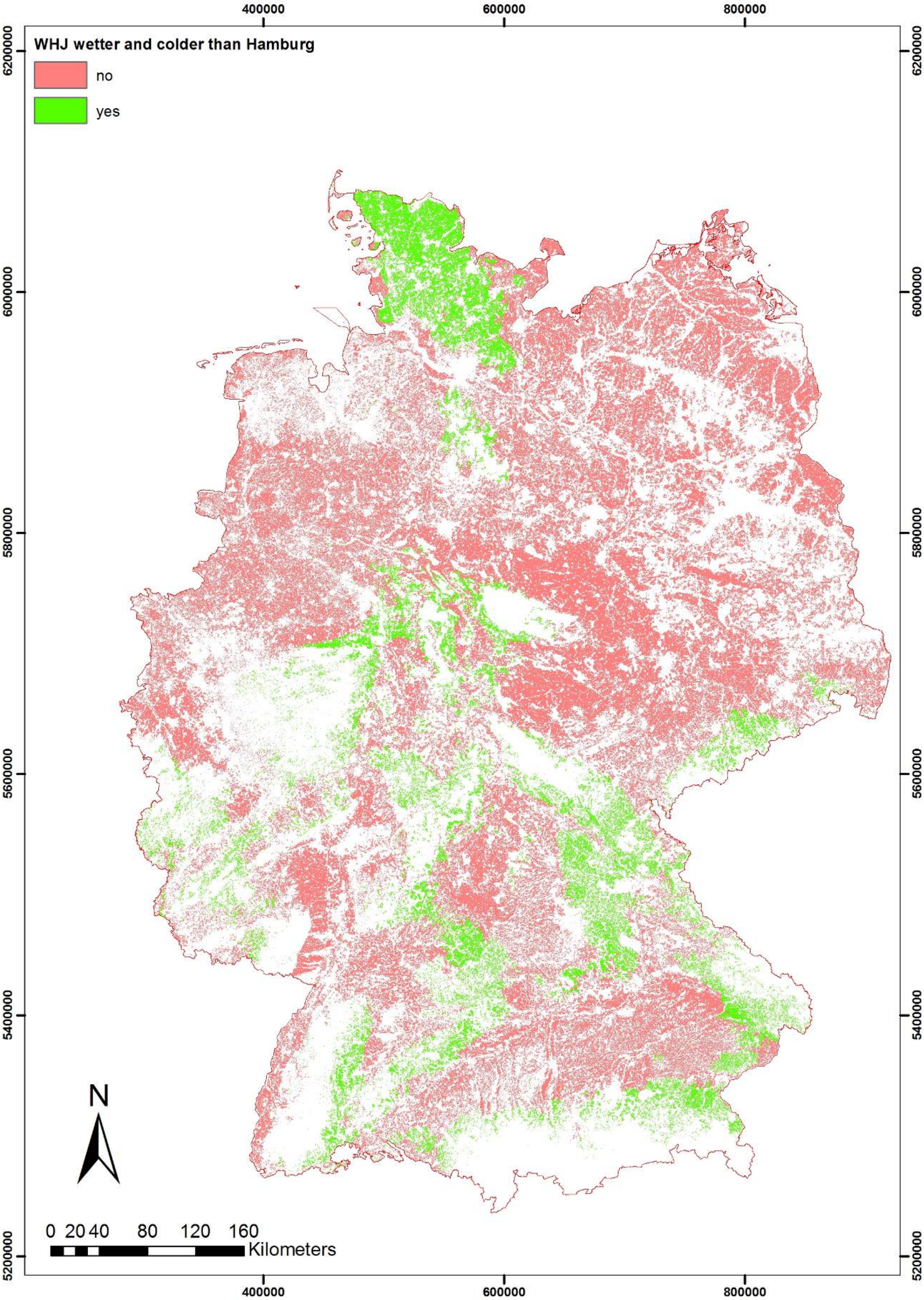


Figure 3-38: Climate conditions of FOCUS GW-scenario „Hamburg“ compared to DWD-climate data: wetter in winter and annually colder areas (green)

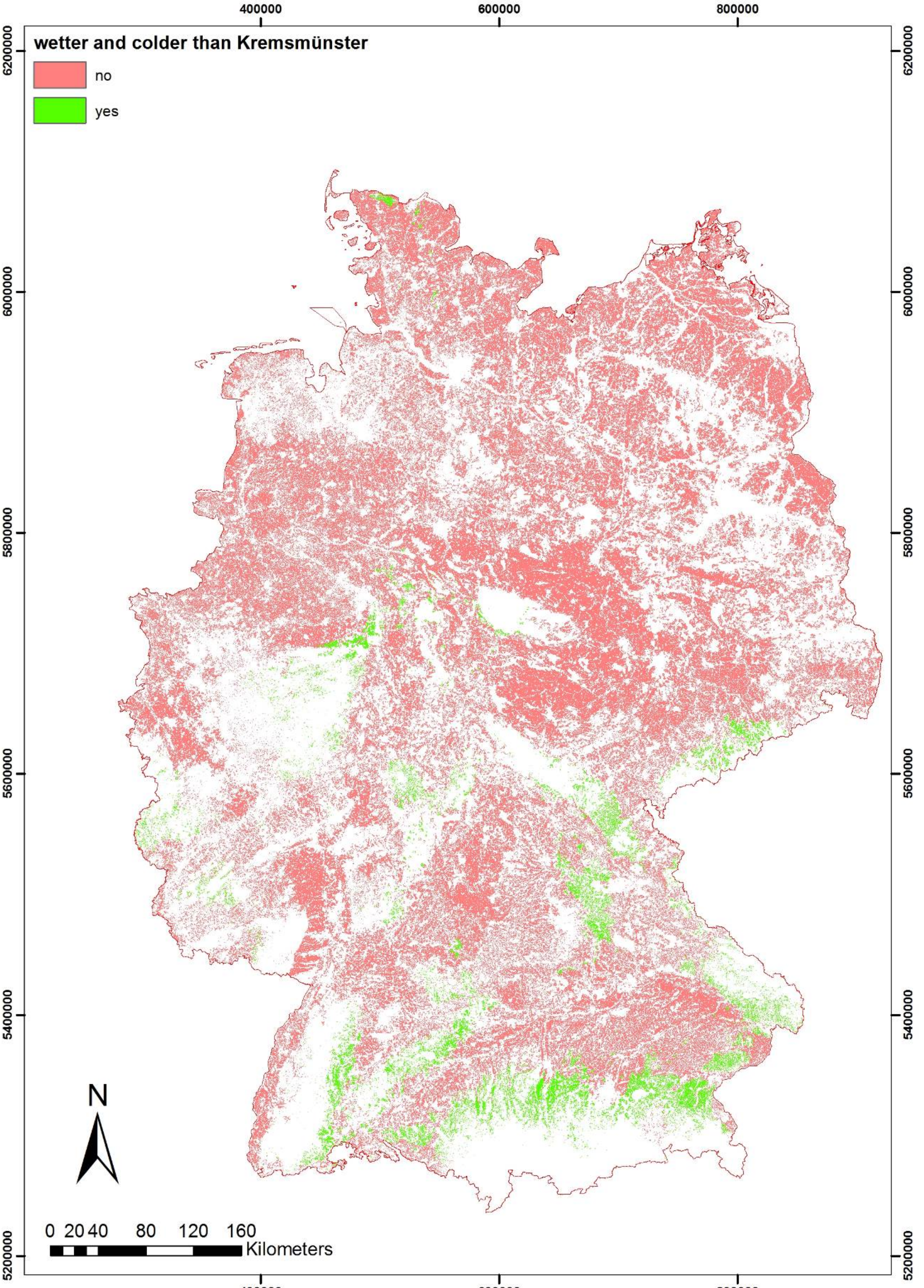


Figure 3-39: Annual climate conditions of FOCUS GW-scenario „Kremsmünster" compared to DWD-climate data: wetter and colder areas (green)

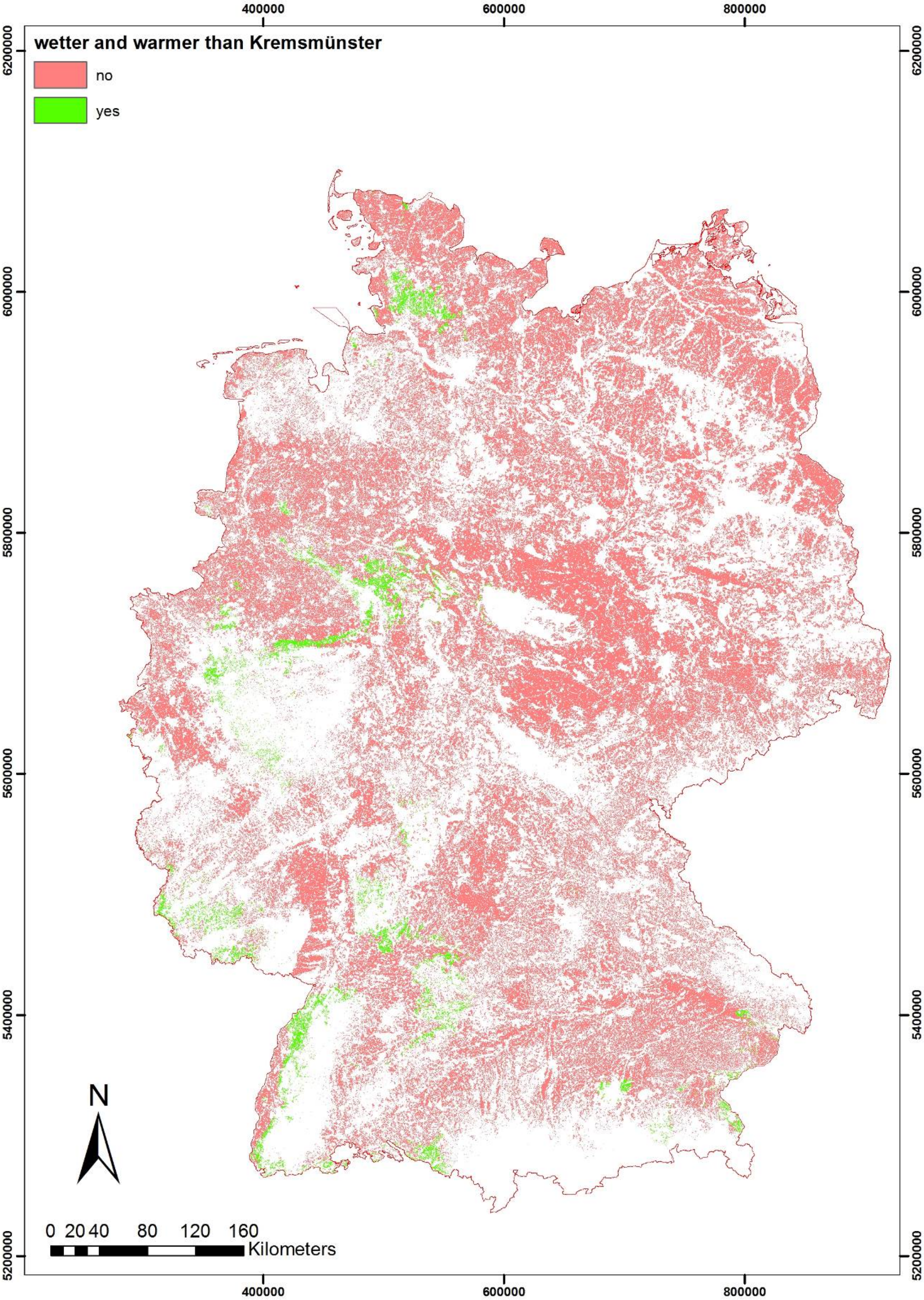


Figure 3-40: Annual climate conditions of FOCUS GW-scenario „Kremsmünster“ compared to DWD-climate data: wetter and warmer areas (green)

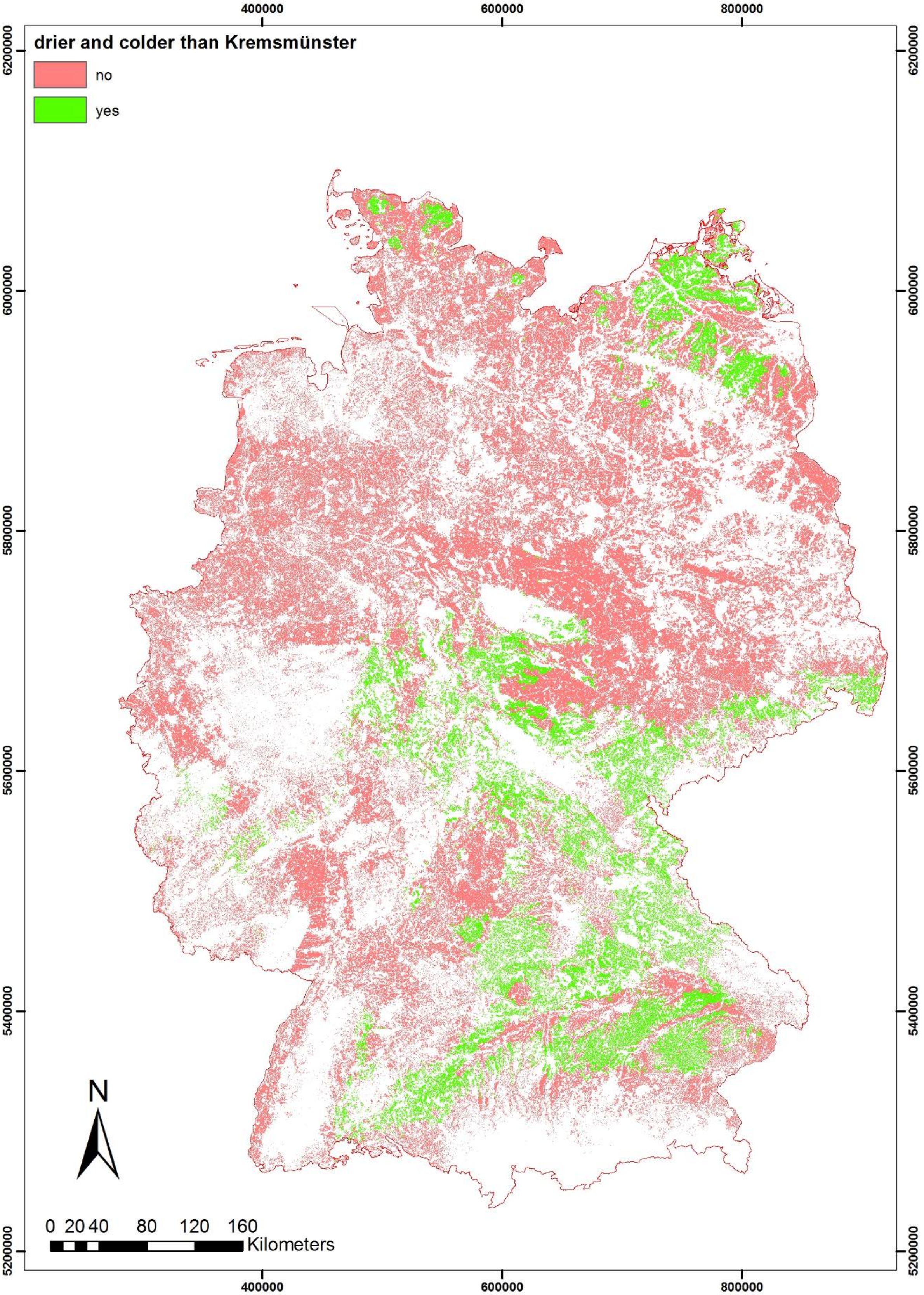


Figure 3-41: Annual climate conditions of FOCUS GW-scenario „Kremsmünster“ compared to DWD-climate data: drier and colder areas (green)

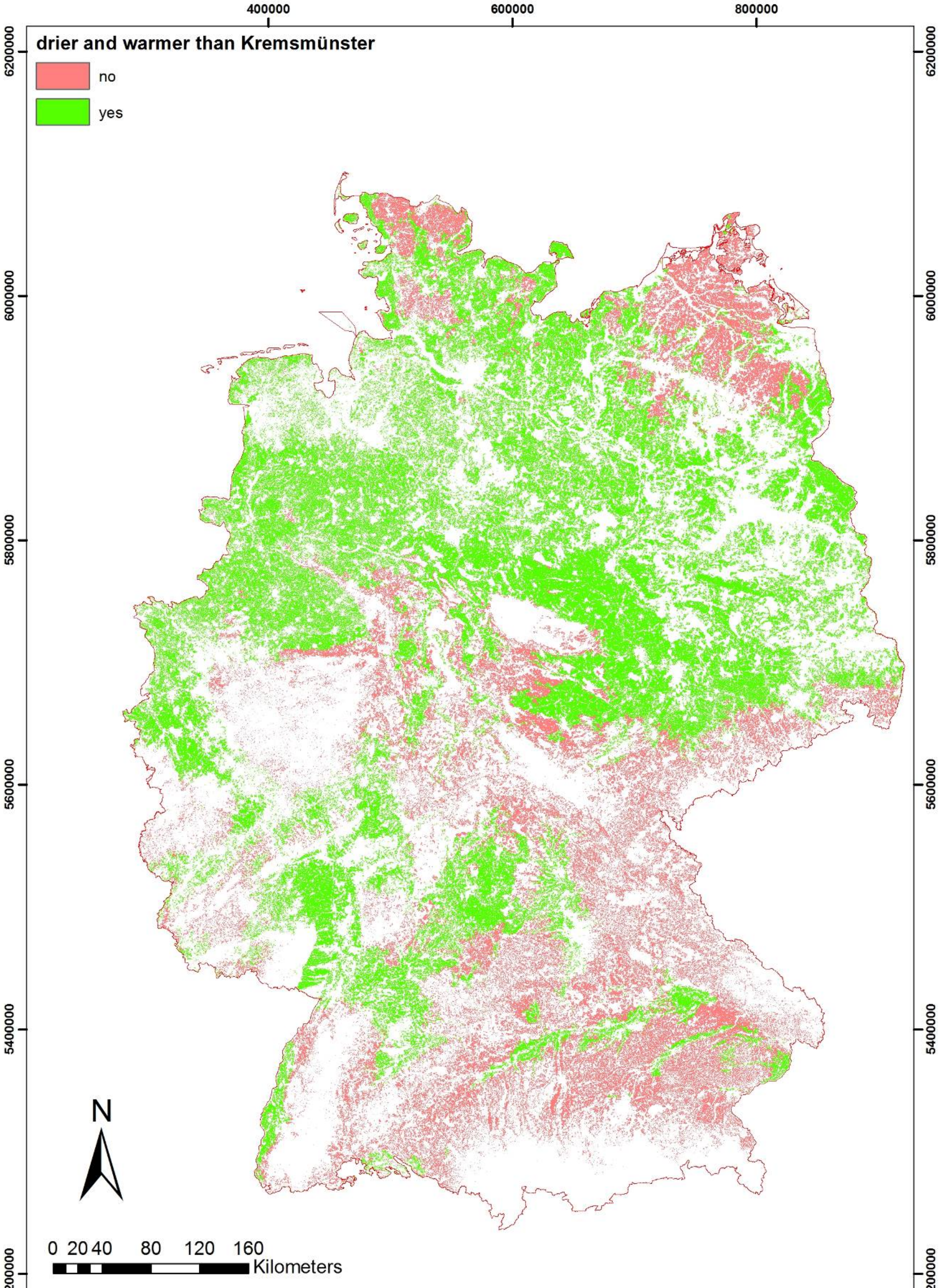


Figure 3-42: Annual climate conditions of FOCUS GW-scenario „Kremsmünster“ compared to DWD-climate data: drier and warmer areas (green)

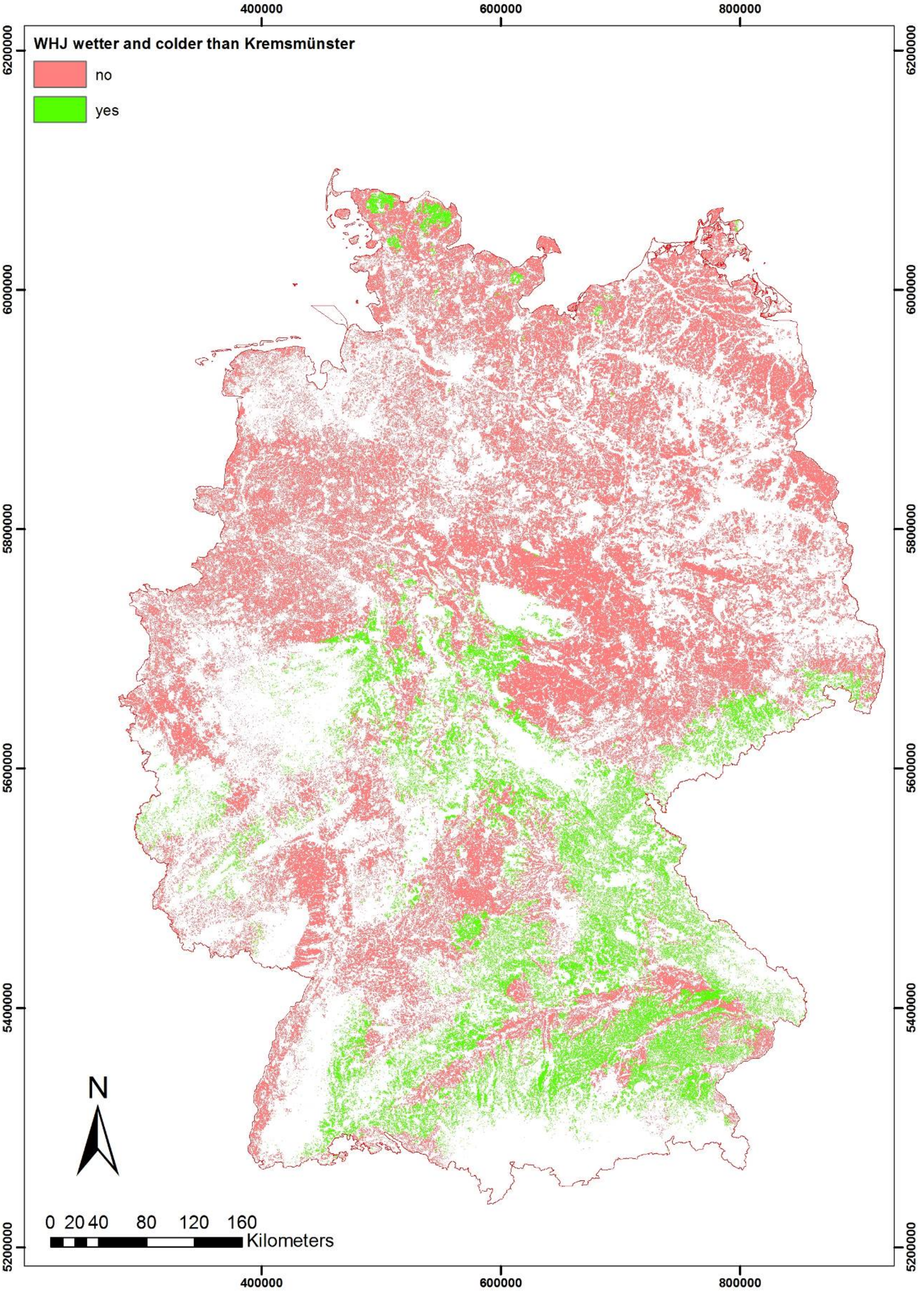


Figure 3-43: Climate conditions of FOCUS GW-scenario „Kremsmünster“ compared to DWD-climate data: wetter in winter and annually colder areas (green)

Table 3-20: Overview of the area percentages of the different precipitation/temperature combinations (related to the year)

	Annual conditions	
Combinations	Hamburg Area percentage [%]	Kremsmünster Area percentage [%]
wetter & colder	22.7	6.4
wetter & warmer	13.4	3.8
drier & colder	27.4	18.9
drier & warmer	30.9	64.1
WHY wetter & year colder	17.6	20.0

Regarding the leaching potential of PPP to the groundwater the combinations can be characterised as follows:

wetter & colder = more disadvantageous areas than Hamburg/Kremsmünster
drier & warmer = more advantageous areas than Hamburg/Kremsmünster
wetter & warmer = tendential more disadvantageous than Hamburg/Kremsmünster (but not clearly)
drier & colder = tendential more advantageous than Hamburg/Kremsmünster (but not clearly)
winter half-year wetter & year colder = more disadvantageous than Hamburg/Kremsmünster

However, it has to kept in mind that wetter conditions lead to more substance leaching into the groundwater but not necessarily to higher concentrations of the leachate, as in drier conditions also the leachate amount is lower. As the leachate concentration is the key parameter for the regulatory decision, it is difficult to define a worst case in terms of precipitation.

Table 3-21: Overview of the area percentages of the different precipitation/temperature combinations (related to the summer and winter half-year)

	Summer		Winter	
Combination	Hamburg area percentage [%]	Kremsmünster area percentage [%]	Hamburg area percentage [%]	Kremsmünster area percentage [%]
wetter & colder	13.6	1.9	18.6	15.4
wetter & warmer	27.8	0.6	14.6	42.9
drier & colder	5.8	44.6	53.2	1.9
drier & warmer	47.5	47.6	10.1	37

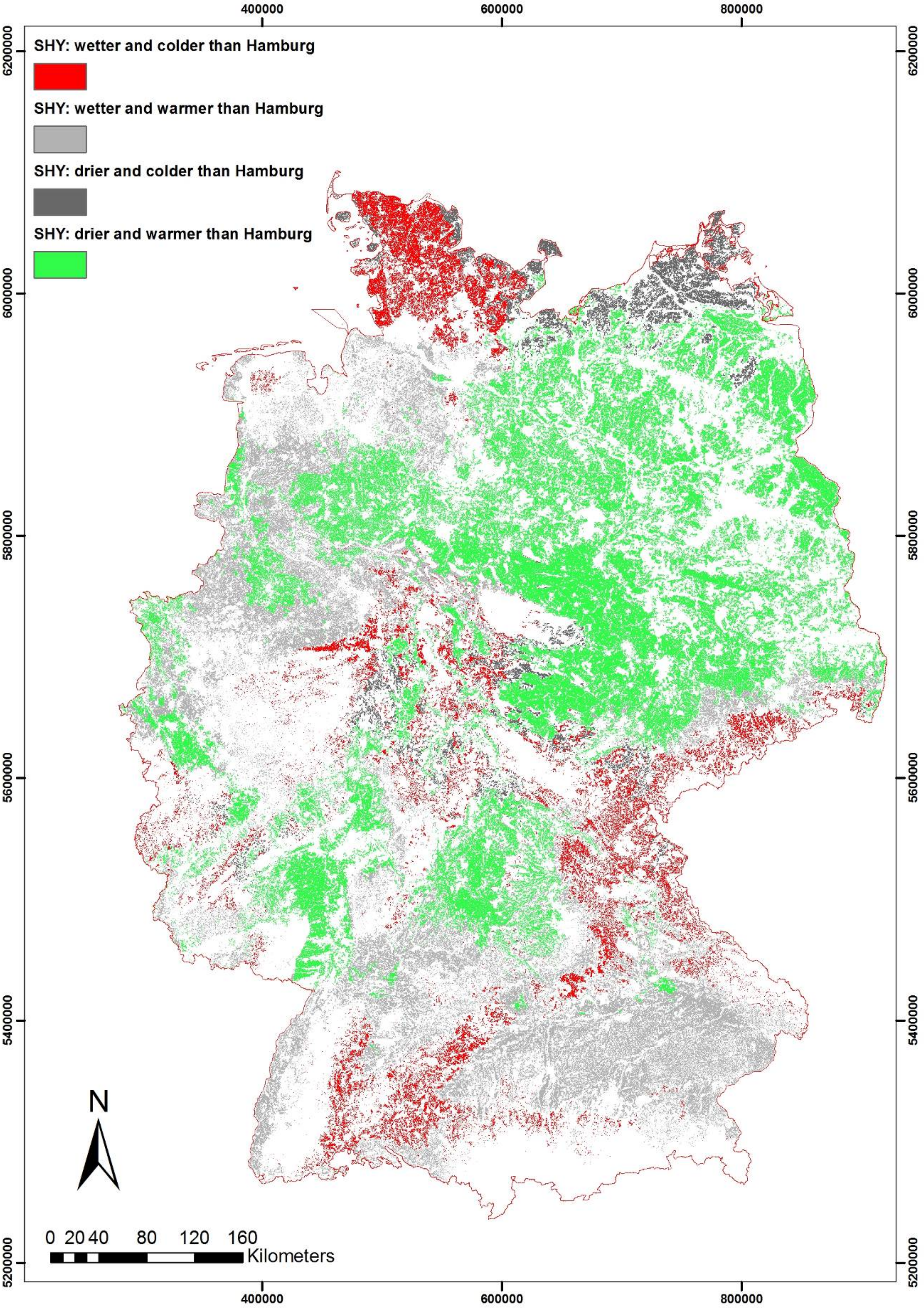


Figure 3-44: Summer climate conditions of FOCUS GW-scenario „Hamburg“ compared to DWD-climate data: combined view.

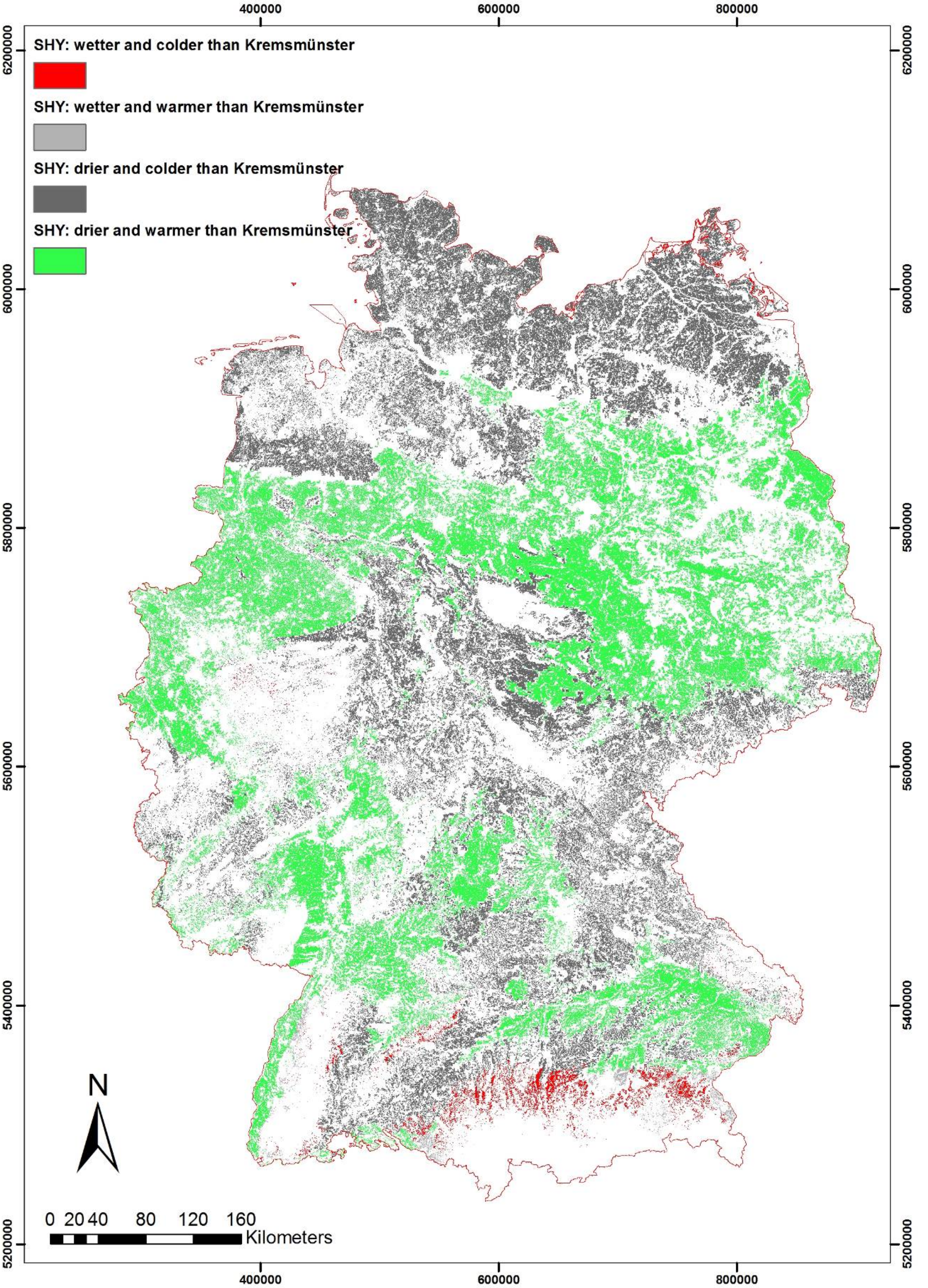


Figure 3-45: Summer climate conditions of FOCUS GW-scenario „Kremsmünster“ compared to DWD-climate data: combined view.

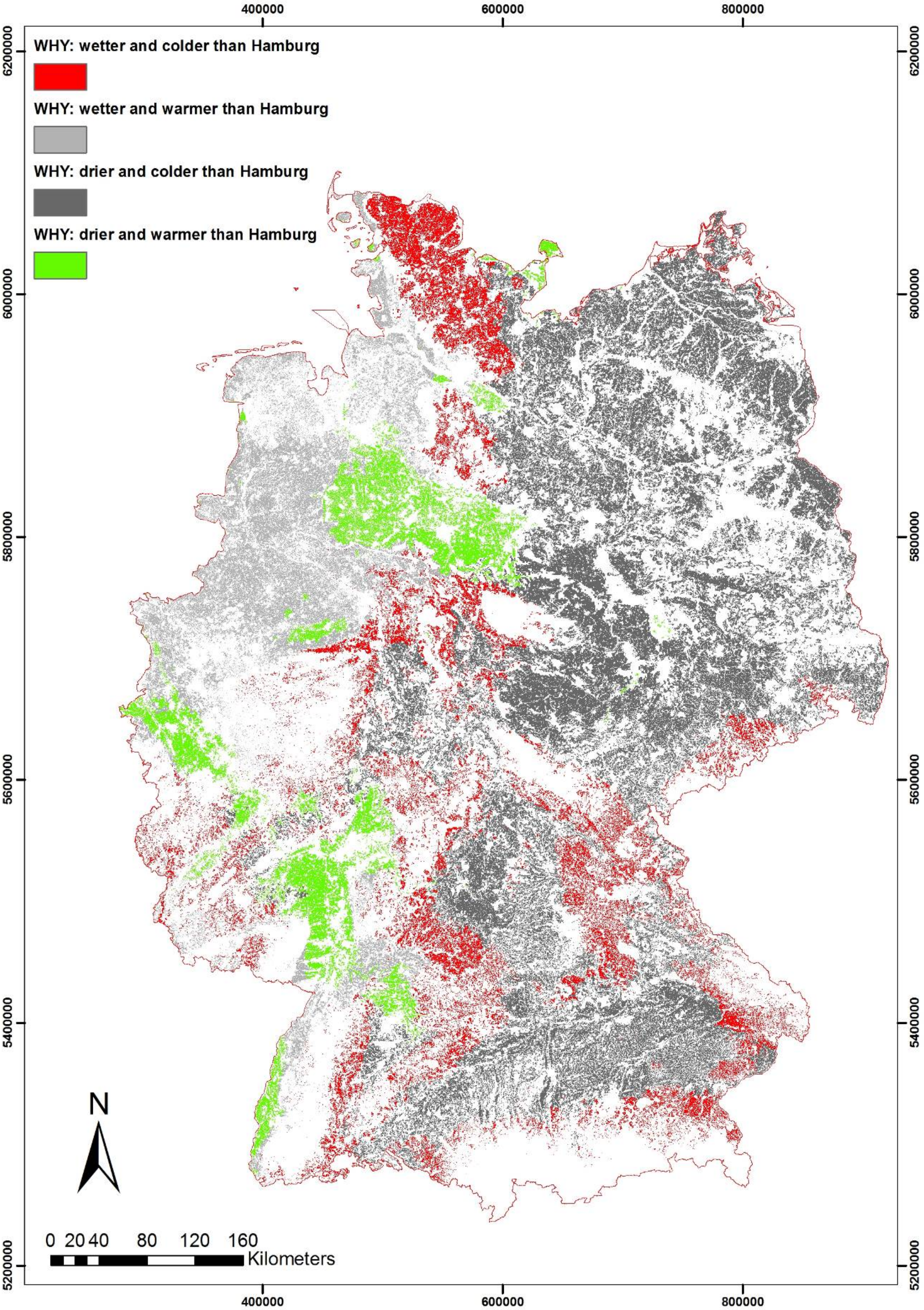


Figure 3-46: Winter climate conditions of FOCUS GW-scenario „Hamburg“ compared to DWD-climate data: combined view.

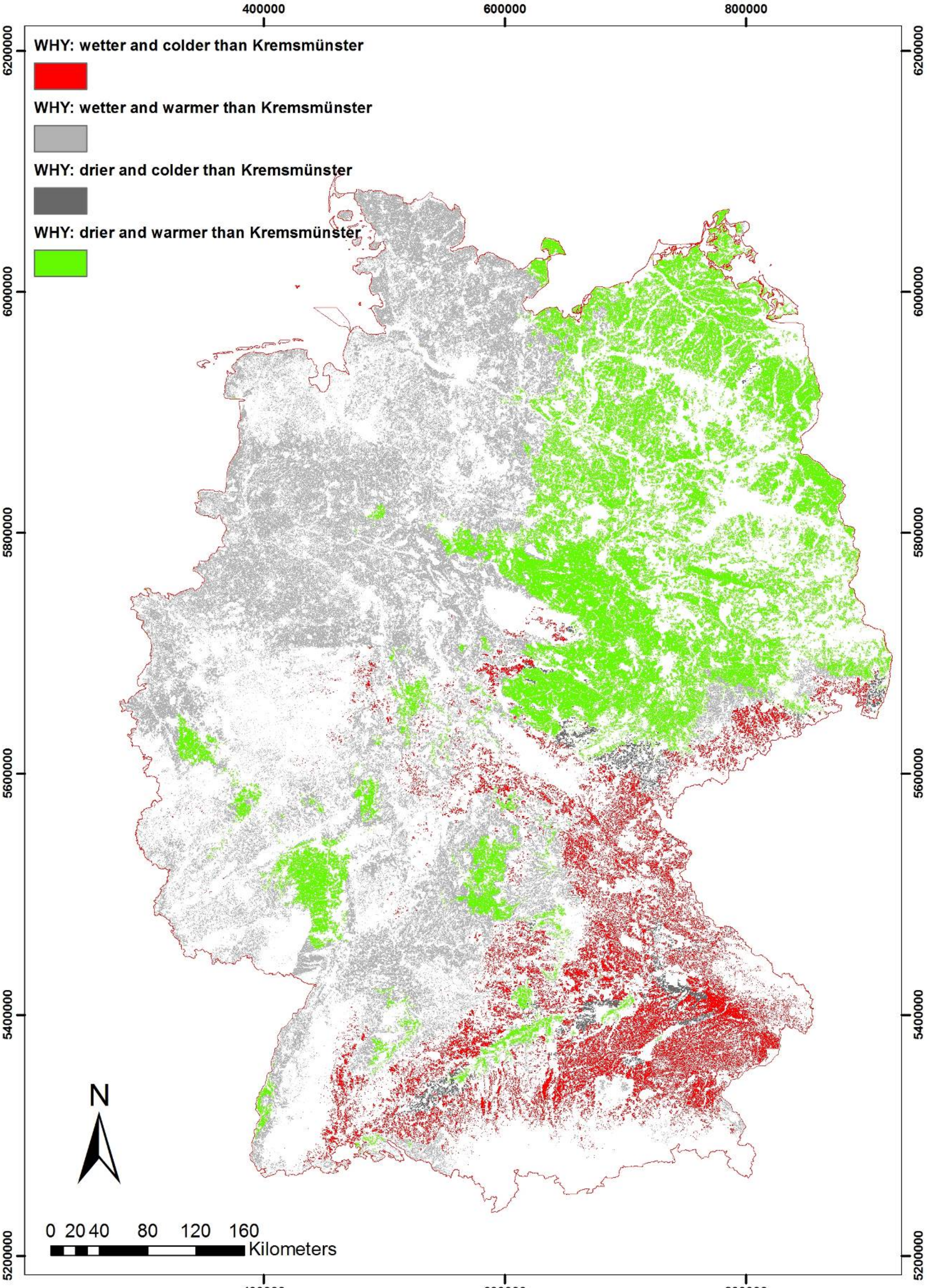


Figure 3-47: Winter climate conditions of FOCUS GW-scenario „Kremsmünster“ compared to DWD-climate data: combined view.

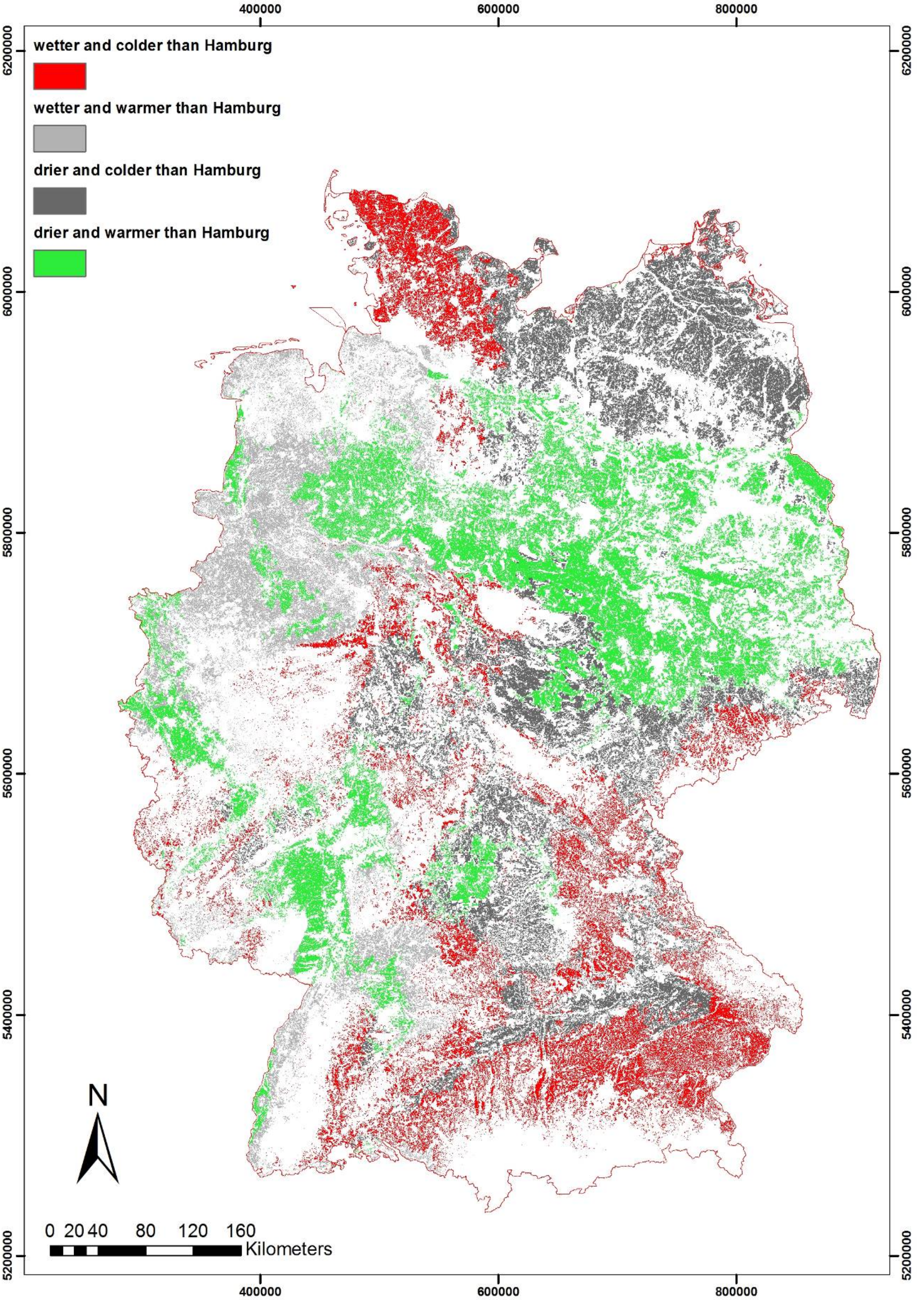


Figure 3-48: Annual climate conditions of FOCUS GW-scenario „Hamburg“ compared to DWD-climate data: combined view.

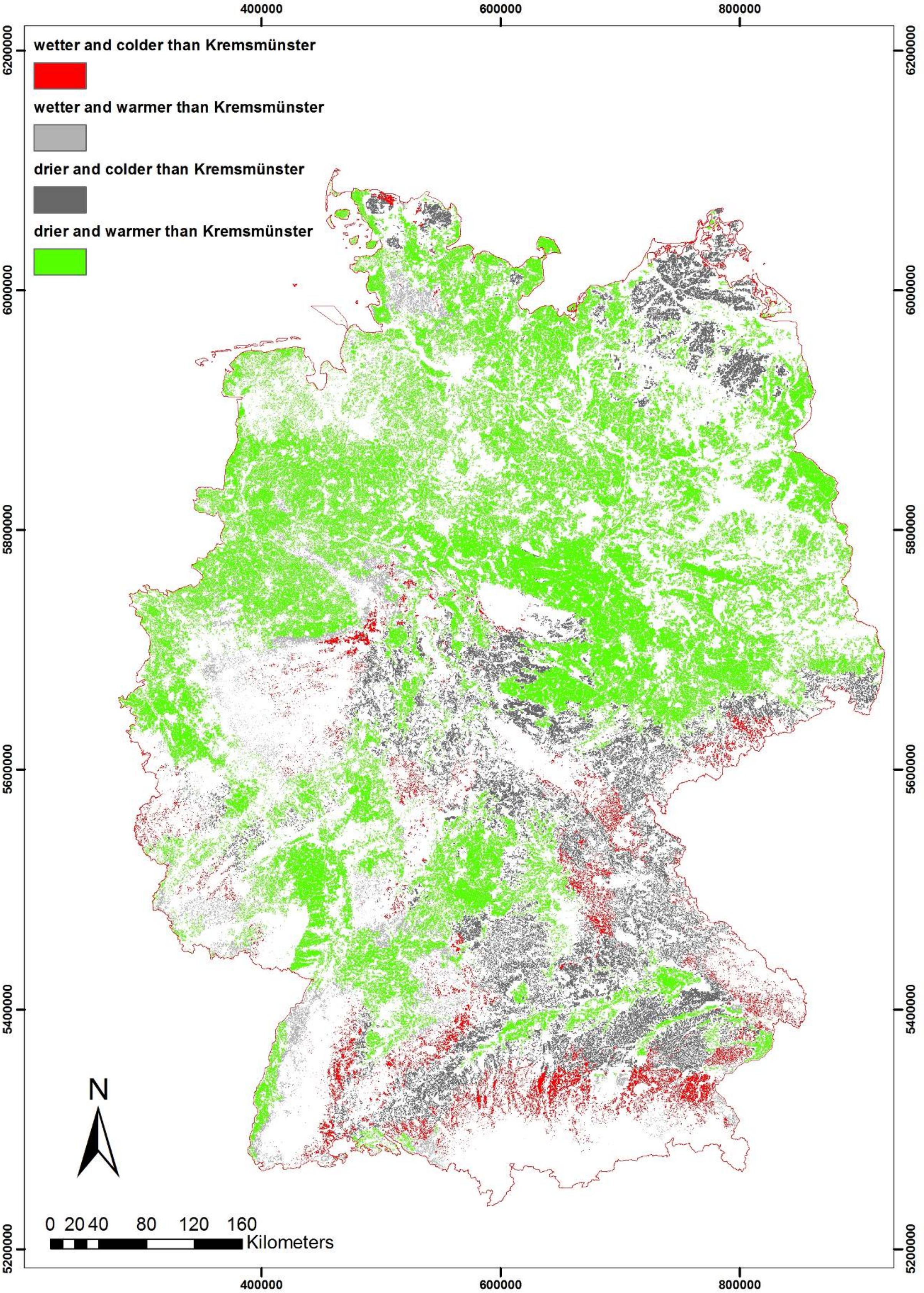


Figure 3-49: Annual climate conditions of FOCUS GW-scenario „Kremsmünster" compared to DWD-climate data: combined view.

3.2.2.4 Summary of the results concerning the analysis of climatic parameters

In the previous sections the examination of the spatial distribution of different climatic parameters concerning temperature and precipitation in Germany was described in detail.

It turned out that Hamburg doesn't seem to represent a realistic worst-case scenario regarding the climate. About 40 % of the agricultural is characterised by higher yearly precipitation than the FOCUS scenario. This applies more for summer but also for winter precipitation. For the parameter "average temperature" the relevant area that is covered by the Hamburg scenario is even lower (around 45 %), whereat a higher area (76 %) is covered by the summer temperature and a minor area (25 %) is covered by the winter temperature.

Wetter regions are for example almost the whole Alpine foreland, most parts of the Franconian and Swabian Jura, parts of the southern Rhine rift valley, the Erzgebirge, the Saar-Nahe Uplands, parts of the Weser Upland, parts of the Westphalian plains, almost total Schleswig Holstein and other regions of minor size.

Colder regions can be found for example in the most parts of the Alpine foreland, in parts of the South German Scarplands, Northeast Bavaria, the Erzgebirge, in great parts of the Hessian and Thuringian Uplands and other smaller regions in Rhineland Palatinate, Mecklenburg-Western Pomerania and Schleswig Holstein.

However, only about 23 % of the arable land is both wetter and colder than the FOCUS groundwater scenario Hamburg. These areas are located in the Alpine foreland, Northeast Bavaria, most parts of the Swabian and Franconian Jura, further parts of the South German Scarplands, smaller parts of the Thuringian and Hessian Uplands, the Erzgebirge, the Eifel, the Saar-Nahe Uplands, the Hunsrück, smaller parts of the Sauerland and the Weser Upland and most parts of Schleswig Holstein (the latter widely with a temperature difference to Hamburg lower than 0.5 °C).

In contrast the scenario Kremsmünster shows a higher level of spatial representativity concerning the examined climatic parameters and therefore rather owns the characteristic of a worst-case. That means that for 90 % of the relevant area in Germany lower yearly average precipitations can be observed. This overall conservative percentile belongs rather to the summer precipitation values of Kremsmünster (97 % of the area covered), whereat only 40 % of the area is covered by the average winter precipitation. The spatial protection level for the yearly temperature is lower but at around 70 % still on a higher level than the Hamburg scenario. The average winter temperature of Kremsmünster shows a higher coverage (80 %) than the average temperature in the winter half year (48 %).

More precipitation during the year than Kremsmünster can be found in parts of the Alpine foreland, parts of the South German Scarplands, parts of Northeast Bavaria, parts of the Sauerland and the Weser Uplands for example.

Lower temperatures than in Kremsmünster can be observed in parts of the South German Scarplands and parts of Northeast Bavaria for example.

In combination of the two climatic categories only 6.4 % of the arable land can be characterized colder and wetter than Kremsmünster. These regions are located for example in the southern part of the Alpinian foreland, parts of the Swabian and Franconian Jura and the Erzgebirge.

From the STEP 1 analysis the FOCUS Kremsmünster groundwater scenario seems to be a more suitable realistic worst case in terms of the calculation of PEC_{gw} compared to the FOCUS Hamburg scenario. But as the general experience with the FOCUS groundwater scenarios shows, the concentrations estimated for Kremsmünster are often lower than Hamburg. This is most probably due to the soil properties.

Overall the analysis shows an existing wide range of averaged precipitation amounts and temperatures for the agricultural area in Germany, which follows both a west-east- and an altitudinal gradient.

3.2.3 Results of the spatial representativity analysis of soil parameters

3.2.3.1 C_{org}-content (1 m depth weighted)

In contrast to the FOCUS Hamburg scenario most of the soil profiles of the original BÜK 1000 N show organic matter contents of 0 already in the second soil horizon. That has a significant impact on the modelled leaching behaviour. As it did not seem reasonable that the organic matter class h0 is widely found already at soil depth of about 50 cm the original C_{org}-contents were replaced by more recent results of Düwel et al. (2007) and Utermann et al. (2009). The detailed methodology thereof is described in chapter 3.2.1.3. In the course of the examination concerning the C_{org}-content a 1 m-depth weighted average was calculated.

The values which manifested after the calculation of the average are marked with points in the cumulative distribution function (see Figure 3-50).

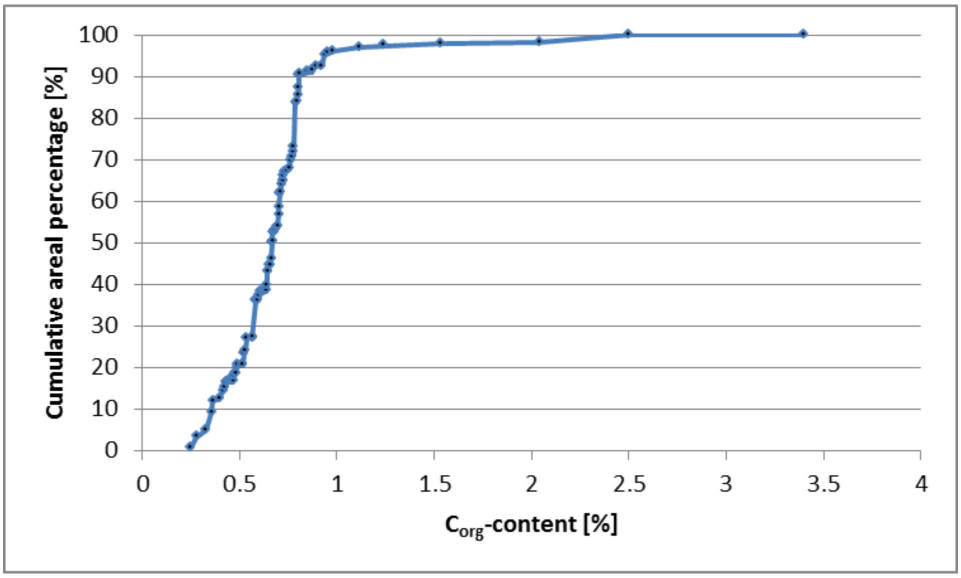


Figure 3-50: Cumulative distribution function related to the soil C_{org}-content (1m depth weighted; Düwel et al., 2007 and Utermann et al. ,2009)

As the adsorption of PPP in soil is directly linked to the C_{org}-content in the pesticide leaching models, a higher C_{org} leads to lower PECs and vice versa. The protection level of the scenarios concerning the C_{org}-content results from the difference 100 %-“cumulative area percentage of C_{org} X”. With 27.2 % respectively 7.6 % the scenarios “Hamburg” and “Kremsmünster” show a relatively low level of spatial protection regarding the 1 m depth weighted C_{org}-content in soil.

Table 3-22: Overview of the spatial analysis concerning soil C_{org}-content (1 m depth weighted; Düwel et al., 2007 and Utermann et al., 2009)

Germany-wide			Hamburg		Kremsmünster	
10th percentile [%]	50th percentile [%]	90th percentile [%]	[%]	Cum. area percentage [%]	[%]	Cum. area percentage [%]
0.36	0.67	0.8	0.78	72.8	0.9	92.4

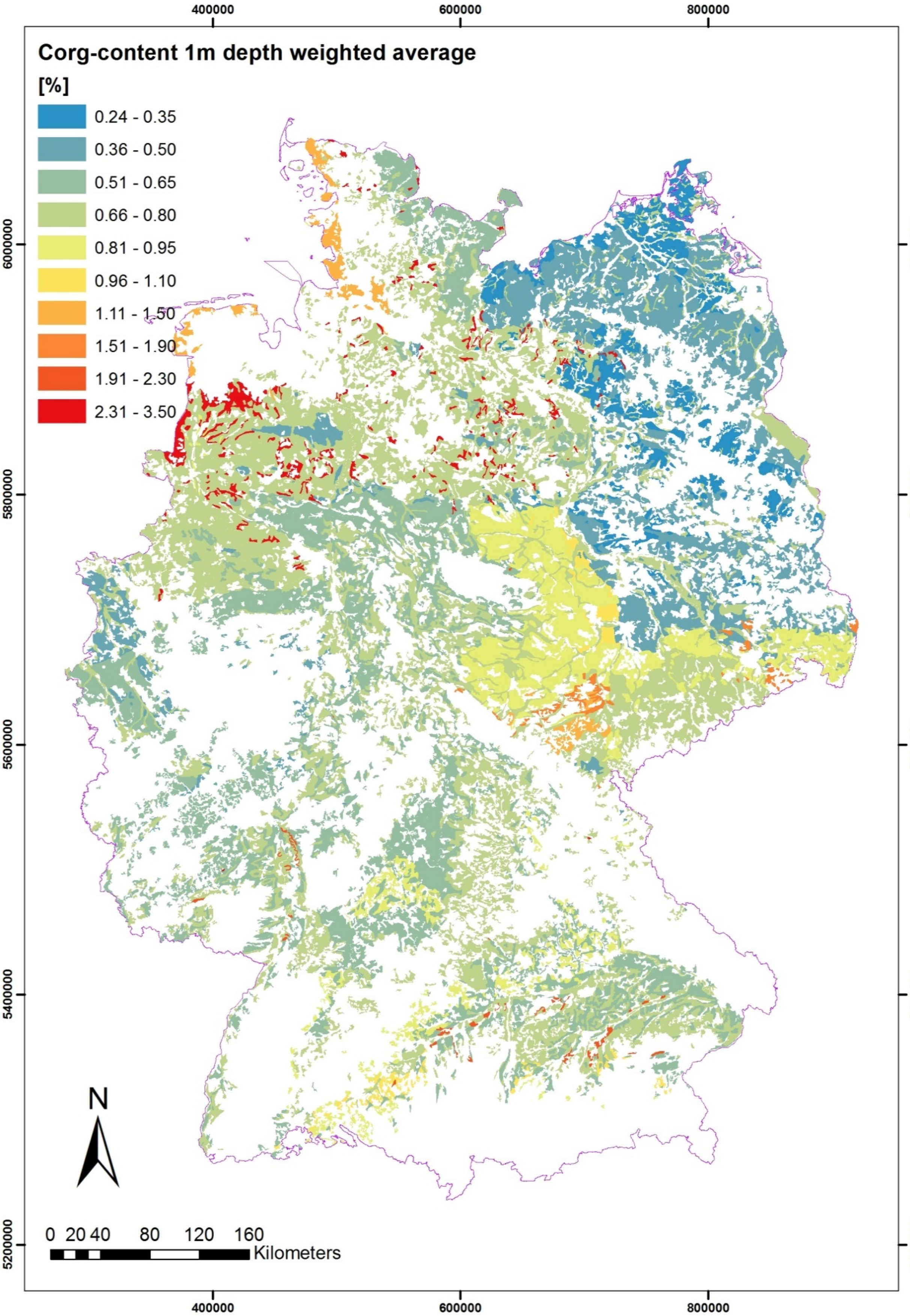


Figure 3-51: Soil C_{org}-content (1m depth weighted average; Düwel et al., 2007 & Utermann et al., 2009) at soils with arable land use (according to BÜK 1000 N)

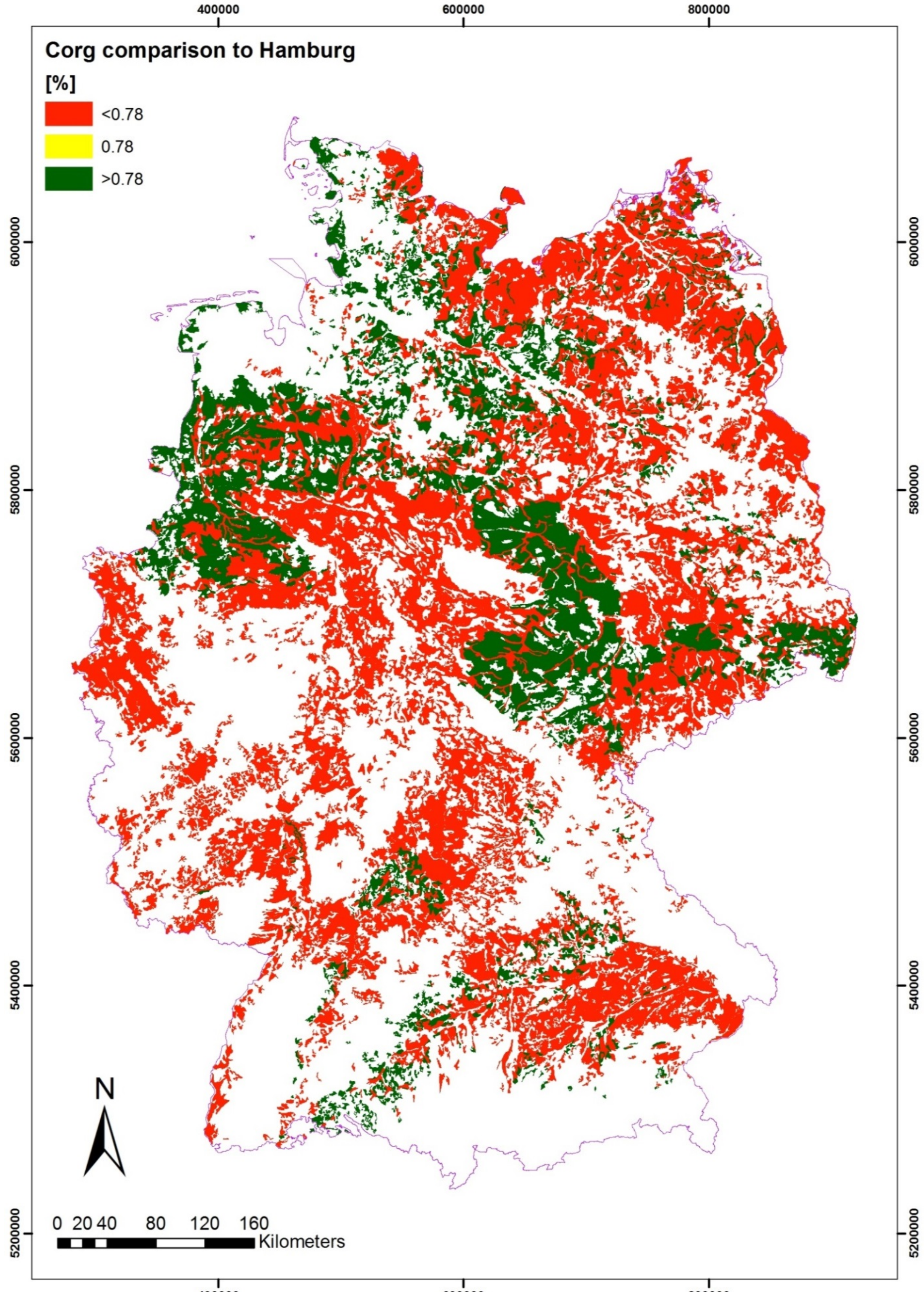


Figure 3-52: Comparison of the soil C_{org}-content (1 m depth weighted average; Düwel et al., 2007 & Utermann et al., 2009) with the FOCUS GW-scenario "Hamburg"

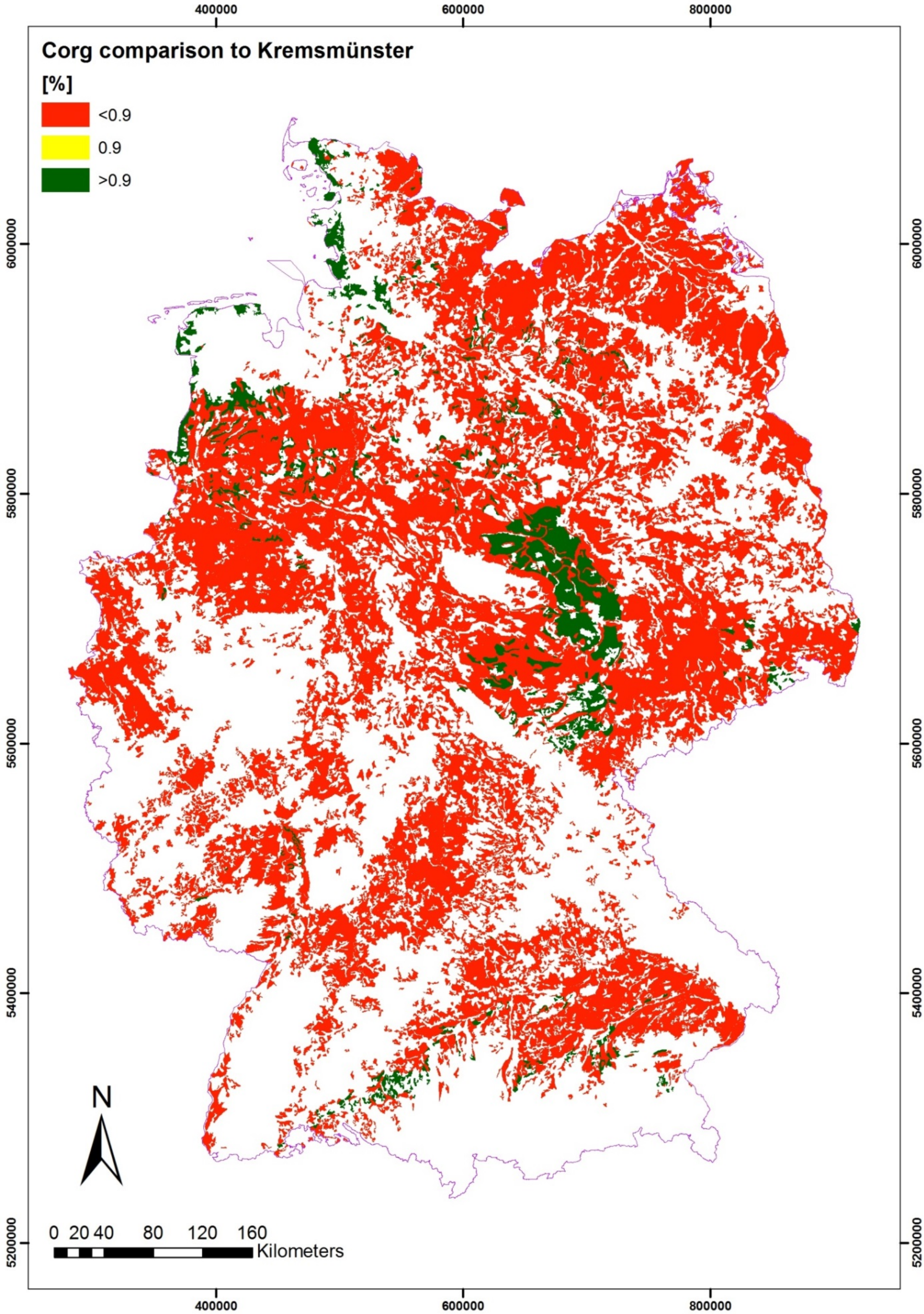


Figure 3-53: Comparison of the soil C_{org}-content (1 m depth weighted average; Düwel et al.. 2007 & Utermann et al., 2009) with the FOCUS GW-scenario “Kremsmünster”

Figure 3-51 shows the 1 m depth weighted average of the C_{org} content in soils with arable land use type (according to BÜK 1000 N; updated according to Düwel et al., 2007 & Utermann et al., 2009). The lowest C_{org}-values are mostly located in the northeastern part of the North German Lowland. The highest C_{org}-values can be found on peat soils, which can be found all over the North German Lowland in locally small occurrence.

Figure 3-52 and Figure 3-53 illustrate the comparison of the 1 m depth weighted C_{org}-content with the C_{org}-contents of the FOCUS scenarios “Hamburg” and “Kremsmünster” (also 1 m depth weighted). Only a relatively small part of the soils with arable land use has a higher C_{org}-content than the scenarios and therefore a lower leaching potential for PPP.

The results show that – different than generally assumed – the soil profile of the FOCUS Hamburg scenario is not a worst case concerning the C_{org}-content, if related to the depth weighted average over one meter.

Because the leaching tendency is essentially influenced by the carbon content of the top soil, since there the most important degradation and adsorption processes are going on, an additional analysis for this parameter regarding the distribution of the carbon content in the first horizon compared to the FOCUS-scenarios was conducted.

3.2.3.2 C_{org}-content (related to the 1st horizon)

Figure 3-54 shows the cumulative spatial distribution function concerning the C_{org}-content of the first soil horizon of the soils with arable land use type. The examination was also conducted with modified BÜK N 1000 C_{org}-values (see chapter 3.2.1.3). The results show that concerning the organic carbon content in the top soil layer the standard soil of the FOCUS Hamburg scenario represents a 100 % -44 % = 56 % medium-case. Whereas only on 14 % of the areas with arable land use in Germany a higher carbon content than at “Kremsmünster” can be found. Therefore the scenario can’t be considered as a worst-case scenario concerning this parameter.

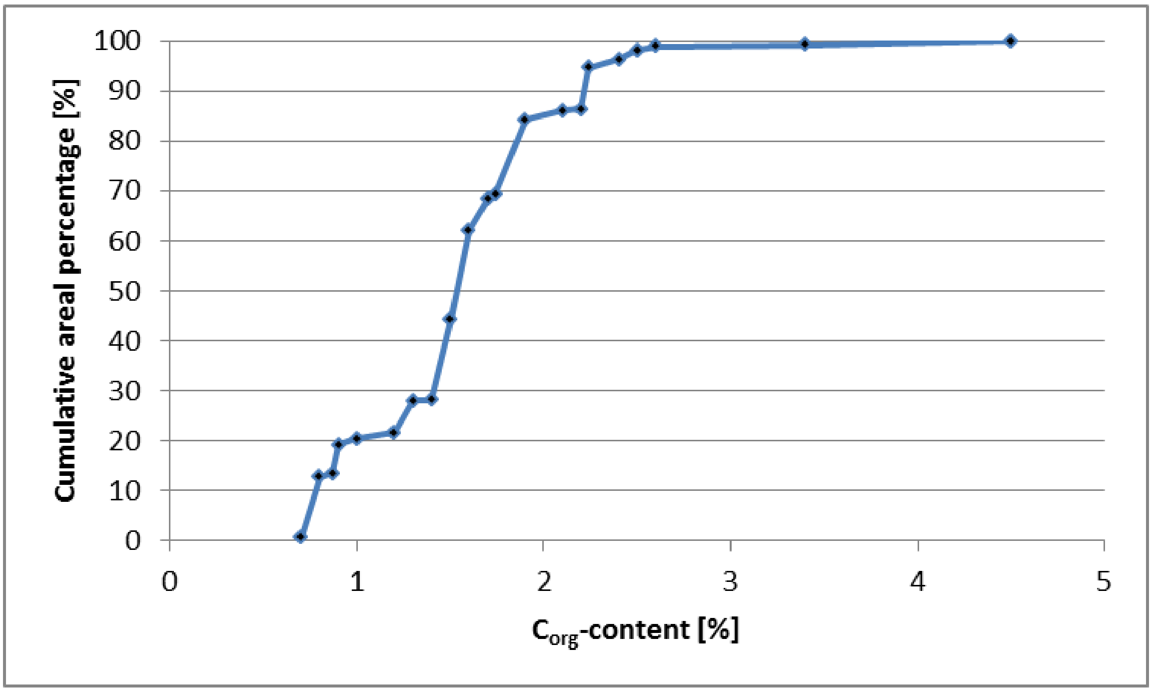


Figure 3-54: Cumulative distribution function concerning C_{org}-content (only 1st horizon; Düwel et al., 2007)

Table 3-23: Overview of the spatial analysis concerning soil C_{org}-content (1st horizon; Düwel et al., 2007)

Germany-wide			Hamburg		Kremsmünster	
10th percentile [%]	50th percentile [%]	90th percentile [%]	[%]	Cum. area percent-age [%]	[%]	Cum. area percentage [%]
0.8	1.6	2.24	1.5	44.3	2.1	86.1

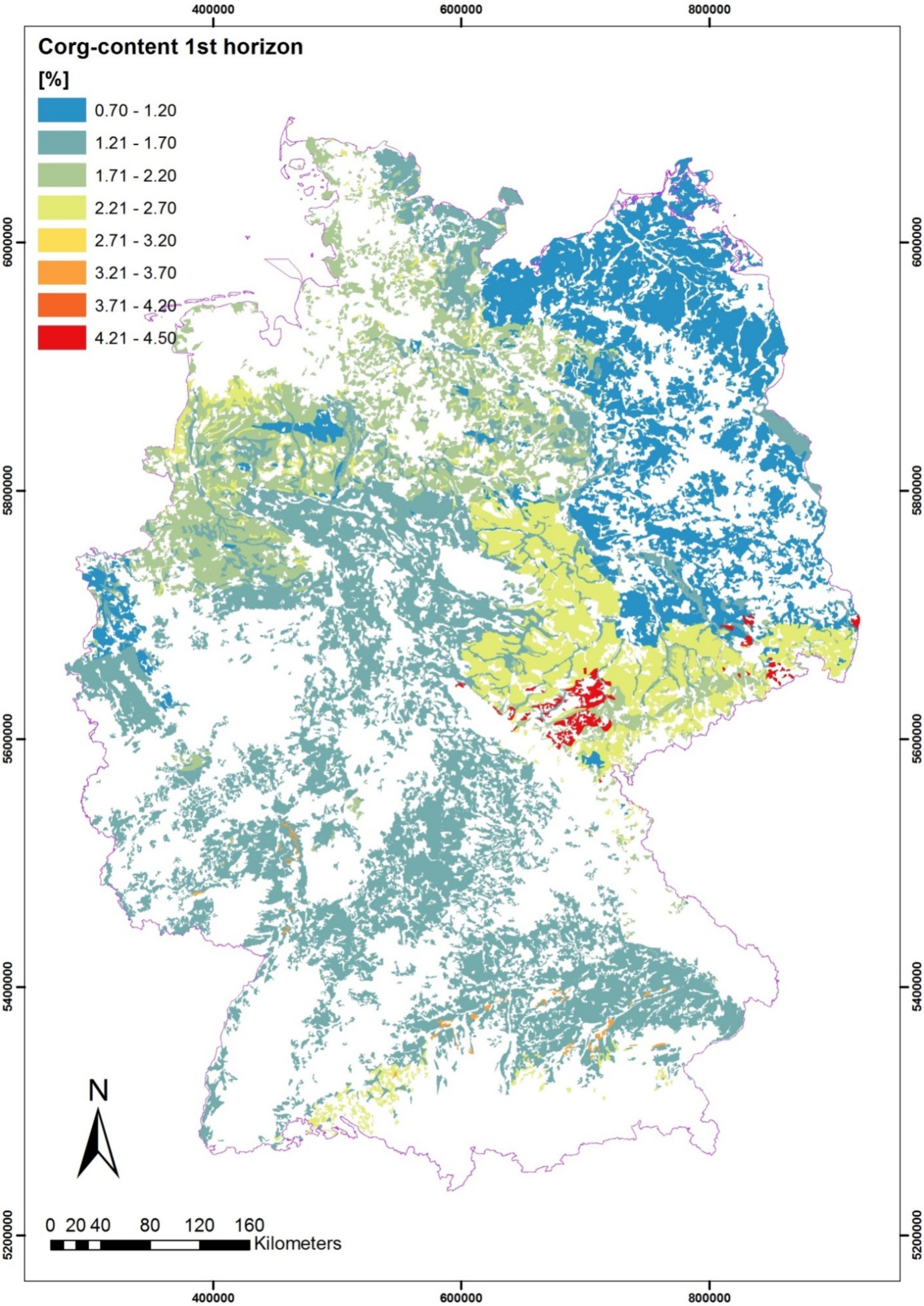


Figure 3-55: Soil C_{org} content (1st horizon; Düwel et al., 2007) at soils with arable land use (according to BÜK 1000N)

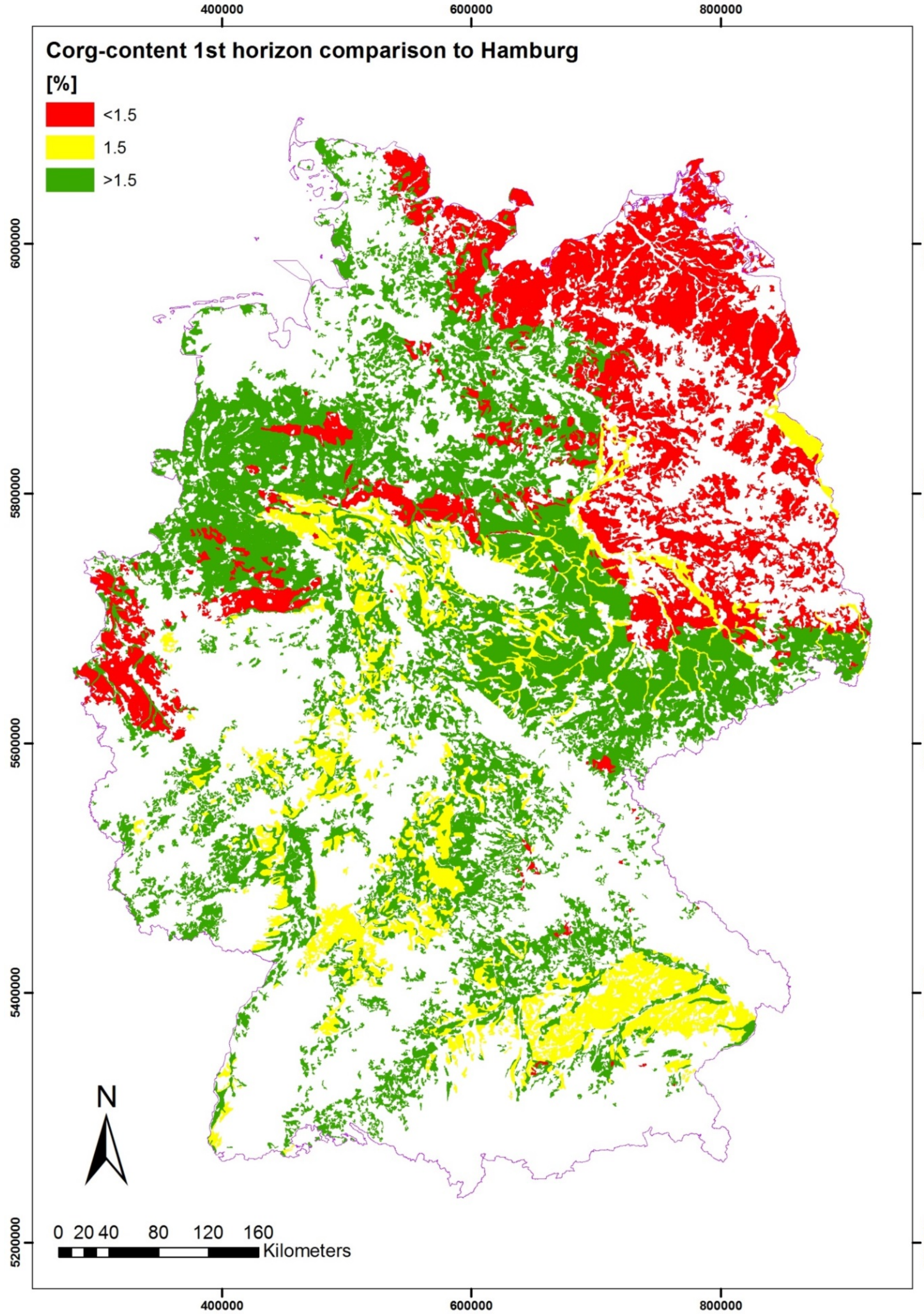


Figure 3-56: Comparison of the soil C_{org}-content (1st horizon; Düwel et al., 2007) with the FOCUS GW-scenario "Hamburg"

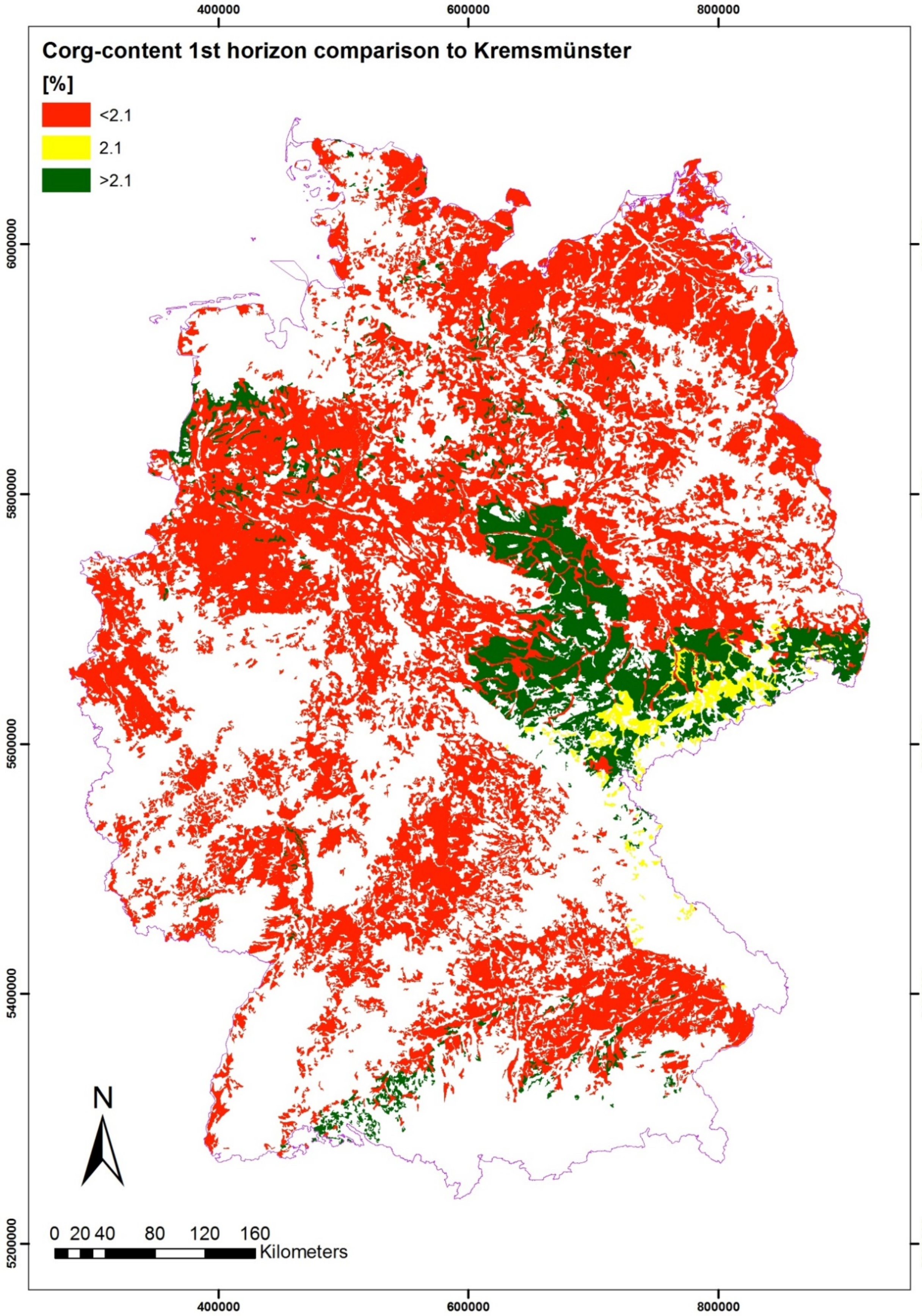


Figure 3-57: Comparison of the soil C_{org}-content (1st horizon; Düwel et al., 2007) with the FOCUS GW-scenario "Kremsmünster"

Figure 3-55 shows the cartographic illustration of the C_{org}-content in the 1st horizon (Düwel et al., 2007) of soils with arable land use (according to BÜK 1000 N). The lowest C_{org}-contents are again localized predominantly in the northeastern part of the North German Lowland, the highest appear in the Thuringian basin, most parts of the Saxonian uplands, in the northern and eastern Harz foreland, the Magdeburger Börde and in peat soils, which can be found in small regions distributed all over the western North German Lowland.

Figure 3-56 and Figure 3-57 show the comparison of the C_{org}-content in the 1st horizon with the soil parametrisation of the FOCUS scenarios “Hamburg” and “Kremsmünster”. Figure 3-56 illustrates the medium-case character of the scenario “Hamburg”. About half of the areas have a lower C_{org}-content than this scenario and therefore are more vulnerable concerning this leaching parameter. Figure 3-57 shows the best-case character of the scenario “Kremsmünster” concerning the C_{org}-content in the top soil. Except 14 % the agricultural areas in Germany show a lower C_{org}-content than this scenario.

3.2.3.3 pH-value (1 m depth weighted)

Figure 3-58 shows the cumulative distribution function concerning the pH-value depth weighted over 1 m. On the soils with arable land use type seven different soil reaction classes can be found. The values resulting from the average calculation are marked with black dots on the distribution curve. If pesticides can be classified as weak acids they usually sorb well in acid soils and sorb less in basic soils. The FOCUS scenario “Hamburg” cannot be considered a worst-case for such substances, since 100 % - 33 % = 67 % of the arable areas in Germany have more alkaline soils (thus more vulnerable than the scenario “Hamburg”). The scenario “Kremsmünster” in contrast is an 89 % worst-case, because only on 100 % - 89 % = 11 % of the areas the soils are more alkaline.

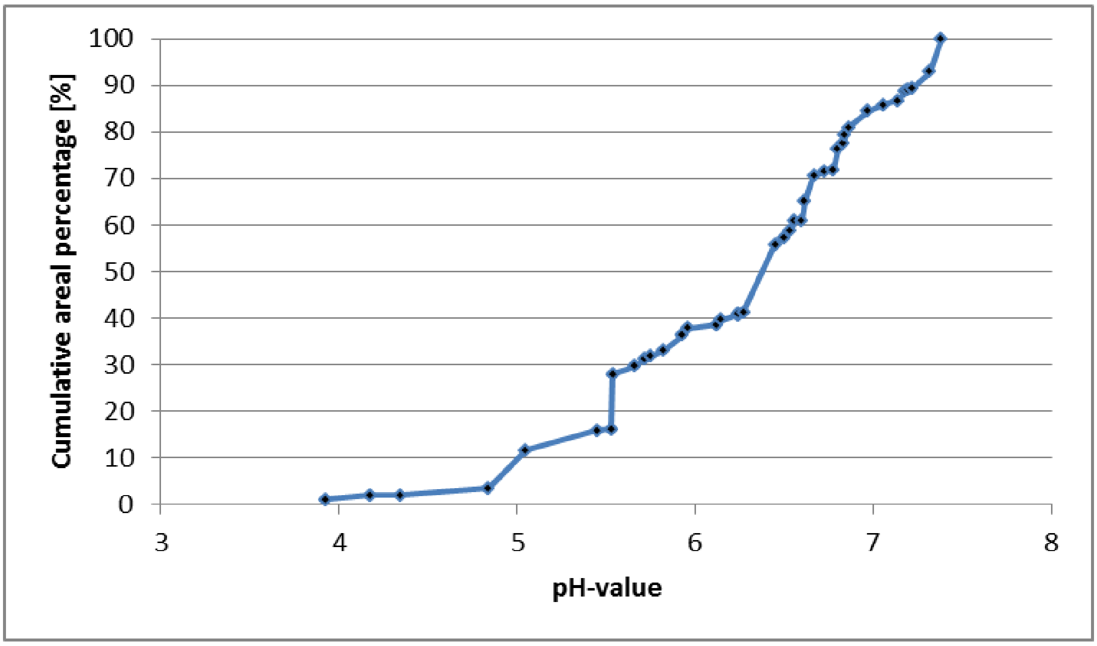


Figure 3-58: Cumulative spatial distribution function concerning the soil pH-value (according to BÜK 1000 N)

Table 3-24: Overview of the spatial analysis concerning soil pH-value (according to BÜK 1000 N)

Germany-wide			Hamburg		Kremsmünster	
10th percentile pH-value	50th percentile pH-value	90th percentile pH-value	pH-value	Cum area percentage. [%]	pH-value	Cum area percentage. [%]
5.05	6.45	7.32	5.845	33	7.26	89.2

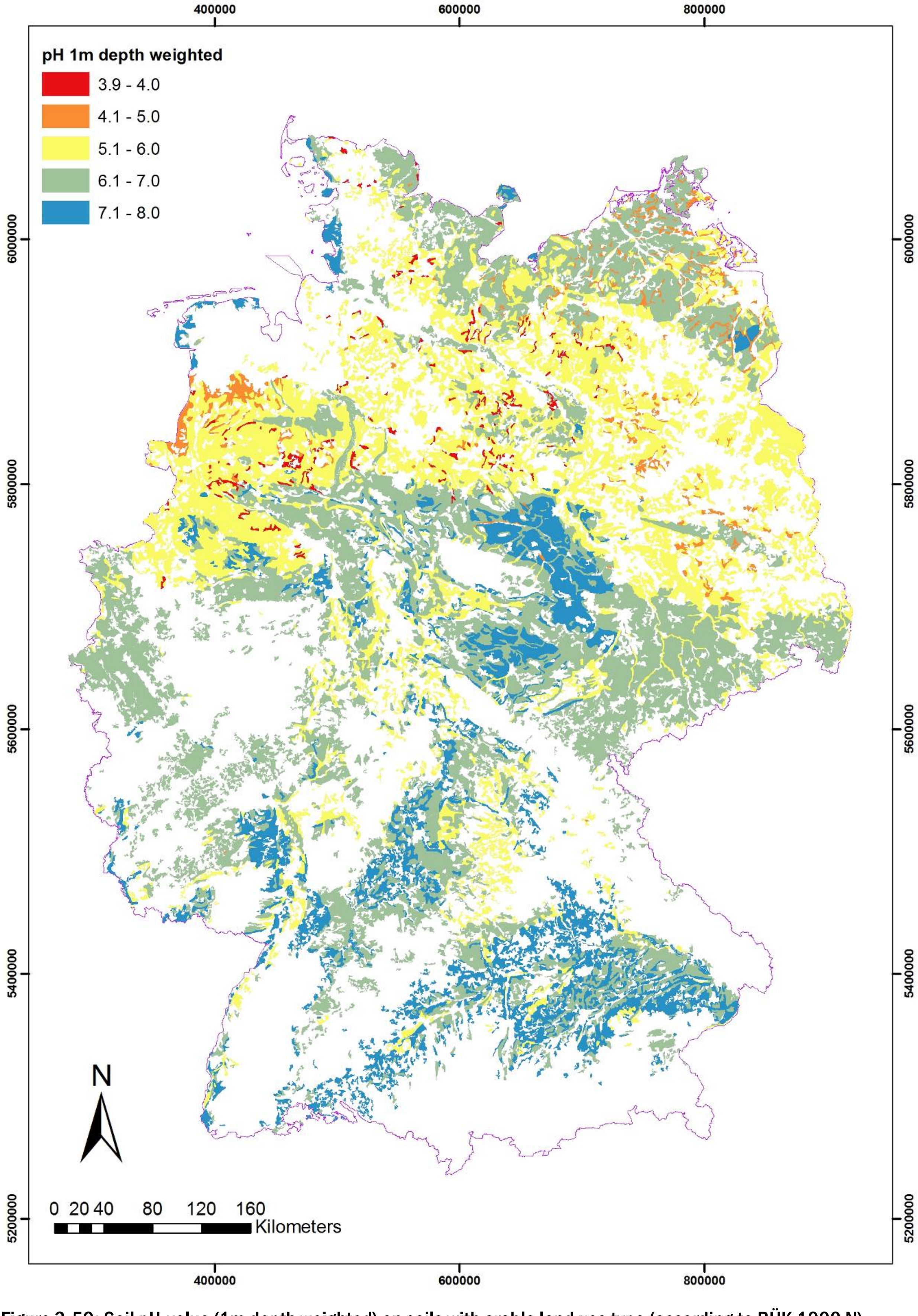


Figure 3-59: Soil pH-value (1m depth weighted) on soils with arable land use type (according to BÜK 1000 N)

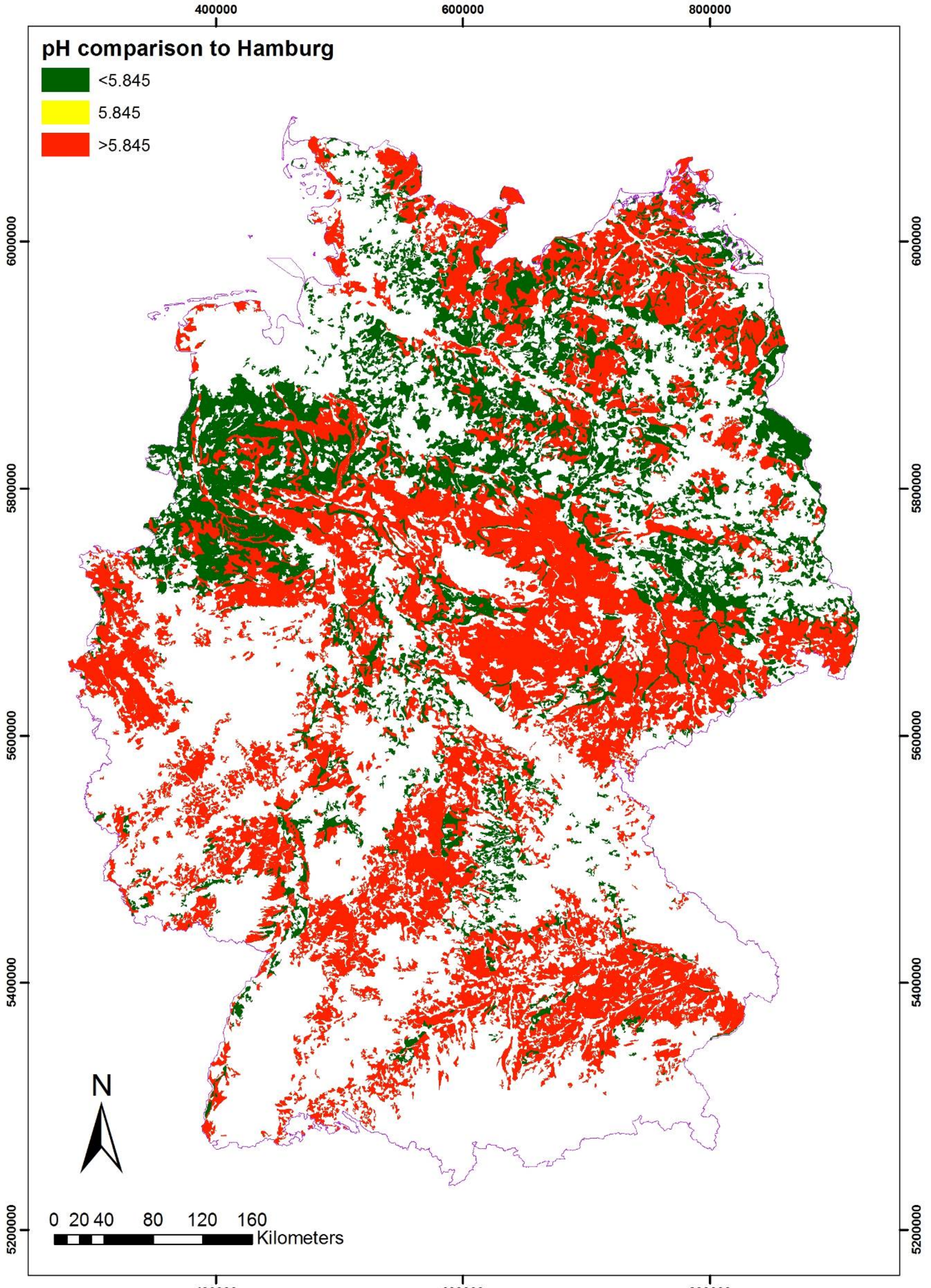


Figure 3-60: Comparison of the soil pH-value (1m depth weighted; according to BÜK 1000 N) with the FOCUS GW-scenario “Hamburg“

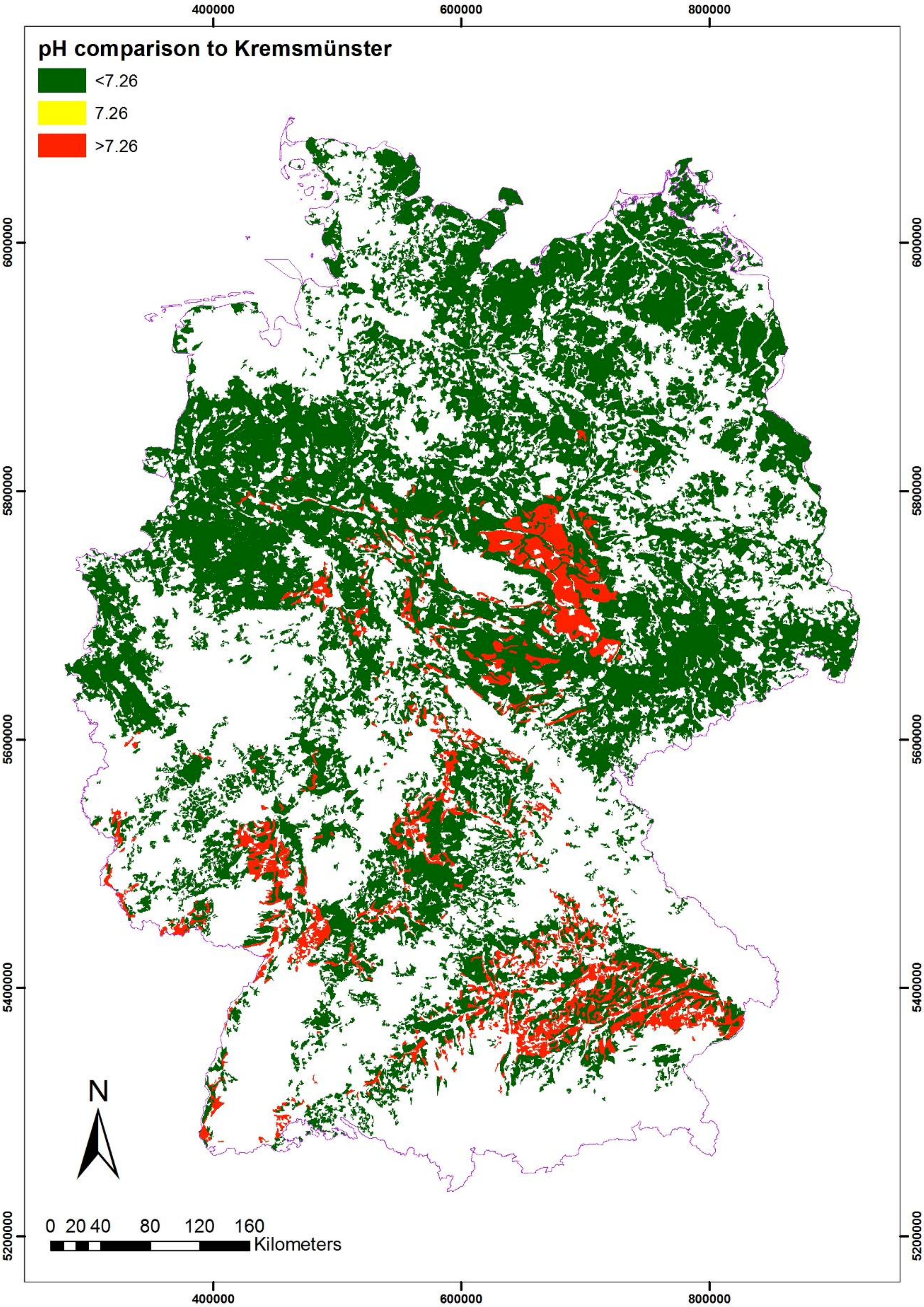


Figure 3-61: Comparison of the soil pH-value (1m depth weighted; according to BÜK 1000 N) with the FOCUS GW-scenario "Kremsmünster"

Figure 3-59 shows the cartographic illustration of the 1 m depth-weighted pH-value of soils with arable land use type (according to BÜK 1000 N). The lowest pH-values can be found on peat soils in the North German Lowland. The highest pH-values are located in the so called Lössbörden north and east of the Harz Mountains, in Rhine Hesse, parts of the South German Scarplands or the Alpin foreland.

Figure 3-60 and Figure 3-61 show the comparison of the soil pH-values of the soils with arable land use type with the soils of the scenarios “Hamburg” and “Kremsmünster”, respectively. Figure 3-60 illustrates that the scenario “Hamburg” is not a worst-case concerning this soil parameter, since around two thirds of the areas are represented by more alkaline soils. In contrast Figure 3-61 shows that the scenario “Kremsmünster” is a worst-case, because only around 10 % of the reference area has a higher pH-value in soil.

3.2.3.4 Kf-value (1 m depth weighted)

Figure 3-62 shows the cumulative spatial distribution function concerning the 1 m depth weighted saturated water permeability. On soils with arable land use type five different permeability classes occur. The resulting values from the average calculation are marked with black dots in the distribution curve. Concerning the parameter saturated water permeability the scenario “Hamburg” is a worst-case, the scenario “Kremsmünster” is a medium case. However this parameter is not considered in the model PELMO. Instead it is generally assumed, that the water permeability doesn’t limit the water movement in soil.

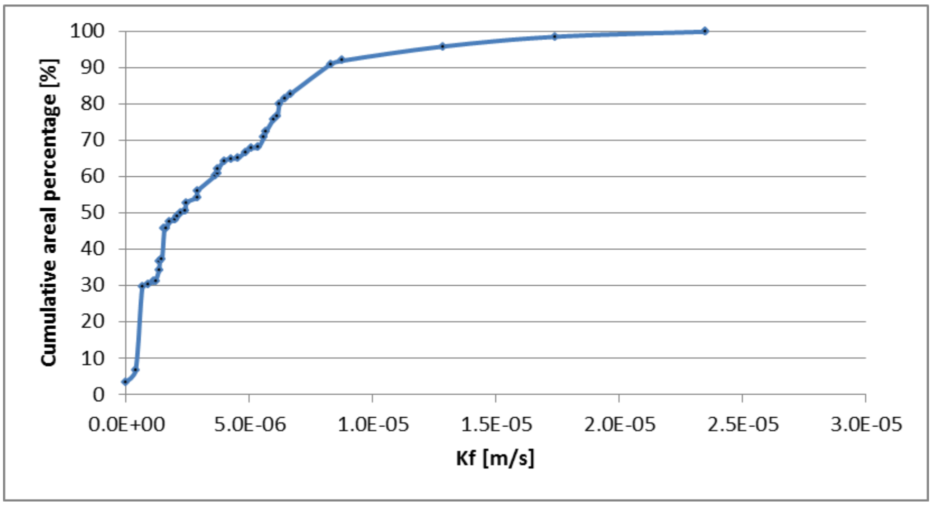


Figure 3-62: Cumulative spatial distribution function concerning the Kf-value (according to BÜK 1000 N)

Table 3-25: Overview of the spatial analysis concerning the Kf-value (according to BÜK 1000 N)

Germany-wide			Hamburg		Kremsmünster	
10th percentile [m/s]	50th percentile [m/s]	90th percentile [m/s]	[m/s]	Cum. area percentage [%]	[m/s]	Cum. area percentage [%]
6.60E-07	2.23E-06	8.30E-06	2.78E-05	100	2.32E-06	50.1

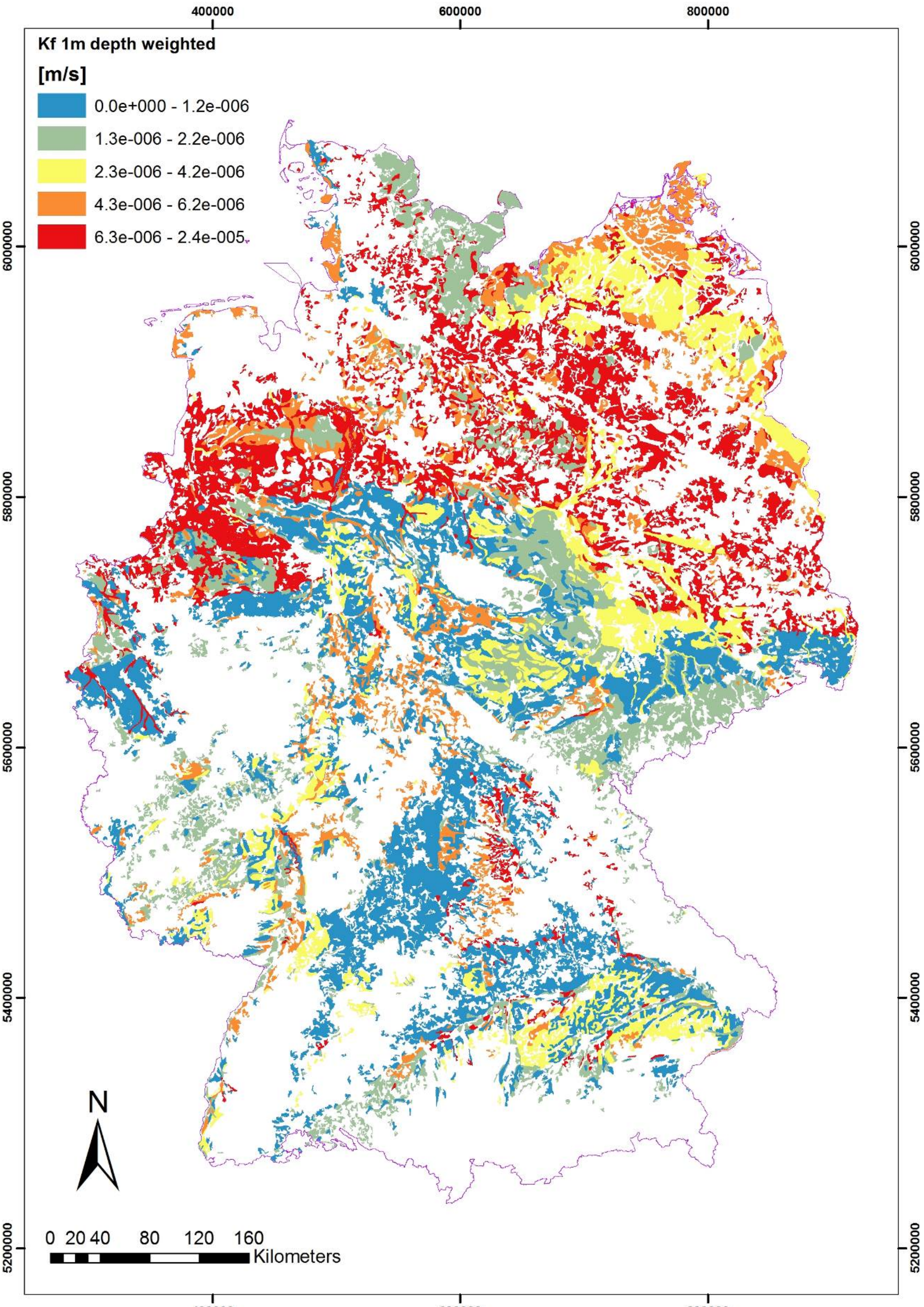


Figure 3-63: Kf-value (1m depth weighted) on soils with arable land use type (according to BÜK 1000 N)

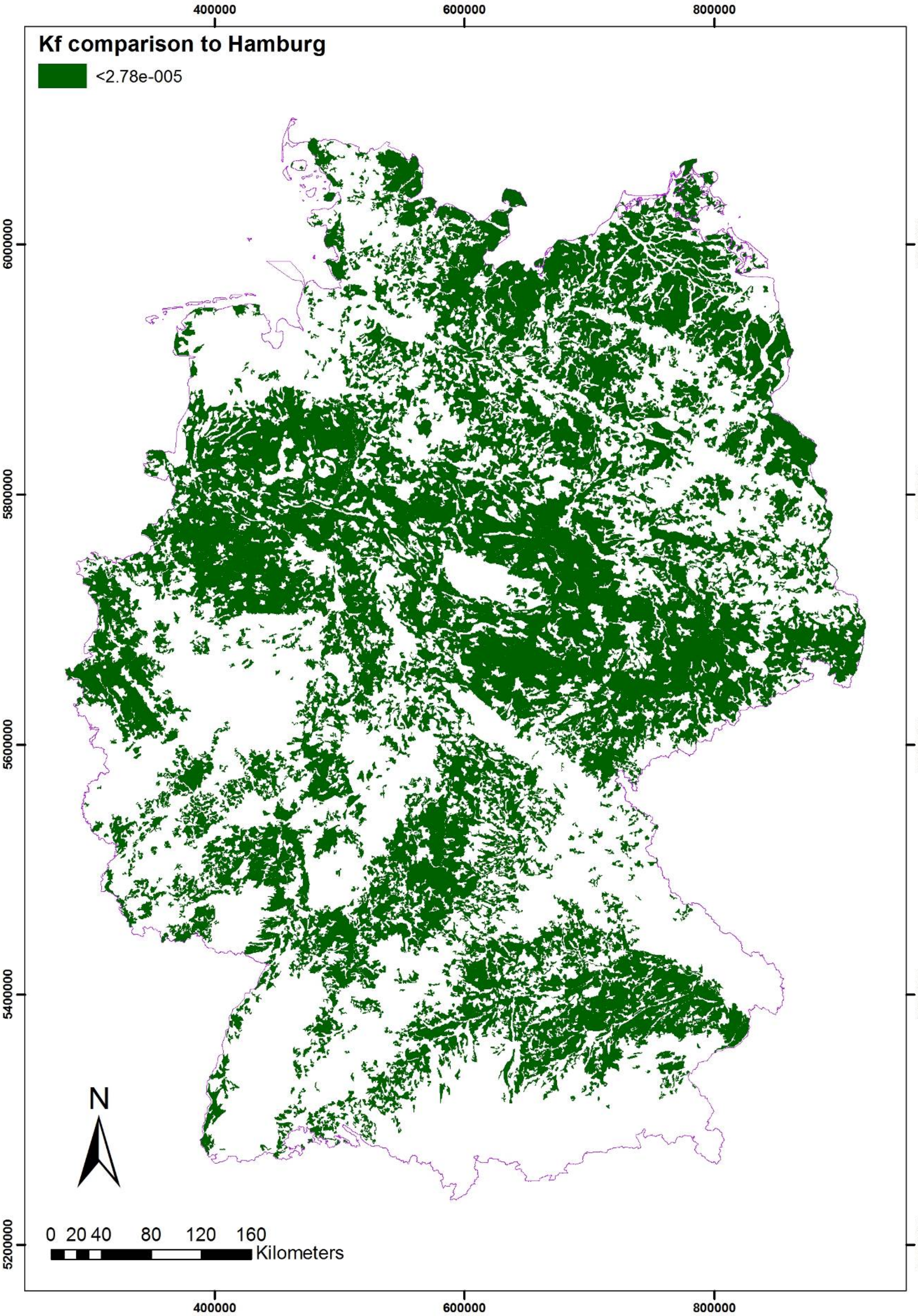


Figure 3-64: Comparison of the Kf-value (1 m depth weighted average; according to BÜK 1000 N) with the FOCUS GW-scenario „Hamburg"

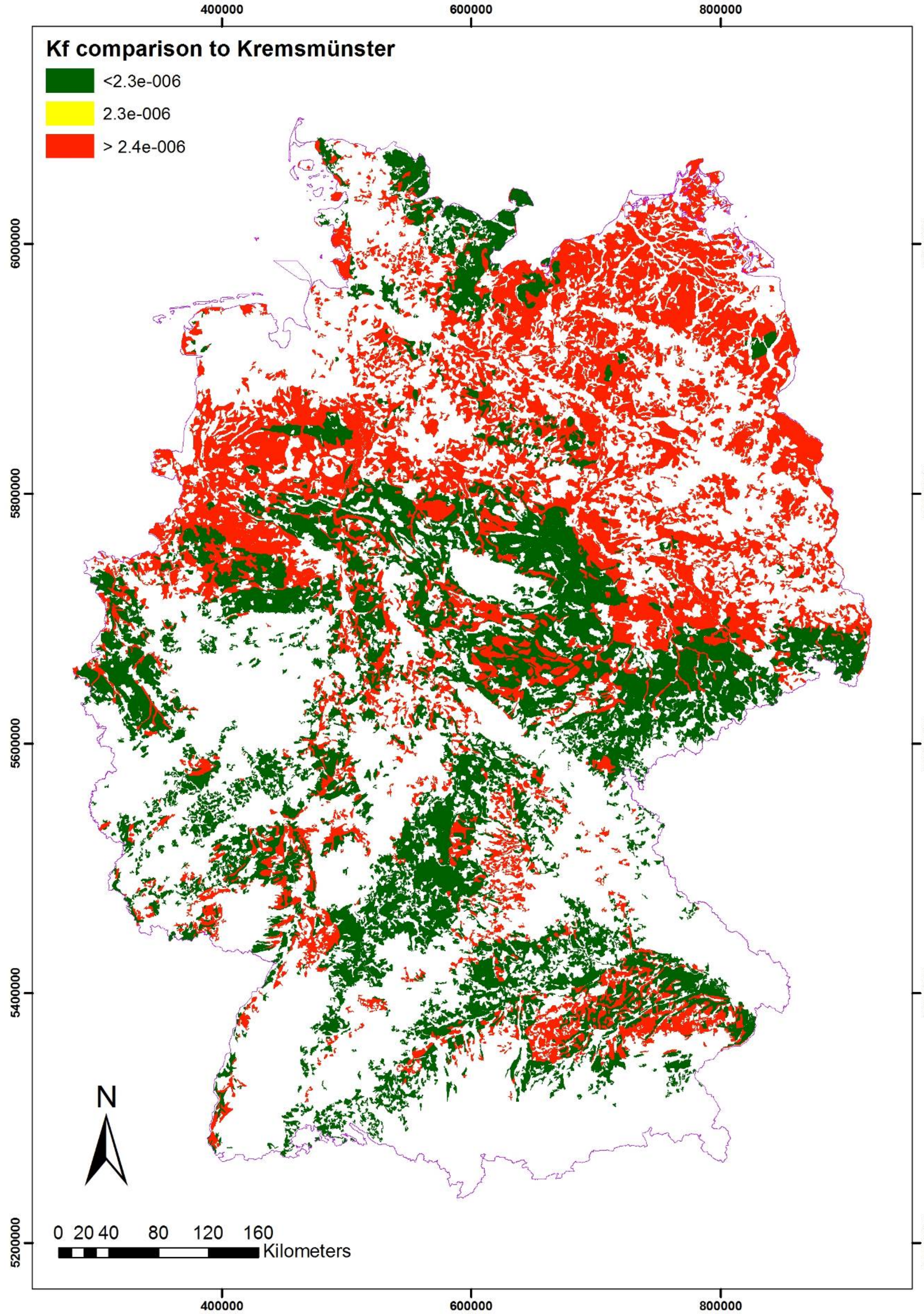


Figure 3-65: Comparison of the Kf-value (1 m depth weighted average, according to BÜK 1000 N) with the FOCUS GW-scenario „Kremsmünster“

Figure 3-63 shows the cartographic illustration of the saturated water permeability on soils with arable land use type (according to BÜK 1000 N). The highest Kf-values are located in the most parts of the North German Plain. Low Kf-values occur for example in the Cologne Bay, the Kraichgau and parts of the South German Scarplands.

Figure 3-64 and Figure 3-65 show the comparison of the saturated permeability on soils with arable land use type with the scenarios „Hamburg“ and „Kremsmünster“, respectively. Figure 3-64 illustrates the absolute worst-case character of the scenario "Hamburg" concerning this soil parameter, there's no area with a higher Kf-value. Figure 3-65 shows the medium-case character of the scenario "Kremsmünster" concerning the saturated water permeability. Half of the reference area has a lower the other half a higher Kf-value.

3.2.3.5 Field capacity (1 m depth weighted)

Figure 3-66 shows the cumulative spatial distribution function of the 1 m depth weighted field capacity on soils with arable land use type. Low field capacities in general lead to an increased water movement in soil, because the storage capacity for water in soil is limited. Concerning this parameter the soil of the FOCUS Hamburg scenario can be considered as a 100 % - 18.6 % = 81.4 % worst-case. This is not the case for the scenario "Kremsmünster" whose soil profile has a higher storage capacity because of the higher field capacity.

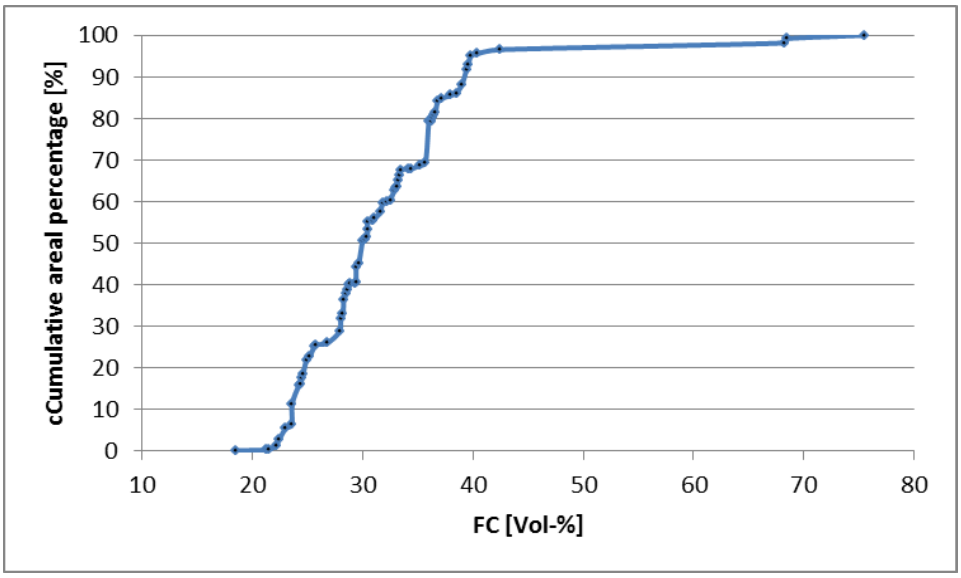


Figure 3-66: Cumulative spatial distribution function concerning the field capacity (1 m depth weighted average, according to BÜK 1000 N)

Table 3-26: Overview of the spatial analysis concerning the field capacity (1 m depth weighted average, according to BÜK 1000 N)

Germany-wide			Hamburg		Kremsmünster	
10th percentile [Vol-%]	50th percentile [Vol-%]	90th percentile [Vol-%]	[Vol-%]	Cum. area percentage [%]	[Vol-%]	Cum. area percentage [%]
23.6	30	39.4	24.6	18.59	35.4	68.7

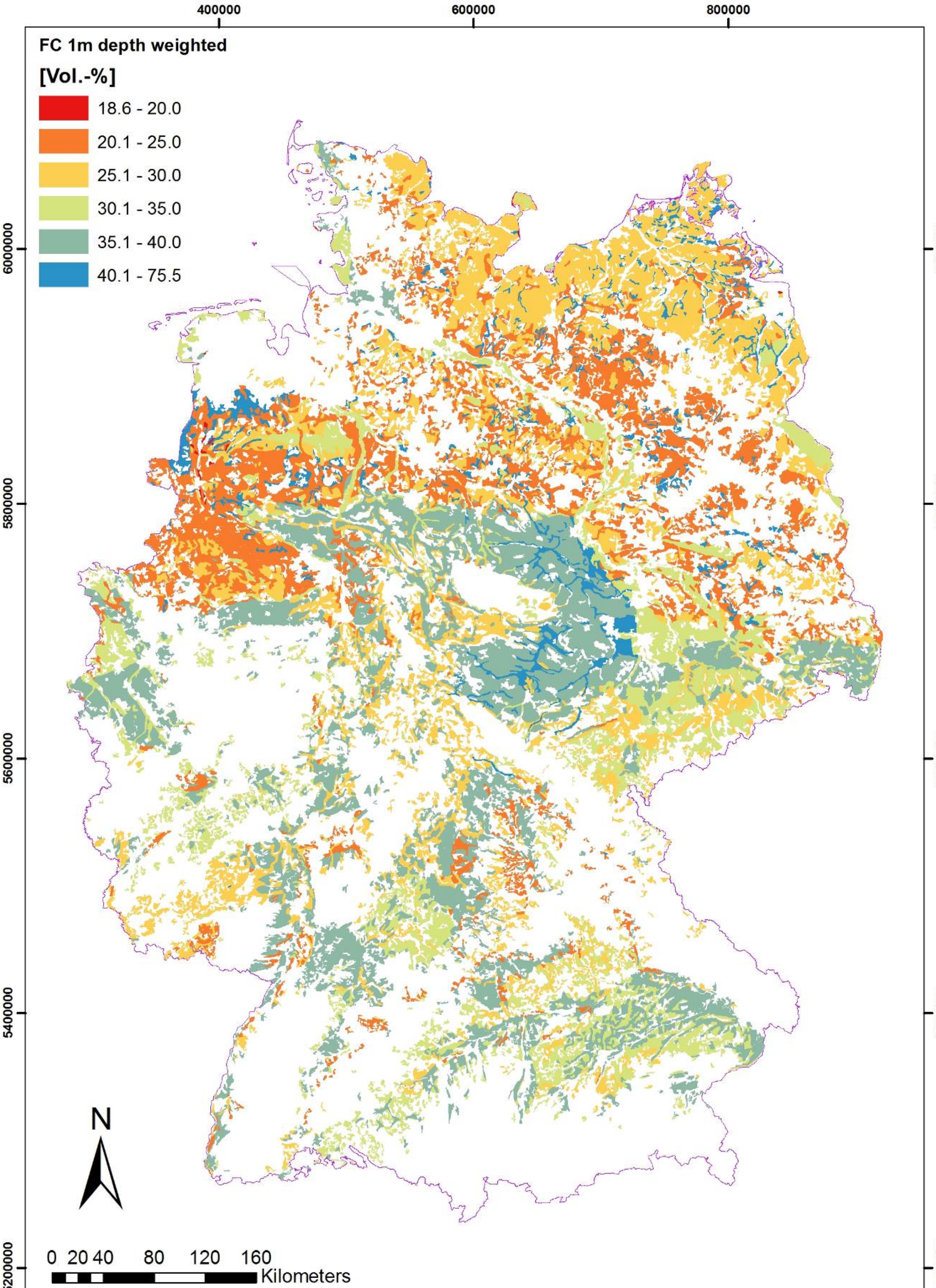


Figure 3-67: Field capacity (1 m depth weighted average) on soils with arable land use type (according to BÜK 1000 N)

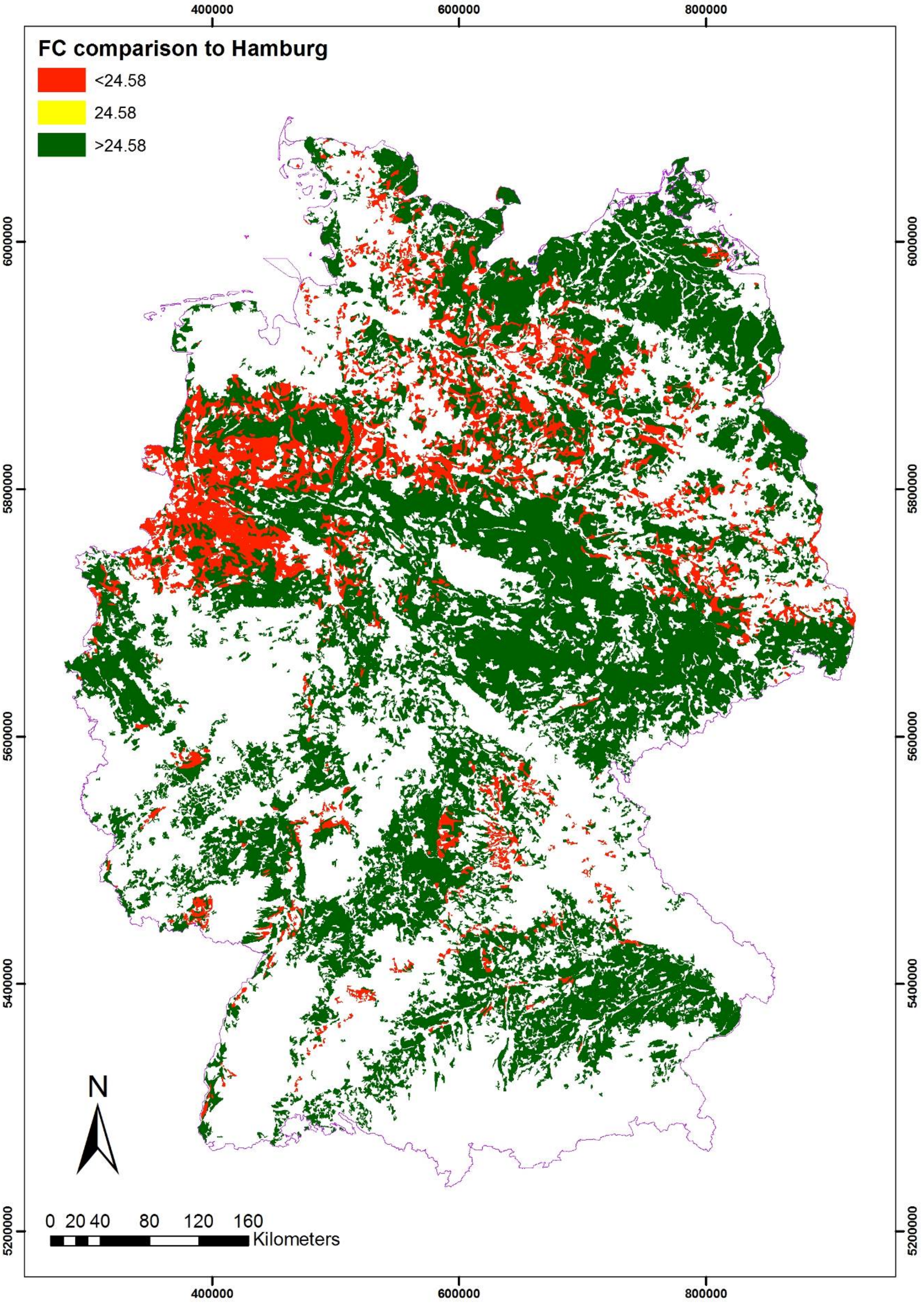


Figure 3-68: Comparison of the field capacity (1 m depth weighted average, according to BÜK 1000 N) with the FOCUS GW-scenario „Hamburg“

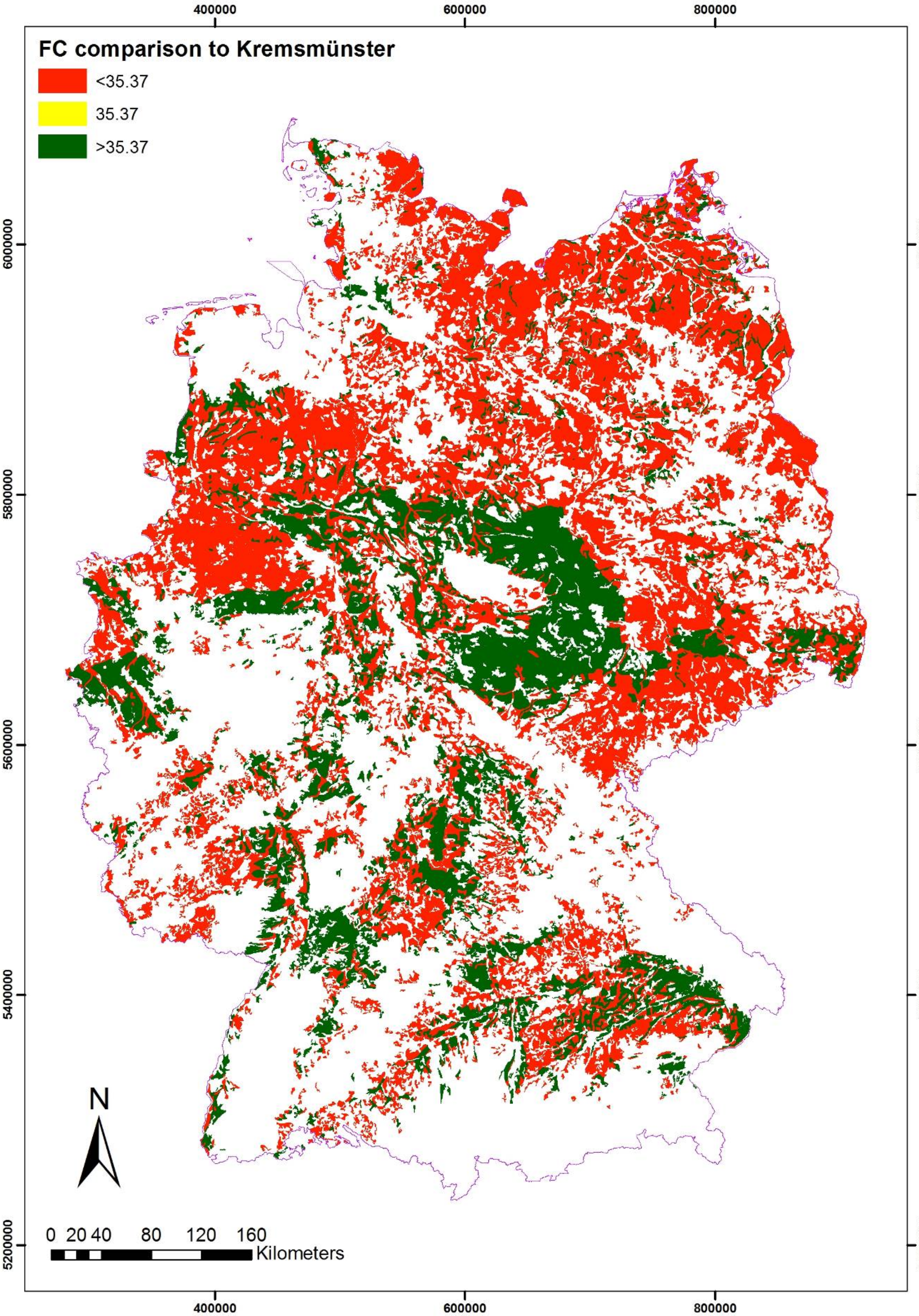


Figure 3-69: Comparison of the field capacity (1 m depth weighted average, according to BÜK 1000 N) with the FOCUS GW-scenario „Kremsmünster“

Figure 3-67 shows the cartographic illustration of the 1 m depth weighted field capacity of the soils with arable land use type (according to BÜK 1000 N). Low field capacities are located in most parts of the North German Lowland. High field capacities occur for example in the Lössbörden north and east of the Harz Mountains.

Figure 3-68 and Figure 3-69 show the comparison of the field capacity with the scenarios „Hamburg“ and „Kremsmünster“, respectively. Figure 3-68 illustrates the worst-case character of the scenario "Hamburg" concerning this soil property. Around 25 % of the reference area show a lower field capacity. Figure 3-69 shows, that this is not the case for the scenario "Kremsmünster": a bit more than two thirds of the reference area are characterised by a lower field capacity.

3.2.3.6 Summary of the results concerning the analysis of soil parameters

In the previous chapters the analysis of each soil parameter was explained in detail. Aim of this examination was to find out the worst-case character of the FOCUS Hamburg and Kremsmünster groundwater scenarios concerning their soil properties with regard to the leaching potential of plant protection products in Germany. Since the scenarios show both worst and best case properties no clear pictures can be stated.

The Hamburg soil is not a worst case regarding the C_{org}-content 1m-depth weighted average. Major parts of the arable land in Germany (73 %) show a lower C_{org}-content than Hamburg. Higher C_{org}-contents are only found in the northern and eastern Harz foreland together with the Magdeburger Börde, the Franconian Jura, further parts of the South German Scarplands, parts of the North German Plains and other areas of smaller extent. But looking at the C_{org}-content of the 1st soil horizon the Hamburg soil can be considered as a medium case since 44 % of the relevant soils own a lower C_{org}-content in that horizon. Such soils are located mainly in northeastern Germany, parts of the Hessian and the South German Scarplands and small parts of the Westphalian basin.

Regarding the pH-value the Hamburg soil scenario is not a worst-case, because 67 % of the arable land own a higher and therefore more unfavorable pH-value for the leaching of compounds which show pH dependent sorption like e.g. weak acids. These areas can be found all over Germany except great parts of the North German Plains and some parts of the central German uplands.

In case of the saturated water permeability value Hamburg is a clear worst-case since the complete area with arable land use shows lower Kf-values. Actually that's a finding with no significance because the Kf-value is not included in the PELMO-software.

The analysis of the field capacity showed the worst-case parametrisation of the Hamburg scenario for that parameter. In only about 19 % of the relevant areas a lower field capacity than Hamburg was observed. These areas are located mainly in the western part of the North German Plains, other smaller parts of the North German Plains and in areas of smaller extend in southern Germany. However, the crucial parameter in PELMO is the available field capacity because soil moisture is never calculated below wilting point.

The Kremsmünster soil shows clearly best-case characteristics for the C_{org}-content both for the 1m depth weighted average and the 1st soil horizon. Around 92 % or 86 % of the regarded area respectively own lower C_{org}-contents.

Looking at the pH-value Kremsmünster can be stated as a worst case for weak acids. Only 11 % of the areas with arable land use show higher pH-values. That's the case for the northern and eastern Harz foreland, parts of the northern Rhine Rift Valley and of the Alpine foreland for example.

Regarding the saturated water permeability Kremsmünster is a medium case, since 50 % of the investigated area has more unfavorable Kf-values, like great parts of northern Germany and parts of the central German uplands, of the northern Rhine Rift Valley and of the Alpine foreland.

Finally looking at the field capacity the Kremsmünster soil is a tendential best case scenario because about 69 % of the relevant areas show lower field capacities which may result in reduced leaching for the FOCUS scenario. Such areas are located all over Germany excepted the Lössbörden, parts of the South German Scarplands, of the Hessian Uplands, of the Alpine foreland, of the Lower Rhine region and of the Rhine Rift Valley. PELMO uses the available field capacity to calculate the PEC in groundwater.

As the main conclusion it can be stated that the Kremsmünster soil is only a worst-case scenario concerning the pH-value and therefore it's not surprising that this scenario often shows lower PEC_{gw} calculations than Hamburg.

3.3 Development of GISPELMO to be used for the step 2 analysis

3.3.1 Introduction

The previously described Step 1 analysis showed that the distribution of organic carbon in soil in Germany compared to the soil profile of the FOCUS Hamburg scenario with a C_{org}-content of 1.5 % could be described as a medium case scenario (44 % of the German soils show lower organic carbon contents in the top horizon than the FOCUS Hamburg soil. However, the related depth weighted organic carbon content was found to be far away from realistic worst case values (72.8 % of German soils showed lower 1 m-averaged organic carbon content than considered in the FOCUS Hamburg soil profile).

The overall vulnerability properties of the FOCUS Hamburg scenario should not be evaluated only based on soil and climate properties especially as the unfavourable annual rainfall (62.3 % worst case) also contributes to the overall performance of the FOCUS scenario. Furthermore, the quality of scenarios cannot be discussed completely independent of other important model parameters such as application pattern, substance properties or crop type.

In order to base this conclusion on a more profound argumentation, a second evaluation was performed where the leaching model PELMO was combined with geo-referenced data. A process-based leaching model for the agricultural area in Germany was developed to describe the protection level of the FOCUS Hamburg scenario dependent on application time and important pesticide parameters such as degradation and sorption.

In the following section the development of this new computer tool based on PELMO is described.

3.3.2 Linking geographic information to PELMO

In order to combine PELMO with the geo-referenced information from german-wide thematic maps an approach was followed similar as the methodology realised in GeoPEARL (Tiktak et al., 2003) and GeoPEARL_DE (Bangert, 2007).

The following data was used:

Point related soil and climate information:

The soil profile parametrisation was based on the soil profiles from the BÜK 1000 N, land use type arable land. The total number of soil profiles in this data base is 129 including variances for different major climatic regions in Germany.

In contrast to the FOCUS PELMO Hamburg scenario most of the soil profiles of the original BÜK 1000 N show organic carbon contents of 0 already in the second soil horizon. That has a significant impact on the leaching behaviour. As it did not seem reasonable that the organic matter class h0 is widely found already at soil depths of about 50 cm the original C_{org}-contents were replaced by more recent results of Düwel et al. (2007) and Utermann et al. (2009). This is explained in more details in chapter 3.2.1.3.

Apart from soil properties daily weather information is necessary for PELMO simulations. Instead of using the database MARS (as it was done for defining the FOCUS scenarios) information from the German weather service DWD (Deutscher Wetterdienst) was considered. In total 299 different weather stations (DWD, 2012) were selected for which daily temperature, relative humidity, and precipitation were available over the period 1985-2010 (26 years).

Unfortunately, not for all these weather stations daily evapotranspiration data was available, too. If this information was not recorded for weather stations respective data from the closest station was used instead. Some more information is given in chapter 3.3.5 (step 2 analysis).

Combining point related climate data with raster data:

The current BÜK 1000 N already provides the link between the 129 soil profiles and geographic units (polygons) which was directly used for the project.

However, an approach for the nationwide regionalisation of the point information from all available weather stations had to be developed. For this regionalisation the eight raster maps on seasonal temperature and precipitation (resolution: 1 km²) which were already considered for the step 1 analysis were again used.

This analysis had to be conducted only once and later became part of the new software tool GISPELMO:

As the initial step all weather stations were classified with regard to one of the three major hydrogeologic regions in Germany (according to Map 5.1 of the HAD (Hydrologischer Atlas von Deutschland); Richts & Vierhuff, 2003) they belong to:

Region 1: Lowlands and loose rock region (including “coast” and “Alpine foreland”)

Region 2: Uplands, primarily built from weakly diagenetic modified solid rocks

Region 3: Uplands, primarily built from strongly diagentic modified and crystallin rock

In the next step mean seasonal temperatures and precipitations were calculated for all weather stations.

These 8 values (4 temperatures, 4 precipitations) per station were then used to calculate the deviations to every raster cell value in the 8 raster maps. Finally for every raster cell in the map the sum of the square of the seasonal averages were calculated (Euclidean distance) as shown in the following equation:

$$Diff_{i,j,k} = \sum_{JZ=1}^{4}\left((Temp_{JZ,i,j} - Temp_{JZ,k)})^2 + (NS_{JZ,i,j} - NS_{JZ,k})^2\right)$$

$Diff_{i,j,k}$: Cumulative difference of raster cell (i,j) from the weather station k

$Temp_{JZ,i,j}$: mean temperature of raster cell (i,j) during season JZ

$Temp_{JZ,Stat(k)}$: mean temperature of station k during season JZ

$NS_{JZ,i,j}$: mean precipitation of raster cell (i,j) during season JZ

$NS_{JZ,Stat(k)}$: mean precipitation of station k during season JZ

With this method, for every raster cell (i, j of the raster map) a vector with dimension k (k: total number of weather stations) was defined. The weather station having the smallest cumulative difference was considered as most representative for a certain raster cell.

After this analysis a new map was available showing the most representative weather station for every pixel in Germany (resolution: 1 km^2).

In the final step the station map was overlapped with the polygons of the soil map resulting in a raster datasets which includes the IDs of the representative weather stations and the IDs of the soil profiles of the BÜK 1000 N for every raster cell. The evaluation resulted in 3348 different combinations of soil profiles and weather stations.

This final step of combination was the base for all leaching maps calculated with the new version of GISPELMO.

3.3.3 Additional functions within PELMO

To establish the spatial basis various new modules had to be implemented into PELMO for the calculation of the nationwide leaching behaviour.

First of all the information from 129 profiles of the BÜK 1000 N had to be provided for PELMO. This was not done using the standard PELMO format (which would have meant a single file for every profile) but a special table was created which contained all important soil core information. The table is shown in appendix 1.

A new code was programmed in order to enable PELMO to read this information and to load the profile information into the existing software for a simulation. In order to make PELMO runs more user friendly internal loops were added which do all simulations within a single batch. It is therefore not necessary that the users select individual simulations.

With these modifications and extensions PELMO is principally able to perform leaching simulations for all 3348 polygons of the previously generated map for Germany.

However, an additional interface had to be defined and programmed which functions as a link between PELMO and the post processing routines which prepare the important output of a GIS-PELMO run. Linking was done based on a simple list in ASCII format (see Appendix 2) which contains following information in every line:

- Polygon code
- Soil profile code
- Weather station code

As already mentioned significant extensions of PELMO's code were necessary in order to enable PELMO to read the different combinations line by line, to perform the respective simulation and to record the simulation results (the 80th percentile of annual concentrations in the percolate) into a file. This output file is the base for all percolate maps as well as for additional tabular outputs.

In order to reduce CPU time the tool was programmed in a way that two simulations can be performed in parallel and to make use of current multi processor cores.

3.3.4 Runoff

One important result of the FOCUS (2009/2014) working group discussion was that all runoff modules in PELMO and PRZM had to be switched off in order to achieve a conservative estimate and to increase harmonisation with FOCUS PEARL (FOCUS 2009/2014). That was a significant change compared to the original FOCUS simulations (FOCUS 2000).

In view of the regulatory intention in FOCUS (2009/2014) it seems to be a comprehensible decision. However, for evaluating the protection level of the FOCUS Hamburg scenario for Germany it is questionable to switch off runoff as a process which is obviously relevant in major parts of the agricultural areas. Considering runoff in the modelling may have an impact on the result of the nationwide evaluation of leachate amounts. To increase scientific reliability of this evaluation the runoff routines were therefore switched on in GISPELMO.

In PELMO the runoff curve number approach (RCN) to calculate runoff is used. These curve numbers depend on crop and soil data. The following table shows the values for all crop-soil combinations implemented into GISPELMO. Basically they were taken from FOCUS (2000). However, the FOCUS groundwater group only defined 4 different soil hydrological classes whereas in an ongoing research and development project about the validation of the FOCUS surface water scenarios for German conditions 5 different soil classes were considered (Bach et al., 2016). In order to consider most recent developments these 5 different soil classes were also implemented into GISPELMO. Furthermore, the link between the BÜK 1000 N soil types and the RCN group was also established using the results of Bach et al. (2016).

Table 3-27: Runoff curve numbers in GISPELMO (according to Bach et al., 2016)

Hydrology soil group → Crop ↓	A	B	BC	C	D
Fallow	77	86	89	91	94
Grass	30	58	65	71	78
Maize	62	83	86	89	93
Barley	54	70	75	80	85
Cereals	54	70	75	80	85
Sugar Beet	58	72	77	81	85
Oats	58	72	77	81	85
Rye	58	72	77	81	85
Rape	54	70	75	80	85
Soybeans	67	78	82	85	89
Potato	62	83	86	89	93
Beans	67	78	82	85	89
Vines	45	62	68	73	79
Tomatoes	62	74	78	81	86
Strawberries	58	72	77	81	85
Apples	36	60	67	73	79
Sunflower	62	83	86	89	93
Cabbage	58	72	77	81	85
Carrots	58	72	77	81	85
Bush berries	36	60	67	73	79
Citrus	36	60	67	73	79
Cotton	67	78	82	85	89
Linseed	54	70	75	80	85
Onions	58	72	77	81	85
Peas	67	78	82	85	89
Tobacco	67	78	82	85	89
Hop	36	60	67	73	79

3.3.5 Daily evapotranspiration

Unfortunately, not for all DWD weather stations daily evapotranspiration data was available.

If this information was not recorded for a weather station respective data from the closest station was used instead. In the following table the link between these 50 stations where data on evapotranspiration was missing and the surrogate weather station is presented.

Table 3-28: Surrogate weather stations if no daily evapotranspiration was available

Original Station		Distance	Surrogate Station	
Station ID	Name	(m)	Name	Station ID
3	Aachen	5227	Aachen-Orsbach	15000
154	Amerang-Pfaffing	18333	Trostberg	5111
191	Arnstein-Müdesheim	22551	Würzburg	5705
294	Barsinghausen-Hohenbostel	15457	Wunstorf	5715
348	Bendorf	36139	Hilgenroth	2211
390	Berleburg, Bad-Stünzel	23270	Kahler Asten	2483
450	Bernkastel-Kues	17451	Deuselbach	953
757	Buchenbach	13986	Freiburg	1443
863	Clausthal-Zellerfeld	16634	Seesen	4651
896	Dachwig	12633	Erfurt-Weimar	1270
991	Dippoldiswalde-Reinberg	20999	Zinnwald-Georgenfeld	5779
1050	Dresden-Hosterwitz	13430	Dresden-Klotzsche	1048
1207	Elster, Bad-Sohl	25570	Plauen	3946
1214	Elzach-Fisnacht	14097	Wolfach	5664
1411	Birx/Rhön	8474	Wasserkuppe	5371
1766	Münster/Osnabrück	41515	Alfhausen	78
2080	Heidelberg	12778	Mannheim	5906
2167	Niederwörresbach	20360	Deuselbach	953
2532	Kassel	32539	Warburg	5347
2578	Kirchdorf/Poel	16078	Boltenhagen	596
2618	Kleiner Inselsberg	29567	Schmücke	4501
2794	Kyritz	26940	Neuruppin	3552
2856	Langenlipsdorf	30823	Wittenberg	5629
2951	Lenzen/Elbe	27660	Lüchow	3093
3034	Lobenstein, Bad	18332	Teuschnitz	5017

Original Station		Distance	Surrogate Station	
Station ID	Name	(m)	Name	Station ID
3083	Lübben-Blumenfelde	34472	Cottbus	880
3098	Lüdenscheid	30168	Lennestadt-Theten	2947
3158	Manschnow	29048	Müncheberg	3376
3204	Martinroda	12068	Schmücke	4501
3284	Michelstadt	12429	Beerfelden	330
3287	Michelstadt-Vielbrunn	19912	Beerfelden	330
3289	Schmieritz-Weltwitz	26007	Jena (Sternwarte)	2444
3348	Moringen-Lutterbeck	21387	Wahlsburg-Lippoldsberg	5279
3540	Neunkirchen-Seelscheid-Krawinkel	15290	Köln-Bonn	2667
3591	Nideggen-Schmidt	20720	Kall-Sistig	2497
3660	Nürburg-Barweiler	24509	Neuenahr, Bad-Ahrweiler	3490
3791	Oldenburg	27416	Großenkneten	44
4349	Sachsenheim	14671	Mühlacker	3362
4464	Schleiz	25040	Plauen	3946
4605	Schwarzburg	30128	Schmücke	4501
4978	Tann/Rhön	16863	Wasserkuppe	5371
5097	Tribsees	29146	Groß Lüsewitz	1803
5158	Ummendorf	28588	Magdeburg	3126
5541	Wiesbaden-Auringen	13511	Kleiner Feldberg/Taunus	2601
5546	Wiesenburg	28881	Wittenberg	5629
5643	Wittstock-Rote Mühle	37757	Menz	3509
5750	Zeitz	15548	Osterfeld	3821
5797	Lichtentanne	22614	Aue	222
5825	Berge	31565	Neuruppin	3552

3.3.6 Substance properties and crops considered for the analysis

In contrast to the step 1 analysis presented earlier the results of this evaluation depend on pesticide properties and the application pattern. In order to cover a reasonable range of situations in total 13 different fictive compounds were considered in the STEP 2 analysis. Their properties differ in their sorption constants (Kf_{oc}) and their degradation rate in soil ($DegT_{50}$). A wide range of these two parameters were considered because they are important driving factors for the leaching behaviour in soil. As shown in Table 3-29 not all combinations of the $DegT_{50}$ - Kf_{oc} - steps have been considered. Cells without crosses were not considered important for the analysis since the respective compounds wouldn't either show any leaching (upper right triangle of the matrix) or they could be classified as extremely leaching substances (lower left triangle of the matrix) which are rather not registered as pesticides. Due to no leaching results above the trigger of 0.1 µg/L the compounds marked in brackets were not used further for evaluation of the STEP 2 analysis. The compound with Kf_{oc} 960 L/kg and $DegT_{50}$ 320 d was also not considered further since the time to reach the soil depth of 1 m was too long compared to the total simulation period of 26 years.

Table 3-29: Sorption and degradation properties of the fictive test compounds used for the analysis

Kf_{oc} (L/kg)→ $DegT_{50}$ (d) ↓	15	30	60	120	240	480	960
5	X		(X)		(X)		
10		X					
20	X		X		(X)		
40				X			
80	X		X		X		
160						X	
320							((X))

X: calculated and used for the analysis, (X) calculated but not used (results always 0) ((X)): simulation period too short

All simulations were performed in maize and winter cereals over a period of 26 years including a warming up period of 6 years and with annual applications one day before emergence of the crop.

The application rate was in general 200 g/ha. However, for some compounds the rate was adapted to achieve a range of leaching concentrations which do not exceed one order of magnitude above or below the trigger of 0.1 µg/L. The actual rates are presented in the following table.

Table 3-30: Annual application rates of the fictive test compounds used for the analysis

Crop	Kf_{oc}	$DegT_{50}$	AppRate (kg/ha)
winter cereals	15	5	0.20
winter cereals	15	20	0.02
winter cereals	15	80	0.01
winter cereals	30	10	0.20
winter cereals	60	20	0.20
winter cereals	60	80	0.02
winter cereals	120	40	0.20
winter cereals	240	80	0.20
winter cereals	480	160	0.20
maize	15	5	5.00
maize	15	20	0.02
maize	15	80	0.01
maize	30	10	0.20
maize	60	20	0.20
maize	60	80	0.02
maize	120	40	0.20
maize	240	80	0.20
maize	480	160	0.20

3.4 GISPELMO results

3.4.1 Soil water hydrology

3.4.1.1 Runoff

As previously described all GISPELMO simulations were done using the PELMO runoff routines. The annual runoff amounts simulated were in the range of 5 L/m² up to 250 L/m² with significantly higher amounts of runoff in maize than in winter cereals due to fallow conditions during the autumn and winter periods. The spatial distribution of the 20-year-averaged annual runoff amounts in Germany according to PELMO is presented in Figure 3-70. The regions with the lowest annual runoff amounts are located mainly in North-East-Germany, where sandy soils and low annual precipitation occur, whereas maximum runoff amounts were calculated to be in the low mountain range especially in the Sauerland in North Rhine-Westphalia. This rating is independent on the crop though the absolute amounts may differ.

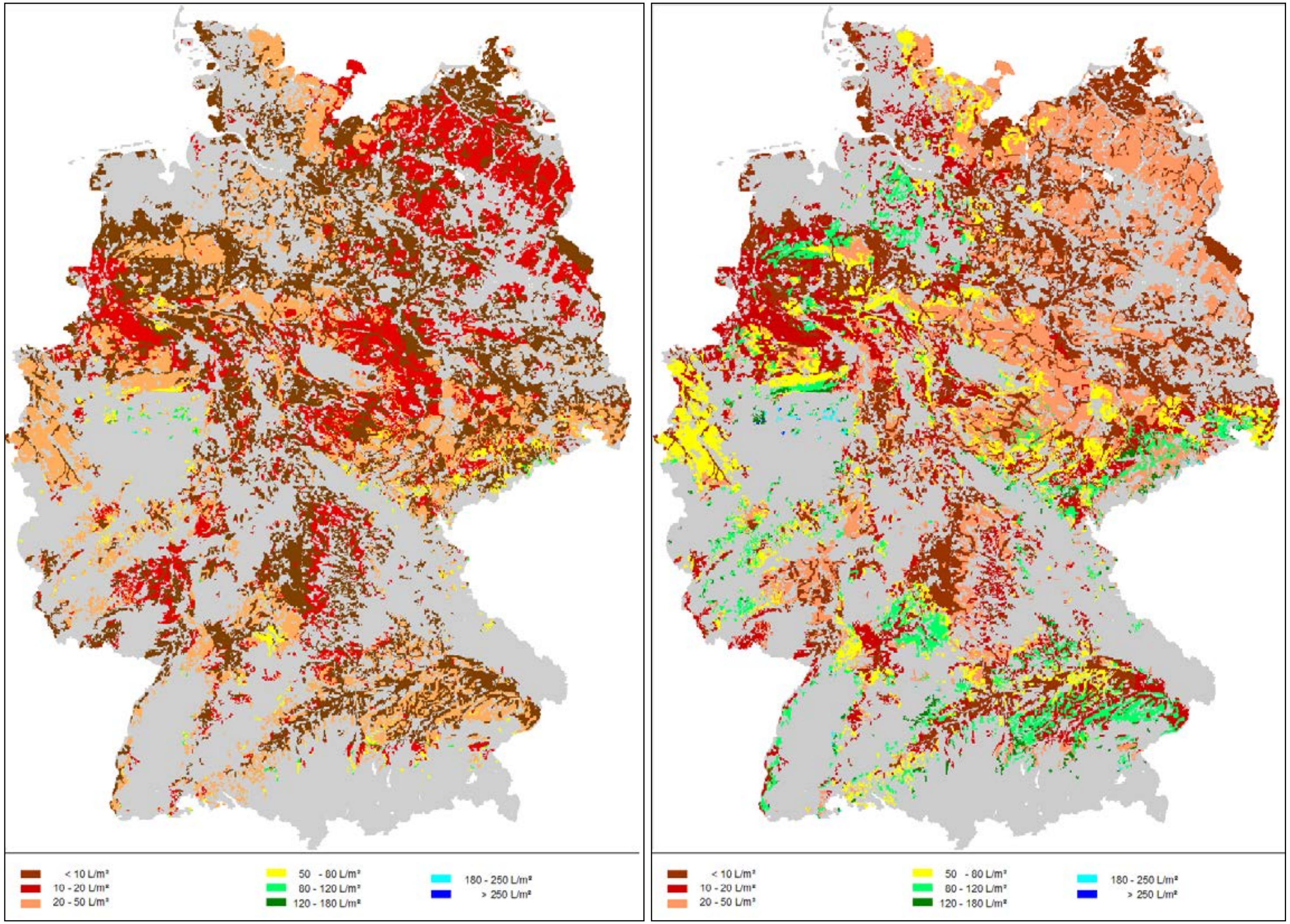


Figure 3-70: Distribution of 20-year-averaged annual runoff amounts (left: winter cereals, right: maize)

3.4.1.2 Percolate

The spatial distribution of the percolate in Germany according to PELMO is presented in Figure 3-72. The pattern is similar as previously discussed for the annual runoff. The regions with the lowest annual percolate amounts are located mainly in North-East-Germany due to the low annual precipitation whereas maximum percolate were calculated in the low mountain range. The map in Figure 3-71 with nationwide percolate amounts according to the Map 4.5 of the HAD (Hydrologischer Atlas Deutschlands) (Duijnisveld et al., 2003) shows comparable results and therefore supports the reliability of the PELMO simulation. Regional deviations may be caused by the fact that both the data bases and algorithms were different in both analyses. The HAD also contains a map of the groundwater recharge (see Figure 3-73; Neumann & Wycisk, 2003), which additionally considers the effect of subsurface lateral water flow (interflow). Since the interflow reduces the estimated percolate amount the resulting groundwater recharge shows lower values than the percolate fluxes in general. To stay in line with the FOCUS groundwater modelling approach it was decided to use the PELMO percolate amounts (without interflow) for the further calculations of the PEC groundwater.

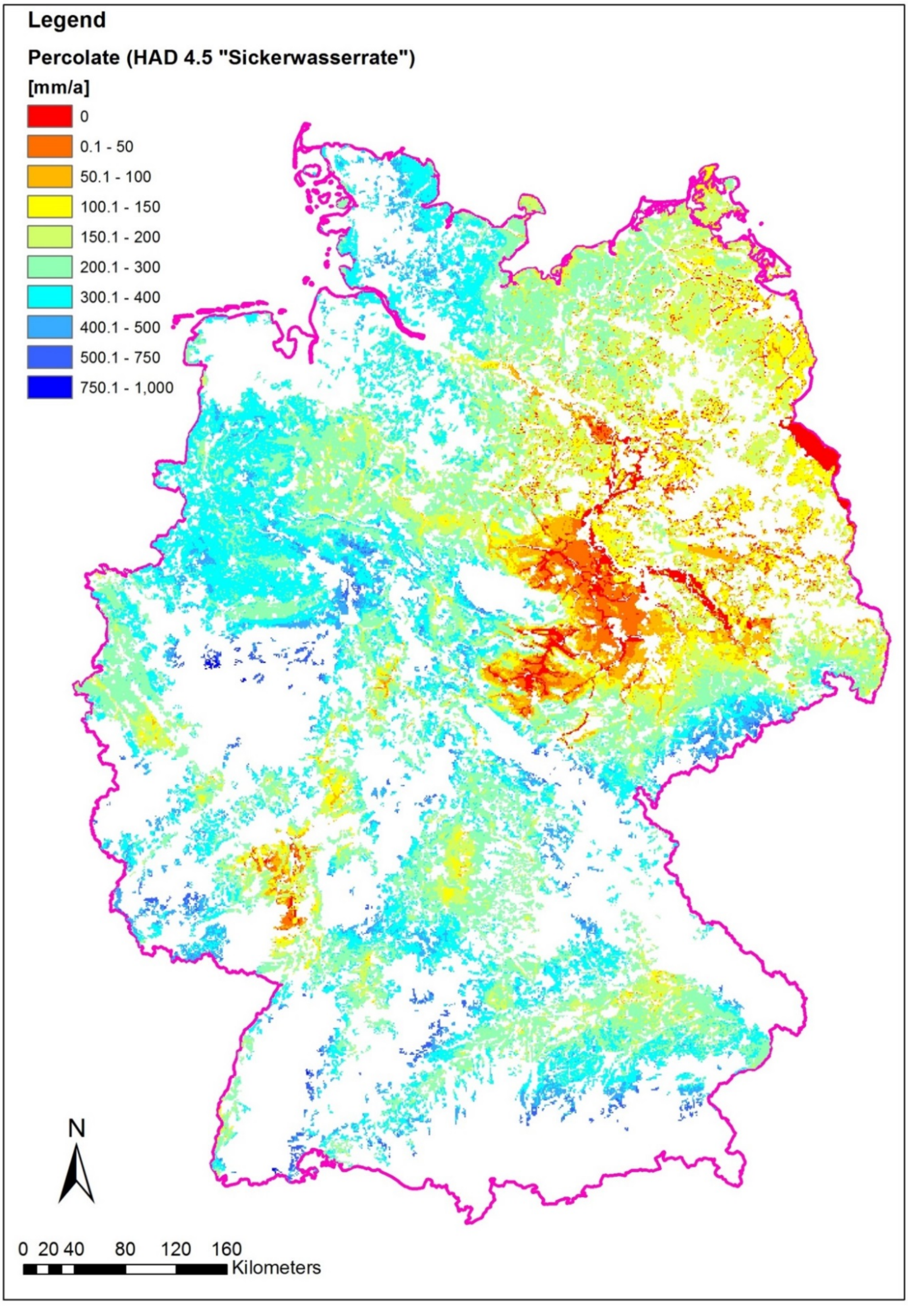


Figure 3-71: Distribution of annual percolate (BGR HAD 4.5 "Sickerwasserrate"; Duijnisveld et al., 2003)

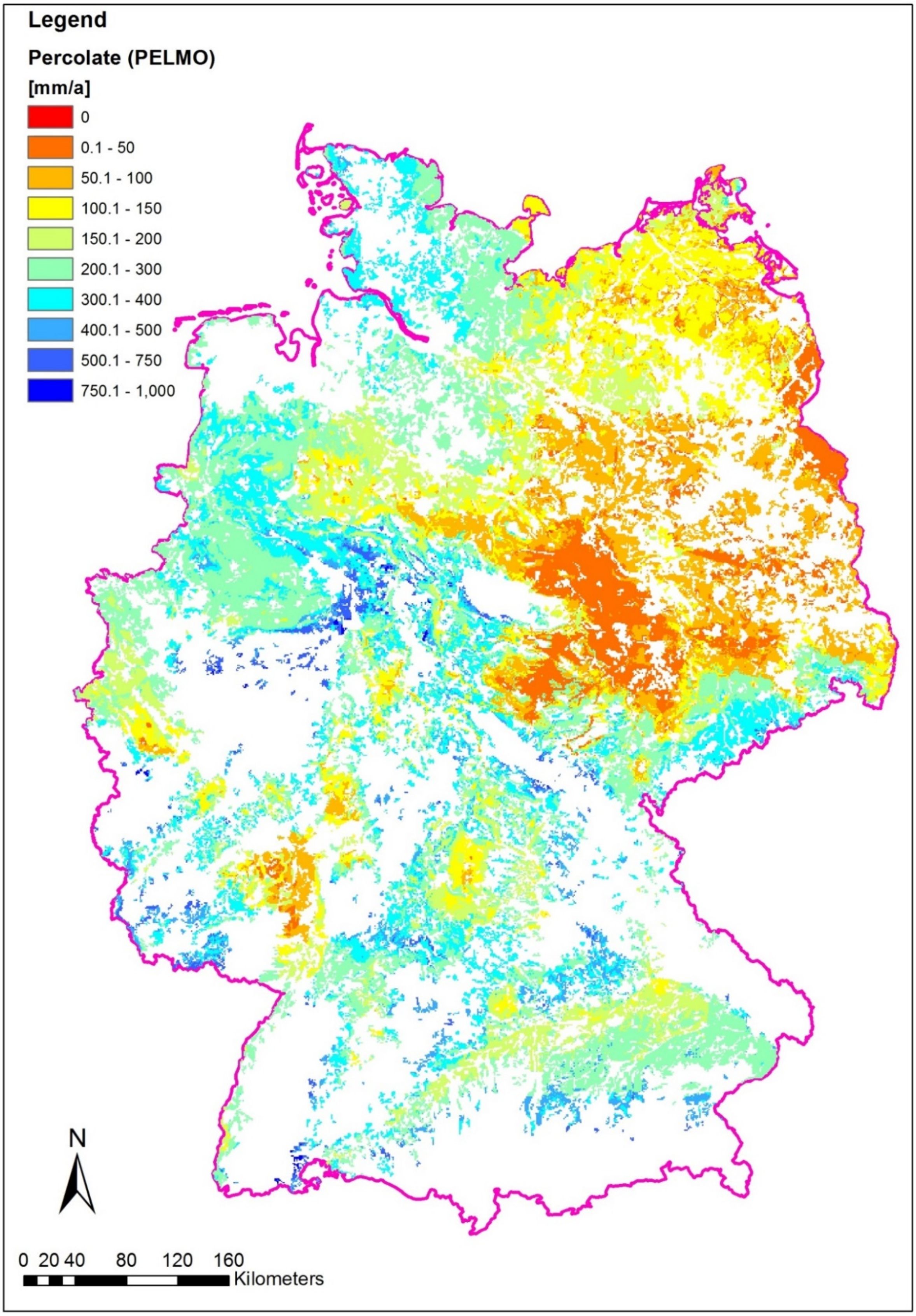


Figure 3-72: Distribution of annual percolate according to PELMO (crop: maize)

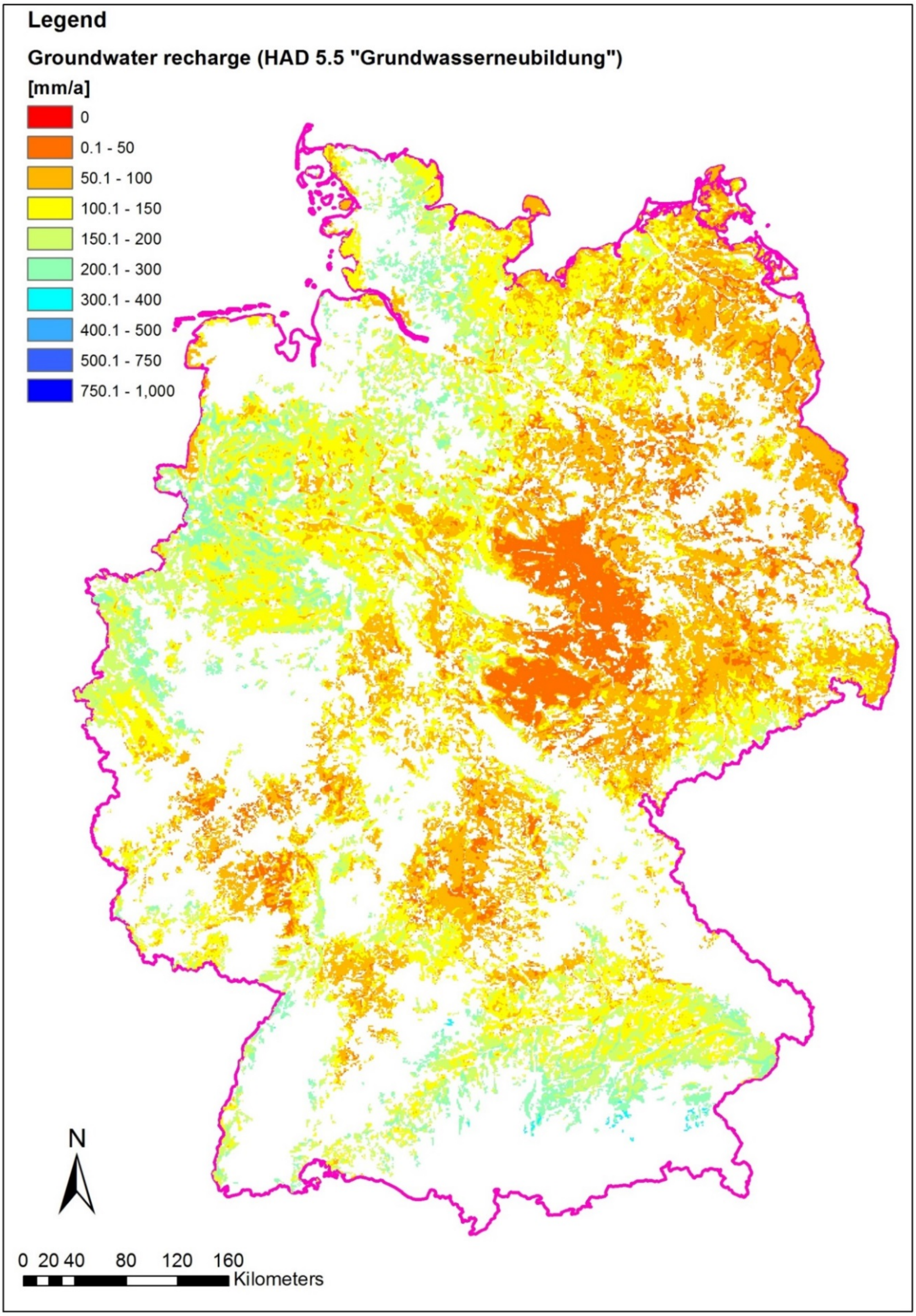


Figure 3-73: Distribution of annual groundwater recharge (BGR HAD 5.5 "Grundwasserneubildung"; Neumann & Wycisk, 2003)

3.4.2 Substance concentrations in percolate

Annual concentrations in the percolate are calculated for 9 substances and 2 crops, all with annual applications one day before emergence of the crop. The results for the compound with Kf_{oc} = 60 L/kg and a $DegT_{50}$ of 20 days are shown in Figure 3-74. For both maps the same legend was used showing concentrations in 9 leaching classes.

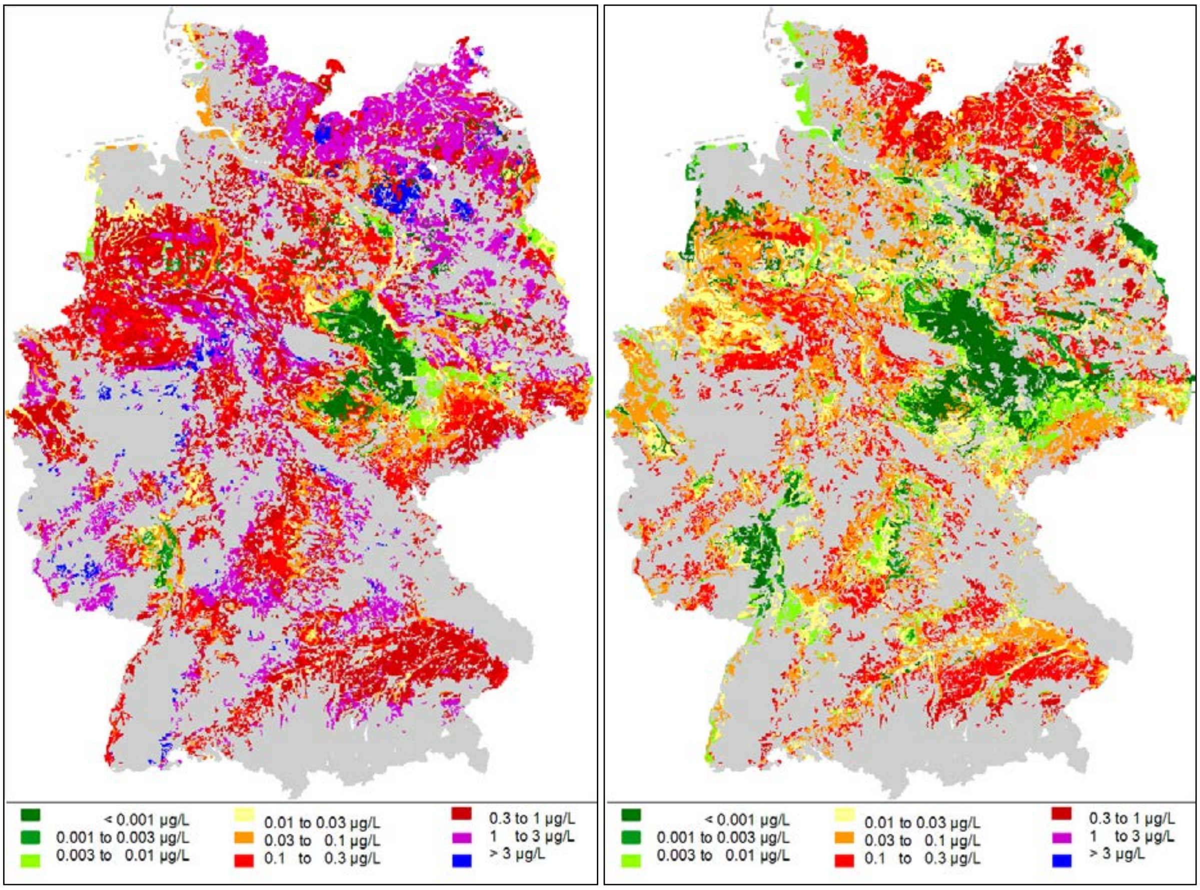


Figure 3-74: 80th temporal percentiles of annual concentrations in leachate (Kf_{oc} 60 L/kg, $DegT_{50}$ 20 d, left: winter cereals, right: maize)

Higher concentrations were simulated in winter cereals (map dominated by red colours which stand for concentration above 0.1 µg/L) compared to maize (map dominated by green and orange colours which stand for concentrations below 0.1 µg/L). This is in line with modelling exercises in FOCUS (2009/2014), which show, that applications in autumn usually lead to more conservative modelling results compared to spring applications. This is because most of the percolate fluxes are expected to appear in autumn/winter. And the time period for the pesticide being degraded in the upper soil horizon after application until the main groundwater recharge is shorter in autumn/winter. However, the evaluation of the protection level of the FOCUS Hamburg scenario is based on the analysis which percentile FOCUS Hamburg represents for the agricultural area in Germany. The evaluation of the absolute concentrations is not analysed further in detail. One example of a typical percentile evaluation of the FOCUS Hamburg scenario is presented in Figure 3-75.

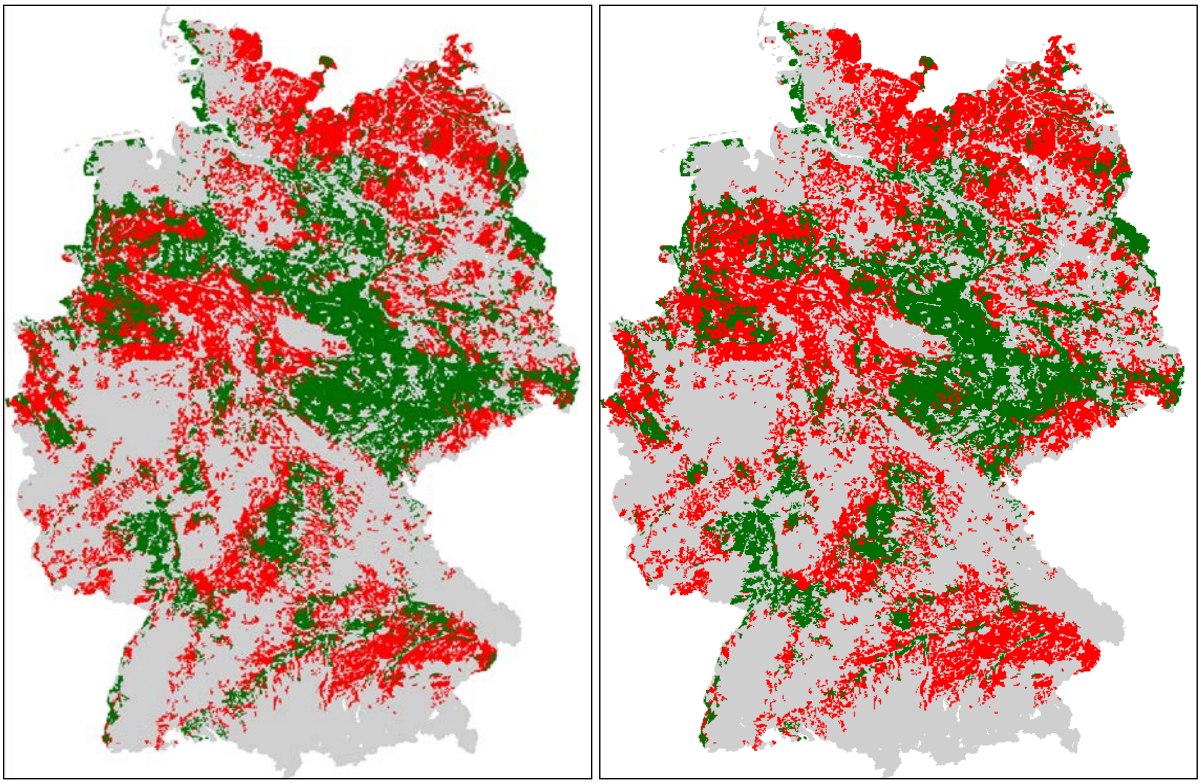


Figure 3-75: 80th temporal percentile of annual concentrations in leachate (Kf_{oc} 60 L/kg, $DegT_{50}$ 20 d, left: winter cereals, right: maize) compared to the respective FOCUS Hamburg scenario (green: below FOCUS Hamburg, red: above FOCUS Hamburg)

The two maps in Figure 3-75 are much more in line with each other than the respective maps in Figure 3-74. That means, at least for this example, that independent whether the application time was chosen in winter (winter cereals) or spring (maize) similar parts of the agricultural area were above or below the Hamburg scenario, respectively. Nationwide PECs and percentile maps of the same kind were calculated for all other 18 crop-compound-combinations, too. The results are presented in appendix 4 and 5 Figure 3-76 presents the aggregated percentile results for all these calculations.

Figure 3-76: Spatial percentile of the PECs from the FOCUS Hamburg scenario compared to the PECs for the agricultural area in Germany calculated with GISPELMO dependent on crop (WC = winter cereals, MZ = maize) and key pesticide parameters

As shown in Figure 3-76 spatially distributed percolate concentrations (80th temporal percentile) for all crop-pesticide combinations were found to be in the range of the 30th and the 65th percentile. The arithmetic mean of the spatial percentiles was 44 %. This relative comparison of the spatially distributed percolate concentrations in 1 m soil depth indicate, that the FOCUS Hamburg scenario is not representing an 80th spatial percentile in Germany, but rather a central spatial percentile is met by the FOCUS Hamburg scenario, only.

Table 3-31 provides more information about the PECs resulting from simulations with GISPELMO compared to the FOCUS Hamburg scenario. The table shows for example that although the FOCUS Hamburg scenario is clearly not representing the 80th spatial percentile (column 6), the 80th temporal concentrations in the percolate of the FOCUS Hamburg scenario do often not extremely differ with the 80th temporal and spatial percentile as calculated with GISPELMO (column 7).

Table 3-31: Spatial percentile of the PECs from the FOCUS Hamburg scenario (FOCUS H) compared to the PECs for the agricultural area in Germany calculated with GISPELMO dependent on crop (WC = winter cereals, MZ = maize) and key pesticide parameters

Crop	Kf_{oc} (L/kg)	$DegT_{50}$ (d)	ApRate (kg/ha)	FOCUS H (Percentile)	FOCUS H (µg/L)	GISPELMO 80 Perc (µg/L)	GISPELMO 90 Perc (µg/L)	GISPELMO MAX (µg/L)
WC	15	5	0.20	50	0.78	2.02	3.11	11.60
WC	15	20	0.02	53	0.64	1.00	1.26	2.24
WC	15	80	0.01	64	1.33	1.55	1.82	2.57
WC	30	10	0.20	43	0.40	1.56	2.52	12.12
WC	60	20	0.20	46	0.33	1.13	1.64	10.08
WC	60	80	0.02	38	0.62	1.06	1.40	2.41
WC	120	40	0.20	42	0.21	0.95	1.36	6.77
WC	240	80	0.20	37	0.14	0.88	1.36	5.38
WC	480	160	0.20	35	0.09	0.79	1.31	5.45
MZ	15	5	5.00	46	0.01	0.04	0.08	18.70
MZ	15	20	0.02	50	0.05	0.08	0.10	0.34
MZ	15	80	0.01	31	0.41	0.55	0.59	0.88
MZ	30	10	0.20	48	0.01	0.02	0.03	0.35
MZ	60	20	0.20	49	0.03	0.11	0.16	0.89
MZ	60	80	0.02	40	0.30	0.51	0.60	1.15
MZ	120	40	0.20	49	0.07	0.26	0.37	1.96
MZ	240	80	0.20	40	0.06	0.38	0.59	2.89
MZ	480	160	0.20	37	0.05	0.43	0.69	3.33
arithmetic mean				44				

In Table 3-32 the ratios between the 80th, 90th and 100th percentile concentrations from GISPELMO simulations and the FOCUS Hamburg scenario are additionally summarised for all crop-compound-combinations: Factors between the GISPELMO's 80th spatial percentiles and FOCUS Hamburg results were in the range of 1.2 to 9.2 (geometric mean 3.2). The respective geometric mean of all ratios for the 90th spatial percentile and the absolute maximum were calculated to be 4.7 and 21.4, respectively.

Table 3-32: Ratio between the spatial percentile of the PECs from the FOCUS Hamburg scenario and various spatial percentiles of the PECs for the agricultural area in Germany calculated with GISPELMO (WC = winter cereals, MZ = maize)

Crop	Kfoc (L/kg)	DegT50 (d)	AppRate (kg/ha)	FOCUS H (Percentile)	FOCUS H (µg/L)	Ratio: GISPELMO 80Perc/ FOCUS H (-)	Ratio: GISPELMO 90 Perc/ FOCUS H (-)	Ratio: GISPELMO-MAX/ FOCUS H (-)
WC	15	5	0.20	50	0.78	2.60	4.01	14.96
WC	15	20	0.02	53	0.64	1.57	1.97	3.52
WC	15	80	0.01	64	1.33	1.16	1.37	1.92
WC	30	10	0.20	43	0.40	3.91	6.29	30.30
WC	60	20	0.20	46	0.33	3.45	4.99	30.74
WC	60	80	0.02	38	0.62	1.72	2.28	3.92
WC	120	40	0.20	42	0.21	4.52	6.46	32.23
WC	240	80	0.20	37	0.14	6.43	9.89	39.29
WC	480	160	0.20	35	0.09	8.49	14.12	58.58
MZ	15	5	5.00	46	0.01	5.37	11.06	2678.14
MZ	15	20	0.02	50	0.05	1.58	1.94	6.66
MZ	15	80	0.01	31	0.41	1.34	1.45	2.14
MZ	30	10	0.20	48	0.01	3.47	5.95	69.25
MZ	60	20	0.20	49	0.03	3.64	5.38	30.81
MZ	60	80	0.02	40	0.30	1.71	1.99	3.82
MZ	120	40	0.20	49	0.07	3.75	5.36	28.40
MZ	240	80	0.20	40	0.06	6.61	10.26	50.65
MZ	480	160	0.20	37	0.05	9.24	14.91	72.38
Geometric mean						3.23	4.67	21.40

The maps with the spatial distributions of the percolate concentrations which are the base for the statistics presented in Table 3-32 are presented in appendix 4. The maps show a dependency of the simulated PEC distribution in Germany on the crop and substance properties and therefore vulnerable locations with higher predicted concentrations in 1 m soil depth change with different crop-substance properties. Nevertheless, there seems to be also an overlap of vulnerable situations which appear to be nearly independent on the pesticide or crop properties. That becomes clear when focusing on the critical situations around the 80th percentile only (see appendix 5). The alternative scenarios which will be discussed in chapter 3.5 and which may better describe the 80th spatial percentile for the agricultural area Germany will focus on these overlapping regions.

3.4.3 Statistical distribution of influencing parameters

Originally it was planned to conduct a linear multiple regression analysis on the results of Step 2, to find out the most influencing soil and climate parameters on the PEC_{gw} calculations with GISPELMO. But several tests and pre-analyses showed that the essential requirement for such an analysis is not given in this case: There is no linear correlation between the dependent and independent variables. Even a transformation of the different variables would be difficult due to the unknown mathematical dependency of the different variables in the simulation model PELMO.

Thus an alternative approach was developed to define scenarios with a higher spatial relevance than the FOCUS Hamburg scenario for Germany. Details thereof are described in the following chapter 3.5. In an intermediate step a descriptive statistic analysis for the results of Step 2 was conducted to investigate the distribution of several soil and climate parameters for the whole agricultural area in Germany in comparison to selected groups of raster cells and to characterise the new scenarios in more detail. Altogether, eleven soil and climate parameters were analysed which are known to have a high influence on the simulated leaching of PPP to groundwater:

- temperature summer half-year (T Shy),
- temperature winter half-year (T Why),
- precipitation summer half-year (Prec Shy),
- precipitation winter half-year (Prec Why),
- percolate,
- potential evapotranspiration (PET),
- runoff,
- C_{org}-content over 1 m soil depth (C_{org}-1mdw),
- available water capacity (aWC; difference between field capacity and wilting point),
- biodegradation factor (BF),
- soil profile depth.

For each parameter, the different percentiles were identified for the spatial distribution in the total agricultural area in Germany (see Table 3-33). For the descriptive statistical analysis of each parameter, first the distribution of the parameter was described in the spatial 75^{th}-85^{th} percentile class of the calculated PEC_{gw} for all different dummy substances. Additionally, the parameter distribution in the two upper 85^{th}-95^{th} and >95^{th} spatial percentile classes of the overall spatial distribution was analysed to identify soil and climate properties which still show significant influence for PEC simulation in the most upper percentiles. The visual parameter distribution in the 75th-85th percentile class was compared both to the overall distribution in Germany and to the parametrisation in the FOCUS Hamburg scenario.

Table 3-33: Different distribution parameters of the most important influencing soil/climate properties on the leaching of PPP to groundwater in agricultural areas in Germany

Parameter	Min	Mean	Max	10th perc	25th perc	50th perc	75th perc	90th perc	Hamburg
T Shy*	10.9	14.5	16.8	13.6	14	14.5	14.9	15.3	13.9
T Why*	-0.2	3.6	6.3	2.5	3.1	3.6	4.1	4.8	4
Prec Shy*	249	381	758	307	333	374	413	461	393
Prec Why*	139	337	863	242	276	332	391	431	377
Percolate	1.00E-10	207	942	58	112	199	284	355	284
PET	458	607	798	552	578	606	638	666	610
Runoff	1.4	33.5	470.9	4.9	8.5	22.2	50.3	82.3	0
C_{org}-1mdw	0.25	0.69	3.4	0.36	0.54	0.67	0.79	0.8	0.78
aWC	0.06	0.17	0.59	0.09	0.14	0.16	0.18	0.22	0.2
BF	0.4	0.54	0.55	0.46	0.55	0.55	0.55	0.55	0.57
Soil profile depth	50	95	100	70	100	100	100	100	100

* the values for T Shy, T Why, Prec Shy and Prec Why differ from the respective values in chapter 6.2 to some extent since the data base there has a higher resolution than here

In the following general observations concerning the main parameter distributions are described using the boxplots:

- Temperature in the summer half-year:

Most of the medians in the 75th-85th percentile class concerning the temperature in the summer half-years (T Shy) of the different compound/crop combinations lie below the median of 14.5 °C for the total agricultural area but above the Hamburg value of 13.9 °C (see Figure 3-77 and Figure 3-78). Overall the medians of the different upper percentile classes lie in a relatively narrow variation of about 0.6°C. Most of the compound/crop combinations show no clear trend between summer temperature and the upper percentile PEC classes. Only few substances show a slight increase (Kf_{oc}=15/$DegT_{50}$=80/maize and Kf_{oc}=60/$DegT_{50}$=80/maize) others a slight decrease (Kf_{oc}=15/$DegT_{50}$=20/winter cereals and Kf_{oc}=30/$DegT_{50}$=10/winter cereals) of the summer temperature with an increasing PEC. Finally, the expected correlation of decreasing temperature with increasing PEC ranges cannot clearly be observed. The fact, that almost all medians of the different compound/crop combinations lie below the median of the total area of concern, underlines that lower temperatures lead to higher PECs in general. But the fact that, against expectations, a reverse trend can be seen for a few substances in the upper spatial percentile is kind of surprising and shows that the parameter average summer temperature is possibly not the key factor on the sites that are worst case situations concerning the PEC for these substances.

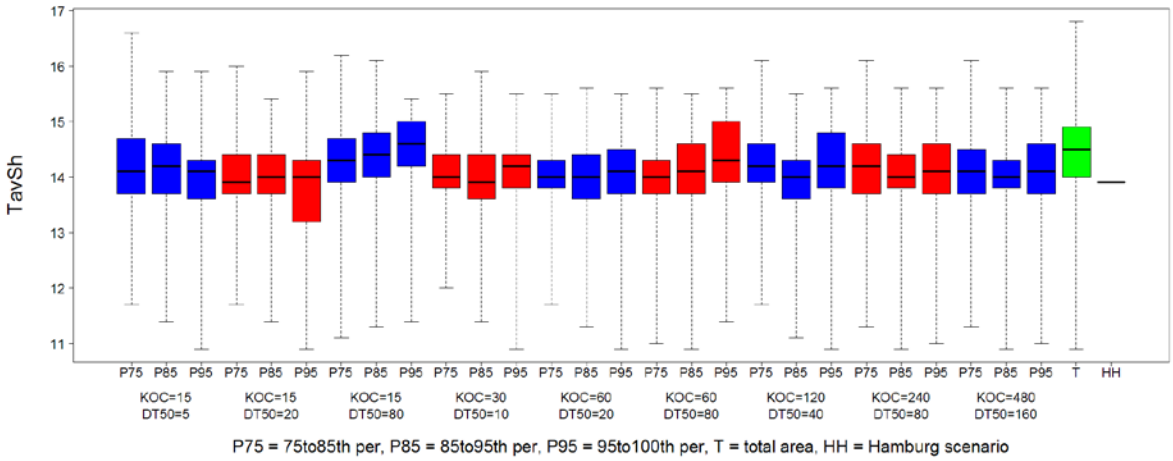


Figure 3-77: Distribution of the summer temperature inside different percentile ranges of the total distribution (one red or blue group of three bars stands for one test substance with specified Kf_{oc} and $DegT_{50}$; the three bars stands from left to right for: 75th – 85th percentile-, 85th – 95th percentile- and >95th percentile-range of the total PEC distribution for maize green: total area; line on the right: HH)

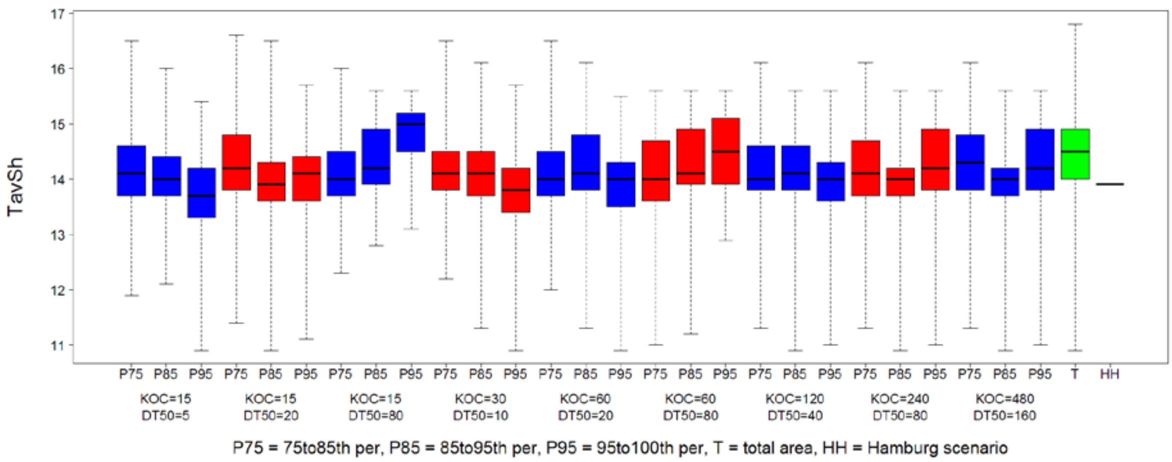


Figure 3-78: Distribution of the summer temperature inside different percentile ranges of the total distribution (one red or blue group of three bars stands for one test substance with specified Kf_{oc} and $DegT^{50}$; the three bars stands from left to right for: 75th – 85th percentile-, 85th – 95th percentile- and >95th percentile-range of the total PEC distribution for winter cereals; green: total area; line on the right: HH)

- Temperature in the winter half-year:

All the medians in the 75th-85th but also in the 85th-95th and the >95th spatial percentile classes concerning the temperature in the winter half-year (T Why) are lower than the median of 3.6 °C for the total agricultural area and also lower than the FOCUS Hamburg value of 4.0 °C (see Figure 3-79 and Figure 3-80). Most of the compound/crop combinations show a decreasing winter temperature with increasing PEC values in the three upper spatial percentile classes. Substances with a low Kf_{oc}-value even more clearly show this negative trend. This observation corresponds to the expectations, that lower winter temperatures are correlated to higher PECs because they prolong the residence time of substances residues in soil during a time with higher groundwater recharge. And finally, the winter temperatures in the FOCUS Hamburg scenario are not representative for the whole agricultural area in Germany.

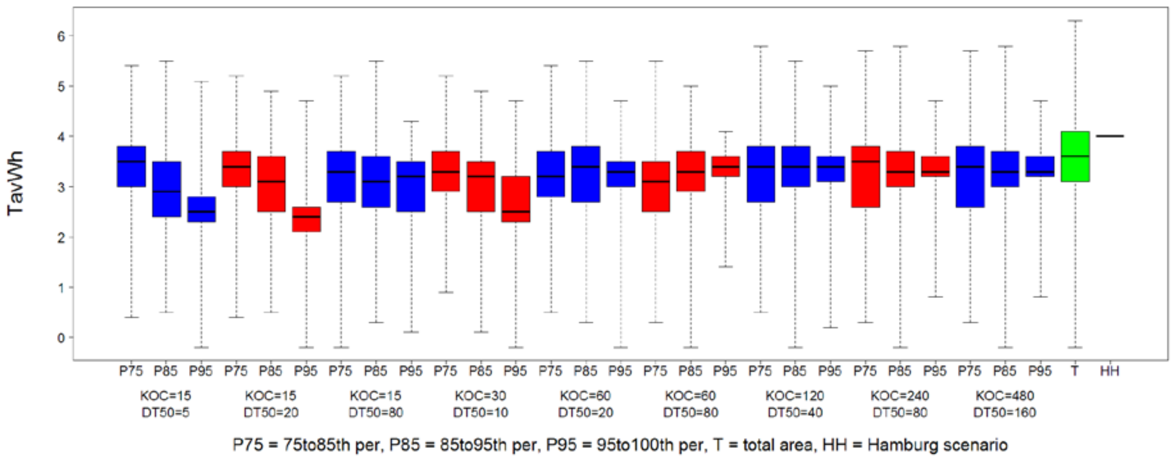


Figure 3-79: Distribution of the winter temperature inside different percentile ranges of the total distribution (one red or blue group of three bars stands for one test substance with specified Kf_{oc} and $DegT_{50}$; the three bars stands from left to right for: 75th – 85th percentile-, 85th – 95th percentile- and >95th percentile-range of the total PEC distribution for maize; green: total area; line on the right: HH)

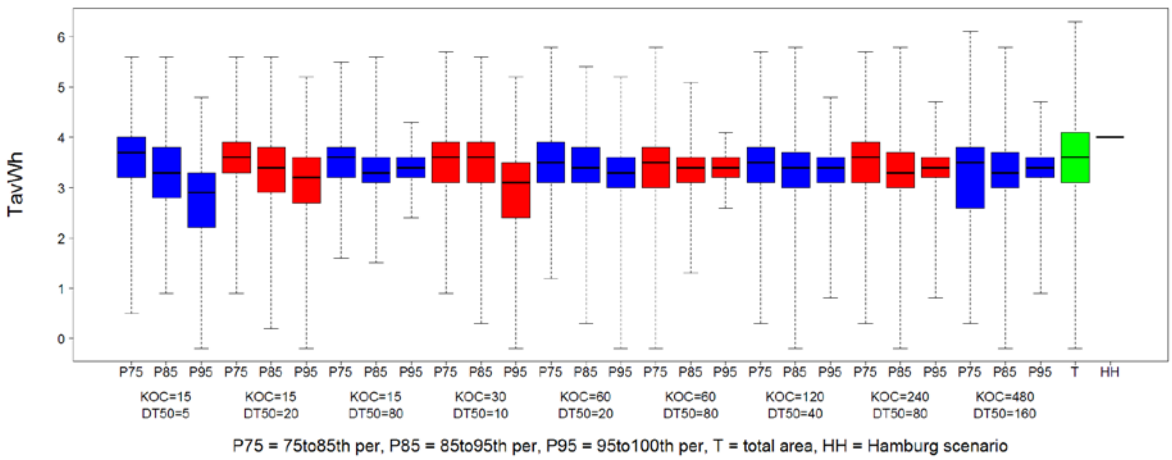


Figure 3-80: Distribution of the winter temperature inside different percentile ranges of the total distribution (one red or blue group of three bars stands for one test substance with specified Kf_{oc} and $DegT_{50}$; the three bars stands from left to right for: 75th – 85th percentile-, 85th – 95th percentile- and >95th percentile-range of the total PEC distribution for winter cereals; green: total area; line on the right: HH)

- Precipitation in the summer half-year:

The median values of precipitation in the summer half-year in the 75th-85th spatial percentile classes for all dummies show rather small deviations from the median summer precipitation of 374 mm for the total agricultural area in Germany and 393 mm for the FOCUS Hamburg scenario. However, a higher scattering of summer precipitation can be observed between the three upper spatial percentile classes (75th-85th, 85th-95th, >95th), especially for the summer application in maize. In the 85th-95th and the >95th percentile classes, some of the medians for the different compound/crop combinations show higher, others show lower values than the total median and the Hamburg scenario value. Especially, the major leaching compounds (Kf_{oc} up to 60) show increasing precipitation in summer with increasing PEC values (except the two dummies: Kf_{oc}=16/$DegT_{50}$=80 and Kf_{oc}=60/$DegT_{50}$=80). In contrast, the less leaching compounds (Kf_{oc} values > 60) show a negative trend of decreasing summer precipitation with increasing PEC values. These results give evidence, that the summer precipitation is an important influencing parameter for PEC calculation, since the trends always can be seen clearly both in a positive and a negative direction. The distribution of the precipitation in the summer half-year in the upper percentile classes may lead to the conclusion, that the summer precipitation amount has an increasing leaching effect on major leaching compounds with lower adsorption in soil, especially if the test substance is applied in spring or summer. For compounds with higher adsorption values that tend to leach only in minor amounts to deeper soil layers, concentrations seem to increase due to less volume of percolate (reverse dilution effect).

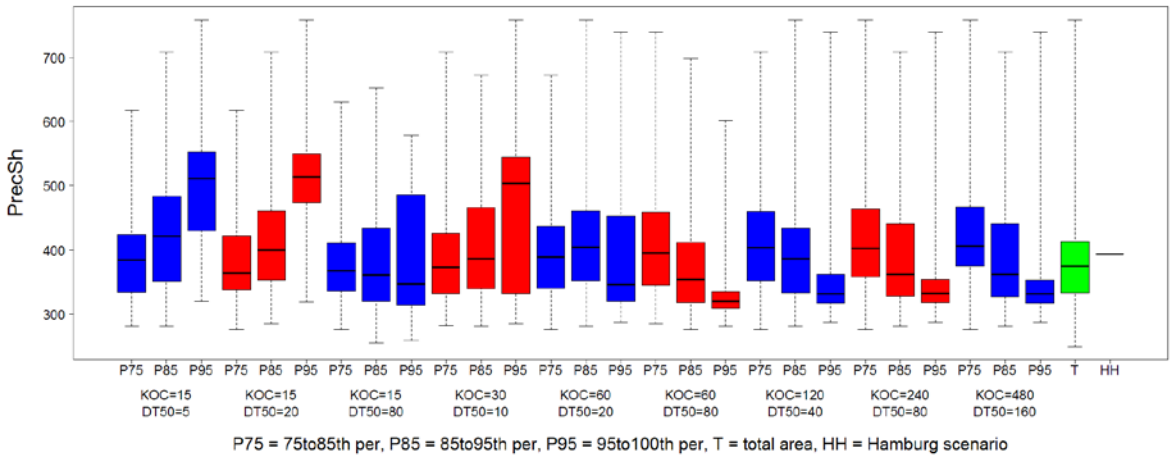


Figure 3-81: Distribution of the summer precipitation inside different percentile ranges of the total distribution (one red or blue group of three bars stands for one test substance with specified Kf_{oc} and $DegT_{50}$; the three bars stands from left to right for: 75th – 85th percentile-, 85th – 95th percentile- and >95th percentile-range of the total PEC distribution for maize; green: total area; line on the right: HH)

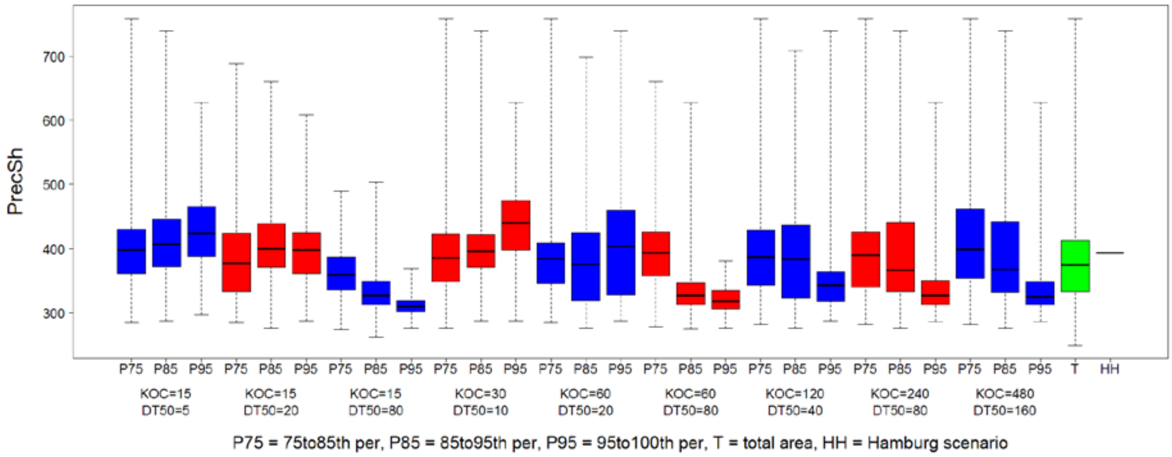


Figure 3-82: Distribution of the summer precipitation inside different percentile ranges of the total distribution (one red or blue group of three bars stands for one test substance with specified Kf_{oc} and $DegT_{50}$; the three bars stands from left to right for: 75th – 85th percentile-, 85th – 95th percentile- and >95th percentile-range of the total PEC distribution for winter cereals; green: total area; line on the right: HH)

- Precipitation in the winter half-year:

The median values of precipitation in the winter half-year in the 75th-85th spatial percentile classes for all dummies in spring application (maize) are quite comparable to the median winter precipitation of 332 mm for the total agricultural area in Germany. However, almost all medians are lower than the winter precipitation of 377 mm in the FOCUS Hamburg scenario for the application in maize. For winter cereals the median values of precipitation in the winter half-year in the 75th-85th spatial percentile classes for all dummy substances are higher than the median winter precipitation of 332 mm for the total agricultural area in Germany. This is also the case for the compounds with lower Kf_{oc} values for the two most upper spatial percentile classes (85th-95th, >95th). However, the FOCUS Hamburg scenario with 377 mm rain in winter cereals seems to be quite comparable to the precipitation values in the 75th-85th spatial percentile classes for applications in winter cereals. Only in the two upper spatial percentile classes (85th-95th, >95th), some medians lie below, others above the Hamburg value (compounds with a positive correlation lie tendentially above, compounds with a negative correlation below).

In conclusion, a tendency of higher winter precipitation with increasing PECs can be observed for substances with lower Kf_{oc} values (except the two dummies: Kf_{oc}=15/$DegT_{50}$=80 and Kf_{oc}=60/$DegT_{50}$=80). This influence might be more visible for winter applications (winter cereals). In contrast, lower winter precipitation with increasing PECs can be observed for substances with higher Kf_{oc} values. These results give evidence, that (comparable to the summer precipitation) the winter precipitation seems to be an important influencing parameter since the trends always can be seen clearly both in a positive and a negative direction. Furthermore it can be concluded that the precipitation amount has an increasing leaching effect on major leaching compounds. For compounds with higher adsorption values, which tend to leach only in minor amounts to deeper soil layers, concentrations seem to increase due to less volume of percolate (reverse dilution effect).

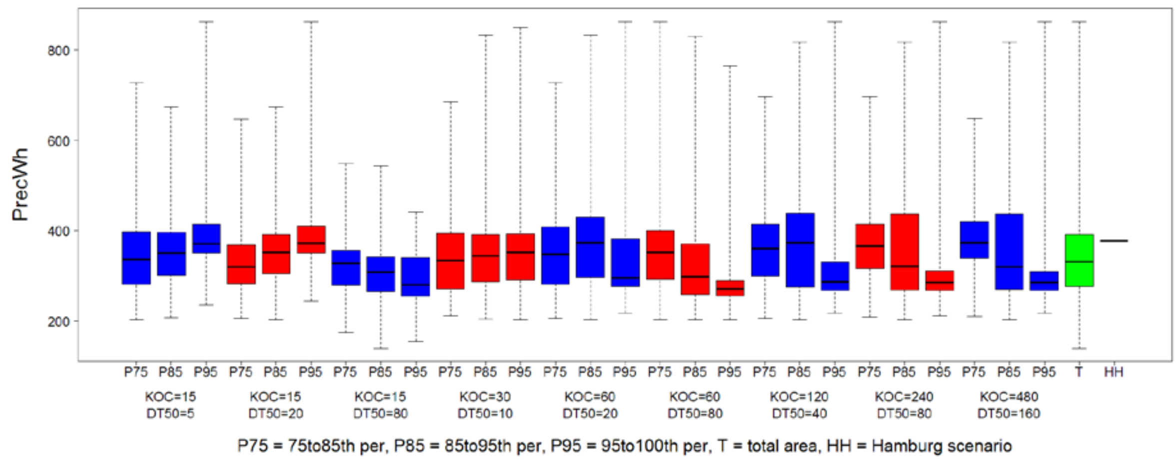


Figure 3-83: Distribution of the winter precipitation inside different percentile ranges of the total distribution (one red or blue group of three bars stands for one test substance with specified Kf_{oc} and $DegT_{50}$; the three bars stands from left to right for: 75th – 85th percentile-, 85th – 95th percentile- and >95th percentile-range of the total PEC distribution for maize; green: total area; line on the right: HH)

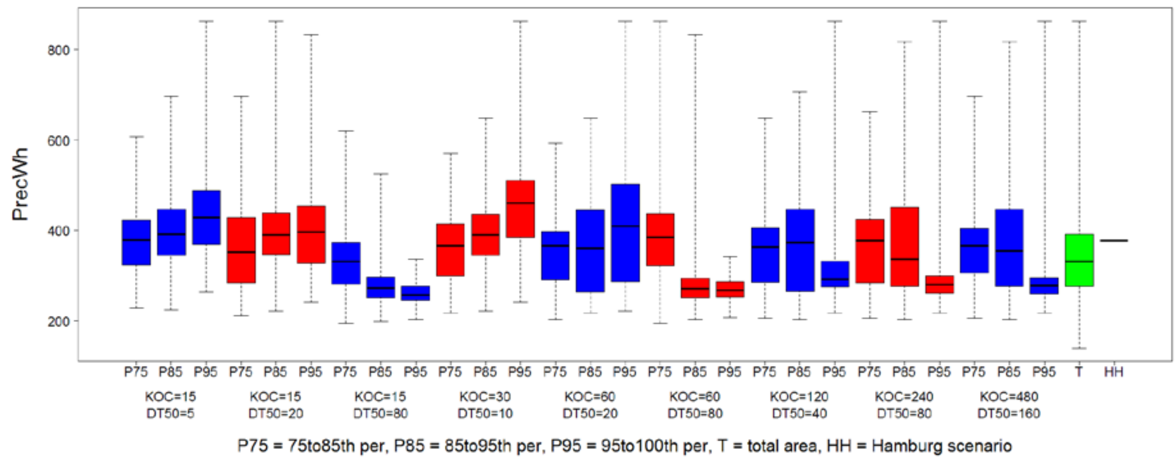


Figure 3-84: Distribution of the winter precipitation inside different percentile ranges of the total distribution (one red or blue group of three bars stands for one test substance with specified Kf_{oc} and $DegT_{50}$; the three bars stands from left to right for: 75th – 85th percentile-, 85th – 95th percentile- and >95th percentile-range of the total PEC distribution for winter cereals; green: total area; line on the right: HH)

- Percolate:

Almost all median values of percolate amounts in the 75th-85th spatial percentile classes for all dummies are higher than the median percolate amounts of 200 mm for the total agricultural area in Germany and quite comparable to the 284 mm for the FOCUS Hamburg scenario. A higher scattering of percolate amounts can be observed for all dummies in the two upper spatial percentile classes (85th-95th, >95th). Again substances with lower Kf_{oc} show increasing percolate amounts with increasing PECs (excepted the compounds: Kf_{oc}=16/$DegT_{50}$=80 and Kf_{oc}=60/$DegT_{50}$=80) and substances with higher Kf_{oc} values show decreasing percolate amounts with increasing PECs. Finally, the observed pattern corresponds to the dependency, which was found and described for summer and winter precipitations. Therefore it can be concluded, that the percolate is an important parameter to influence the PEC in groundwater. A positive correlation is rather shown for leaching substances with low adsorption values and short $DegT_{50}$ and might be stronger for autumn and winter applications. For more persistent substances with higher adsorption values a negative correlation between percolate amounts and simulated test substances concentrations in 1 m soil depth may be possible as well. However, the percolate amount of about 284 mm for the Hamburg scenario is quite comparable with the calculated percolate in the 75^{th}-85^{th} spatial percentile classes for all dummies. This provides evidence, that the FOCUS Hamburg scenario represents a rather conservative leaching scenario and a high spatial percentile according to the estimated soil water fluxes in 1 m soil depth.

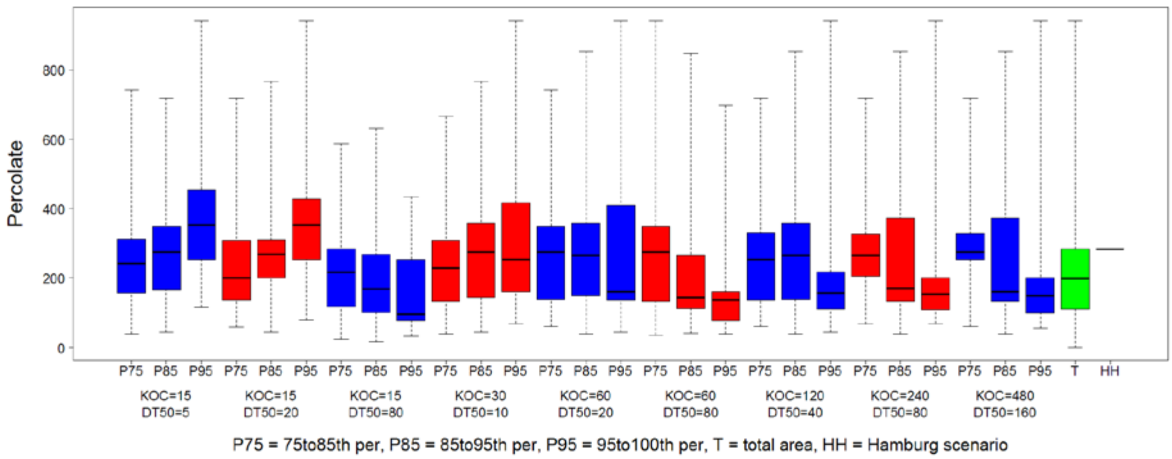


Figure 3-85: Distribution of the percolate inside different percentile ranges of the total distribution (one red or blue group of three bars stands for one test substance with specified Kf_{oc} and $DegT_{50}$; the three bars stands from left to right for: 75^{th} – 85^{th} percentile-, 85^{th} – 95^{th} percentile- and >95^{th} percentile-range of the total PEC distribution for maize; green: total area; line on the right: HH)

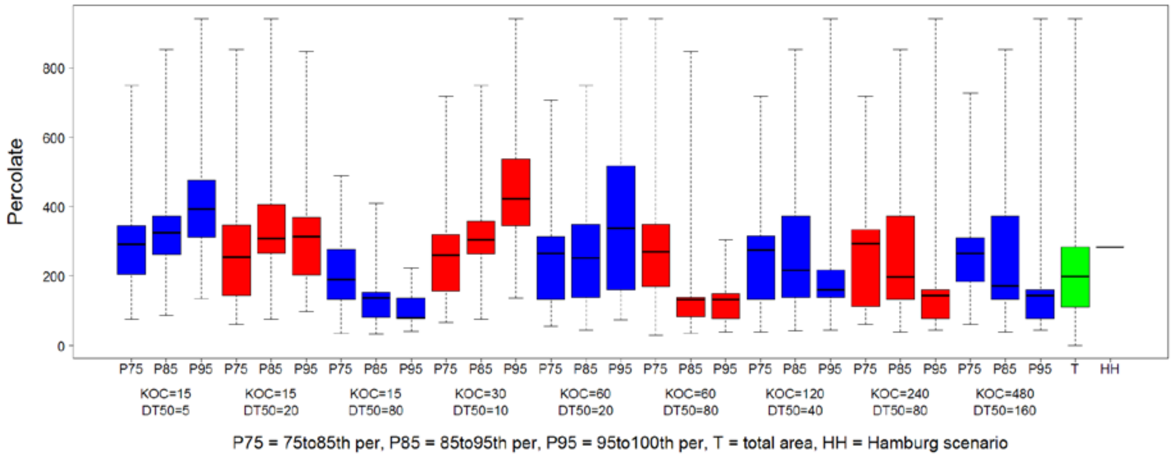


Figure 3-86: Distribution of the percolate inside different percentile ranges of the total distribution (one red or blue group of three bars stands for one test substance with specified Kf_{oc} and $DegT_{50}$; the three bars stands from left to right for: 75th – 85th percentile-, 85th – 95th percentile- and >95th percentile-range of the total PEC distribution for winter crop; green: total area; line on the right: HH)

- Potential evapotranspiration (PET):

The medians of the most compound/crop combinations in the 75th-85th as well as in the 85th-95th and the >95th spatial percentile classes show lower values than the median of 606 mm for the total agricultural area in Germany and the potential evapotranspiration of 610 mm for the FOCUS Hamburg scenario. This is in line with the expectation that lower evapotranspiration leads to higher PECs since more leachate reaches deeper soil layers in this case. However, looking at the trends between the PEC ranges in the three upper spatial percentile classes (75th-85th, 85th-95th, >95th) for every compound, this is not visible in many cases. But nevertheless all the medians differ only about 30 mm in maximum to the total median. Finally, the potential evapotranspiration seems to be an influencing factor depending on the crop and the Kf_{oc} values. The substances with a Kf_{oc} up to 60 in combination with an application in corn show a more consistent trend than the same substances applied in winter cereals: an increase in the PET amount with increasing PEC values can be observed. This might be due to a concentration effect.

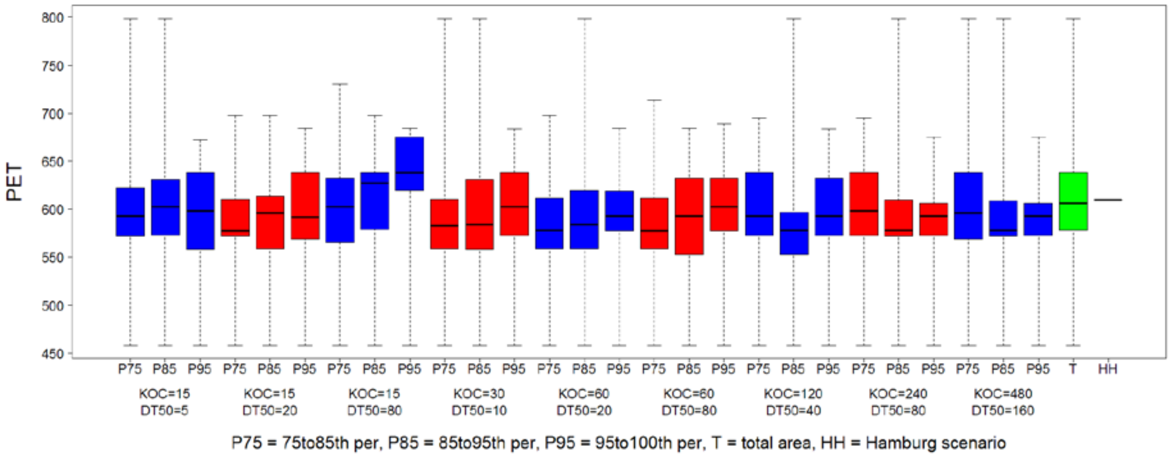


Figure 3-87: Distribution of the potential evapotranspiration inside different percentile ranges of the total distribution (one red or blue group of three bars stands for one test substance with specified Kf_{oc} and $DegT_{50}$; the three bars stands from left to right for: 75th – 85th percentile-, 85th – 95th percentile- and >95th percentile-range of the total PEC distribution for maize; green: total area; line on the right: HH)

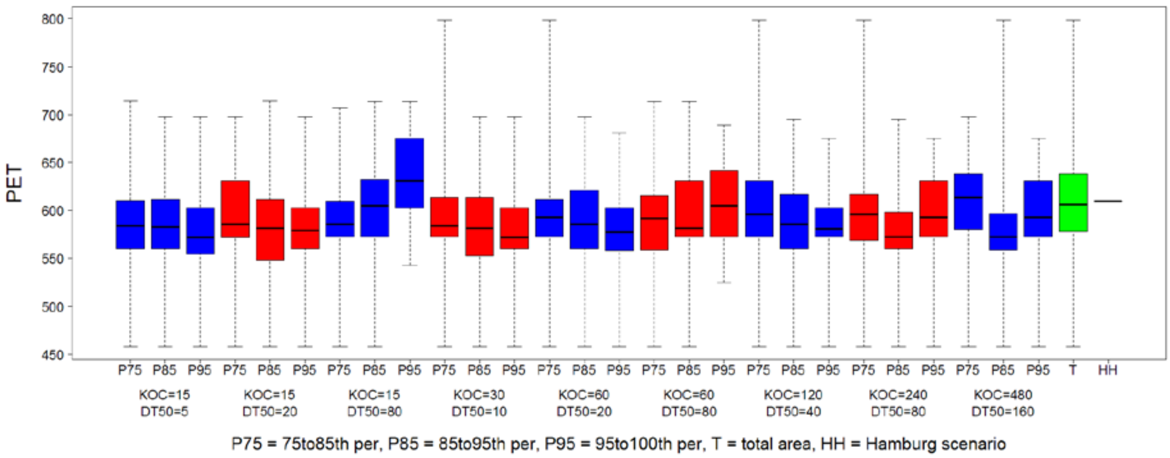


Figure 3-88: Distribution of the potential evapotranspiration inside different percentile ranges of the total distribution (one red or blue group of three bars stands for one test substance with specified Kf_{oc} and $DegT_{50}$; the three bars stands from left to right for: 75th – 85th percentile-, 85th – 95th percentile- and >95th percentile-range of the total PEC distribution for winter cereals; green: total area; line on the right: HH)

- Runoff:

All median values of the different compounds and upper spatial percentile classes are higher than calculated in the FOCUS Hamburg scenario since runoff is not considered in the normal regulatory simulation practice (value is set to 0). Even if the runoff amounts show quite a high scattering in the total distributions, the median values of the spatial percentile class 75th-85th are still quite comparable to the overall median value of 22 mm. The expectation of decreasing runoff amounts with higher PECs, especially in the upper spatial percentile classes (75^{th}-85^{th}, 85^{th}-95^{th}, >95^{th}) cannot be observed. Even a slight trend of increasing runoff with increasing PECs is visible for some substances in the upper percentile classes. Increasing runoff in areas with high precipitation amounts could be an explanation of such relationships. However, there is no direct influence visible between the calculated runoff and resulting groundwater PECs in PELMO.

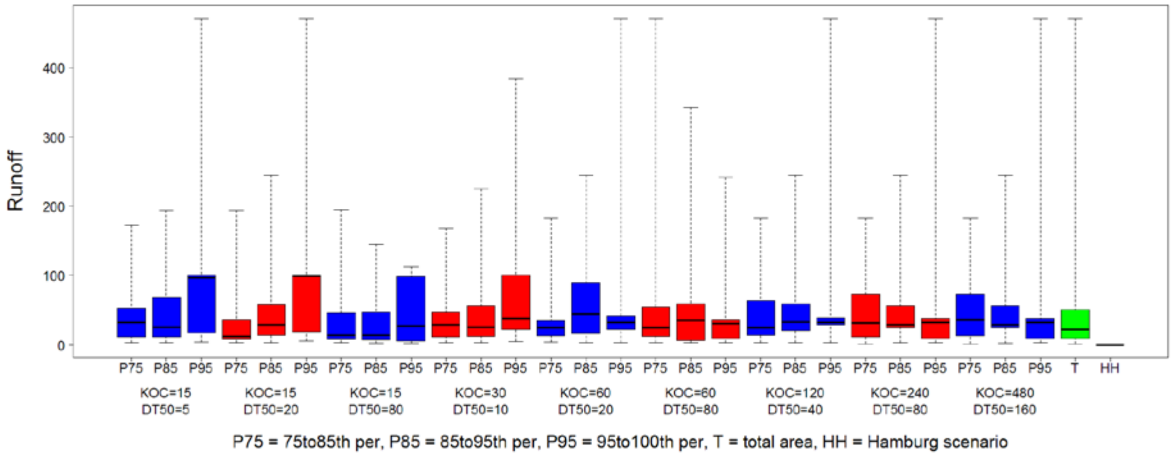


Figure 3-89: Distribution of the runoff inside different percentile ranges of the total distribution (one red or blue group of three bars stands for one test substance with specified Kf_{oc} and $DegT_{50}$; the three bars stands from left to right for: 75^{th} – 85^{th} percentile-, 85^{th} – 95^{th} percentile- and >95^{th} percentile-range of the total PEC distribution for maize; green: total area; line on the right: HH)

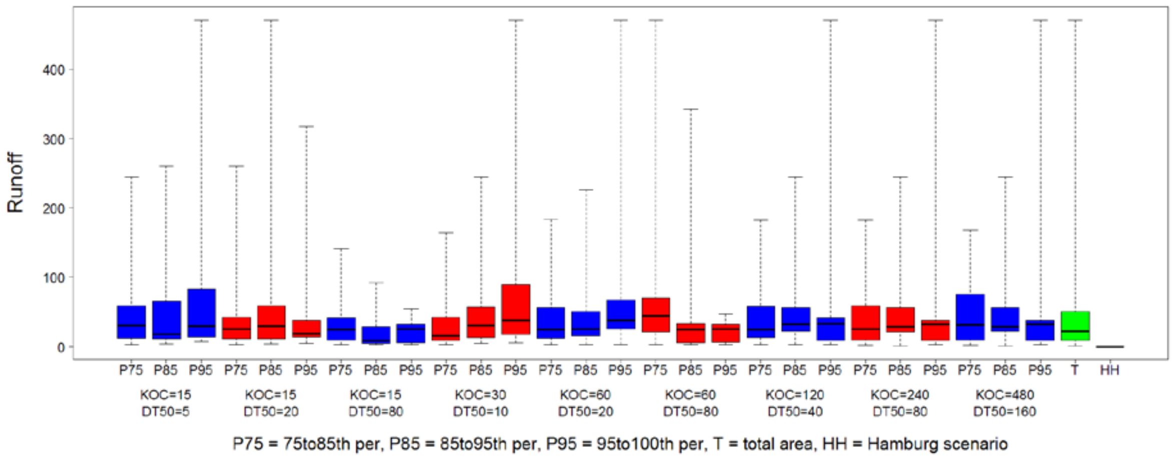


Figure 3-90: Distribution of the runoff inside different percentile ranges of the total distribution (one red or blue group of three bars stands for one test substance with specified Kf_{oc} and $DegT_{50}$; the three bars stands from left to right for: 75^{th} – 85^{th} percentile-, 85^{th} – 95^{th} percentile- and >95^{th} percentile-range of the total PEC distribution for winter cereals; green: total area; line on the right: HH)

- Organic carbon content in the 1 m soil profile (C_{org}):

All medians in the 75th-85th as well as in the 85th-95th and the >95th spatial percentile classes concerning the averaged organic carbon content in 1 m soil depth are lower than the median value of 0.67 % for the total agricultural area in Germany and the value of 0.78 % for the FOCUS Hamburg scenario. Beside, a clear trend of decreasing organic carbon contents in soil with higher PECs can be still observed for most dummy substances in maize and winter cereals in the three upper percentile classes (75th-85th, 85th-95th, >95th). There is evidence for this distinctive trend especially for substances with higher Kf_{oc} values (>= 60) as well as for the dummy substance with a Kf_{oc} of 15 and $DegT_{50}$ of 80 days (the latter in winter cereals only). Finally, there is evidence from the STEP 2 analysis that the organic carbon content in soil is a key parameter for the PEC modelling for all tested substances and different crops (application times), whereat the influence might be more strong for compounds with higher adsorption values (Kf_{oc} > 60). The organic carbon content of 0.78 % in the FOCUS Hamburg is still higher as the median value of 0.67 % for the total agricultural area in Germany but does not represent an appropriate scenario parametrisation.

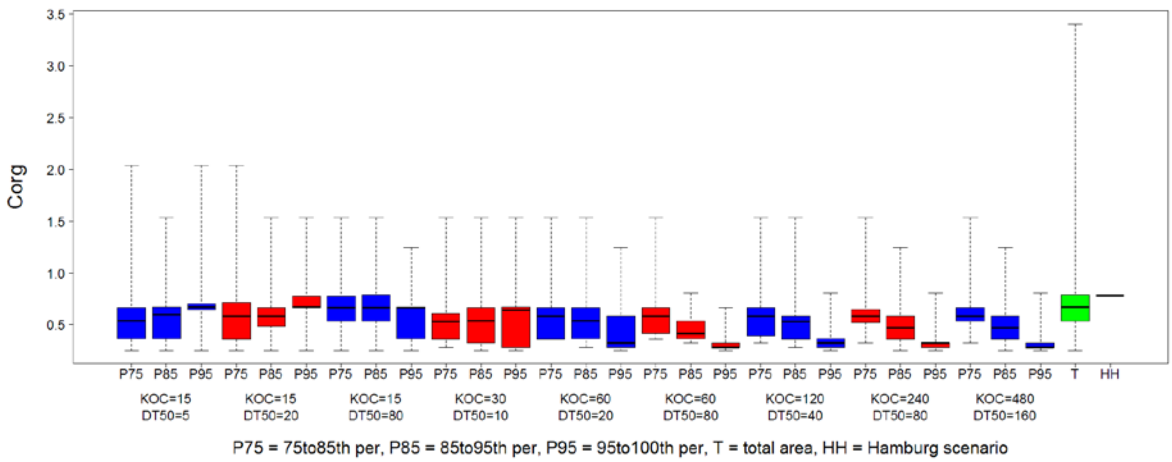


Figure 3-91: Distribution of the Corg-content inside different percentile ranges of the total distribution (one red or blue group of three bars stands for one test substance with specified Kf_{oc} and $DegT_{50}$; the three bars stands from left to right for: 75th – 85th percentile-, 85th – 95th percentile- and >95th percentile-range of the total PEC distribution for maize; green: total area; line on the right: HH)

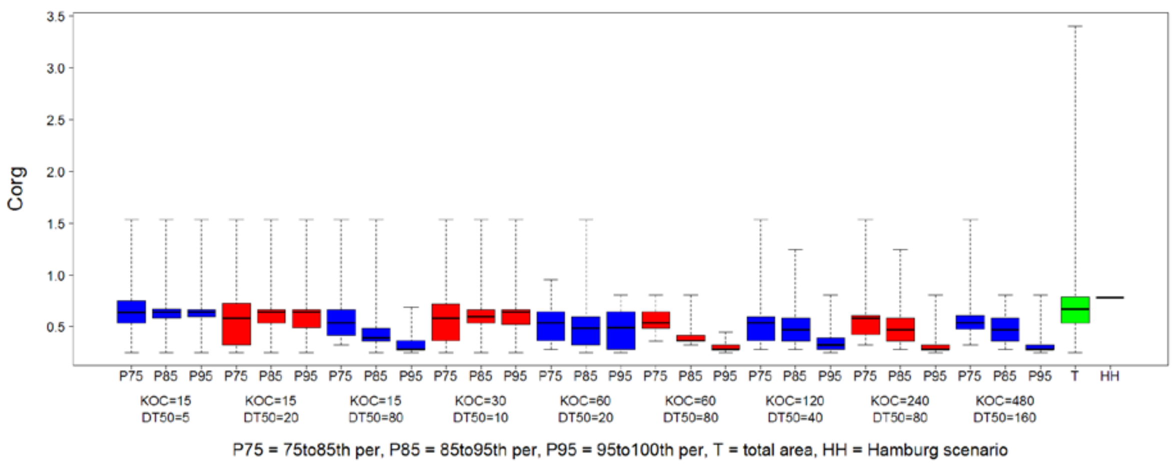


Figure 3-92: Distribution of the Corg-content inside different percentile ranges of the total distribution (one red or blue group of three bars stands for one test substance with specified Kf_{oc} and $DegT_{50}$; the three bars stands from left to right for: 75th – 85th percentile-, 85th – 95th percentile- and >95th percentile-range of the total PEC distribution for winter cereals; green: total area; line on the right: HH)

- Available water capacity:

Concerning this soil hydrologic parameter all medians lie distinctly below the Hamburg value of 20 % and most of them lie on the same level like the total median (16 %). For the most compounds the medians of the different PEC-percentile-ranges show very little variations. Only some medians of substances with low Kf_{oc} values in combination with short $DegT_{50}$ values, considered as being fast leaching substances, decrease with increasing PECs which matches expectations since soils with a lower available field capacity can store less leachate.

In course of this project it could not be clarified why the FOCUS Hamburg value is that high though it is a sandy soil in the deeper soil horizons (60-100 cm). The reference value for sand soils from the BKA5 is 7 %.

In the upper two horizons (0-60 cm) there's a higher silt content and the reference value for the available water capacity in these soil horizons is 21 %.

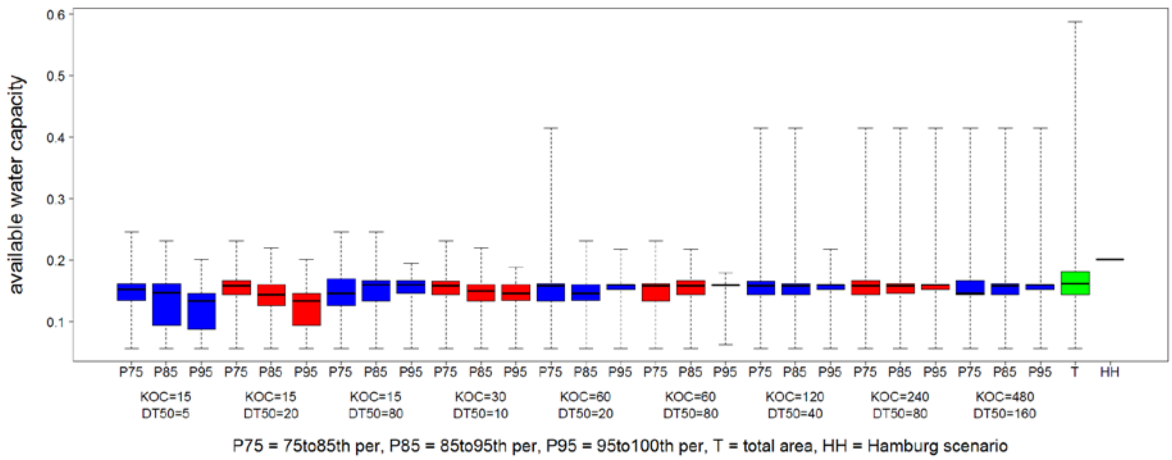


Figure 3-93: Distribution of the aWC inside different percentile ranges of the total distribution (one red or blue group of three bars stands for one test substance with specified Kf_{oc} and $DegT_{50}$; the three bars stands from left to right for: 75th – 85th percentile-, 85th – 95th percentile- and >95th percentile-range of the total PEC distribution for maize; green: total area; line on the right: HH)

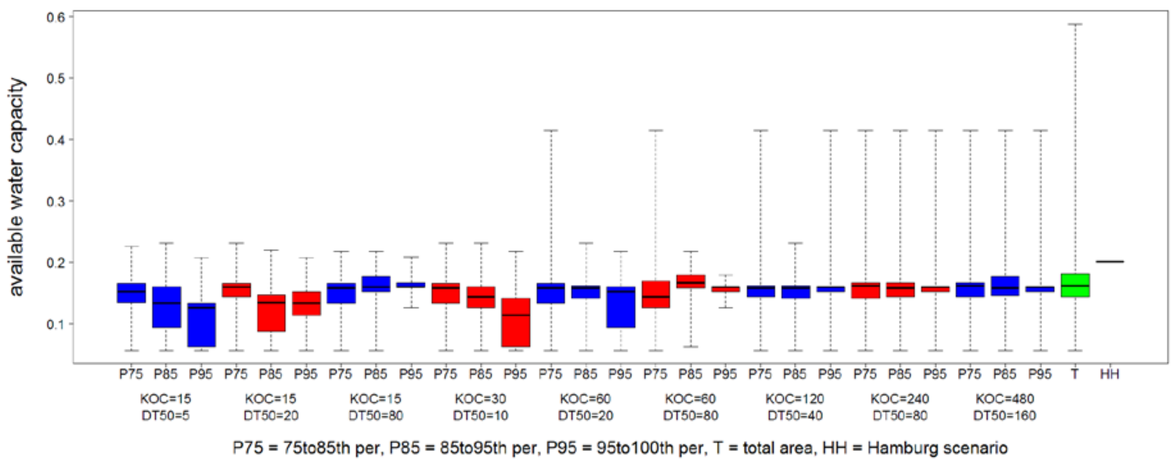


Figure 3-94: Distribution of the aWC inside different percentile ranges of the total distribution (one red or blue group of three bars stands for one test substance with specified Kf_{oc} and $DegT_{50}$; the three bars stands from left to right for: 75th – 85th percentile-, 85th – 95th percentile- and >95th percentile-range of the total PEC distribution for winter cereals; green: total area; line on the right: HH)

- Biodegradation factor:

The medians of all compound/crop combinations concerning the BF have the same value of 0.55. The Hamburg value is slightly higher (0.57). The reason for the difference is that the Hamburg soil profile is not parameterised in line with the FOCUS convention which states a BF of 0.5 up to the depth of 50 cm. The Hamburg soil profile has a BF of 0.5 up to the depth of 60 cm.

A slight trend can be seen that the biodegradation factor decreases with higher PECs but this observation cannot be made for all compounds. It is mainly valid for major leaching compounds. The reason for lower BF values is the minor total thickness of some soil profiles from the BÜK 1000 N database.

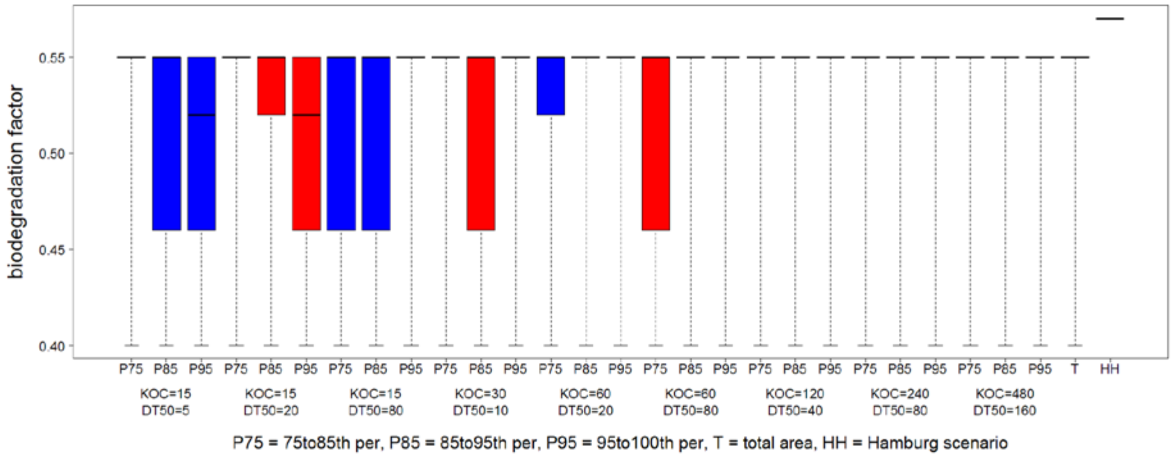


Figure 3-95: Distribution of the biodegradation factor inside different percentile ranges of the total distribution (one red or blue group of three bars stands for one test substance with specified Kf_{oc} and $DegT_{50}$; the three bars stands from left to right for: 75th – 85th percentile-, 85th – 95th percentile- and >95th percentile-range of the total PEC distribution for maize; green: total area; line on the right: HH)

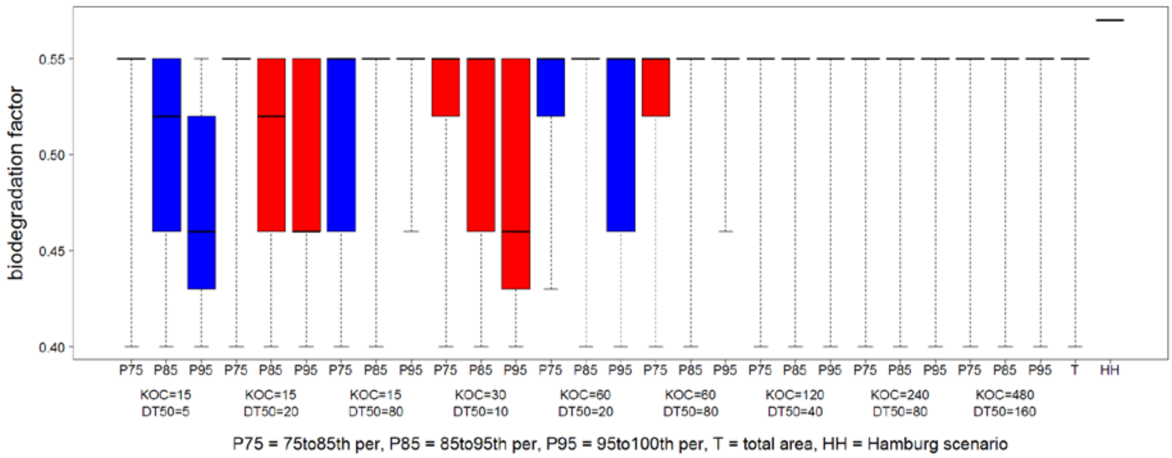


Figure 3-96: Distribution of the biodegradation factor inside different percentile ranges of the total distribution (one red or blue group of three bars stands for one test substance with specified Kf_{oc} and $DegT_{50}$; the three bars stands from left to right for: 75th – 85th percentile-, 85th – 95th percentile- and >95th percentile-range of the total PEC distribution for winter cereals; green: total area; line on the right: HH)

- Soil profile depth:

As the PEC_{GW} values were calculated in a depth of 1 m and the soil profiles were thus investigated only to this depth, it is not surprising that most of the medians are at 1 m. Only a few number of soil profiles in the BÜK 1000 N show a depth less than 1 m. But these soil profiles are found to be vulnerable for leaching of major leaching compounds, as especially in higher percentile ranges (85th-95th and the >95th percentile), the median soil depth decreases remarkably.

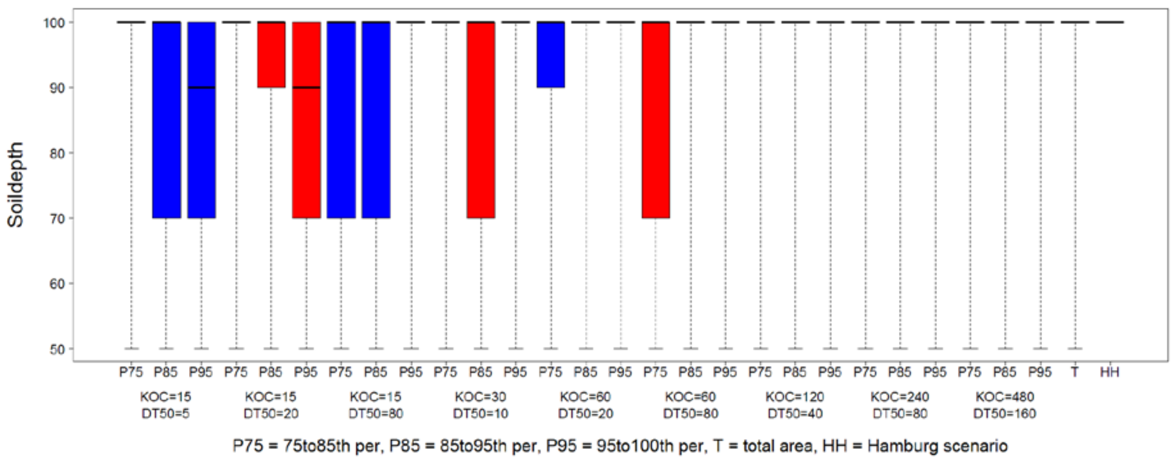


Figure 3-97: Distribution of the soil profile depth inside different percentile ranges of the total distribution (one red or blue group of three bars stands for one test substance with specified Kf_{oc} and $DegT_{50}$; the three bars stands from left to right for: 75th – 85th percentile-, 85th – 95th percentile- and >95th percentile-range of the total PEC distribution for maize; green: total area; line on the right: HH)

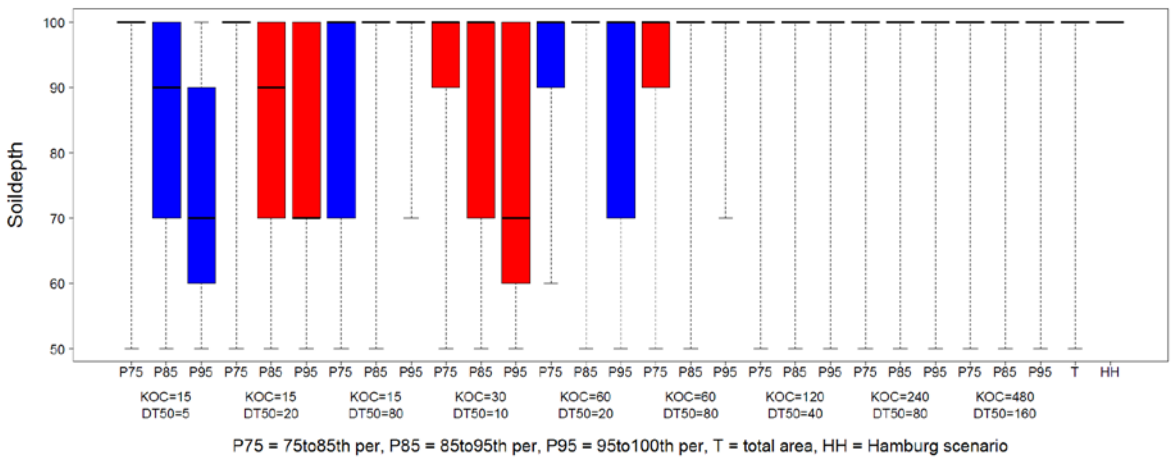


Figure 3-98: Distribution of the soil profile depth inside different percentile ranges of the total distribution (one red or blue group of three bars stands for one test substance with specified Kf_{oc} and $DegT_{50}$; the three bars stands from left to right for: 75th – 85th percentile-, 85th – 95th percentile- and >95th percentile-range of the total PEC distribution for winter cereals; green: total area; line on the right: HH)

3.5 Alternative scenarios based on the results of the step 2 analysis

Considering the results of the analysis of the spatial protection level of the FOCUS Hamburg scenario in chapter 3.4.2, a further analysis was conducted based on the GISPELMO parametrisation in step 2 in order to derive different alternative leaching scenarios for Germany. Therefore regions and locations were identified which represent the 80th spatial percentile of the nationwide agricultural area, taking into account the 80th temporal percentile of 20 sequent weather years.

3.5.1 Methodology

Following principles were applied to identify alternative realistic worst case leaching scenarios in Germany:

- GISPELMO results of all meaningful crop-substance combinations (see crosses in Table 3-29) were considered.
- The 80th temporal percentile of the PECs from 20 years simulation period was preselected.
- The 80th spatial percentile was the target.
- As the target spatial percentile is technically speaking only a single raster cell of the German agricultural area (in the GIS) a range of locations around the target percentile was considered (80 ± 5 %) to receive a reasonable area for the selection of relevant scenarios.
- For a first step, the alternative scenario selection was based on an overlap of all 18 crop-compound maps each with the 80th percentile, to be independent on the used crop/compound-combinations.
- If total overlap was not reached further scenarios were defined in a second step based on sub-classes:
  - major leaching compounds (Kf_{oc} up to 60, 12 crop-compound combinations)
  - less-leaching compounds (Kf_{oc} above 60, 6 crop-compound combinations)
  - winter cereals (9 crop-compound combinations)
  - maize (9 crop-compound combinations)

3.5.2 Results

The areas which represent the 80 ± 5th spatial percentile of the 80th temporal annual concentrations in percolate were calculated for 9 substances and 2 crops, all with annual applications one day before emergence of the crop. The results for one single compound with Kf_{oc} of 60 L/kg and a $DegT_{50}$ of 20 days are shown in Figure 3-99.

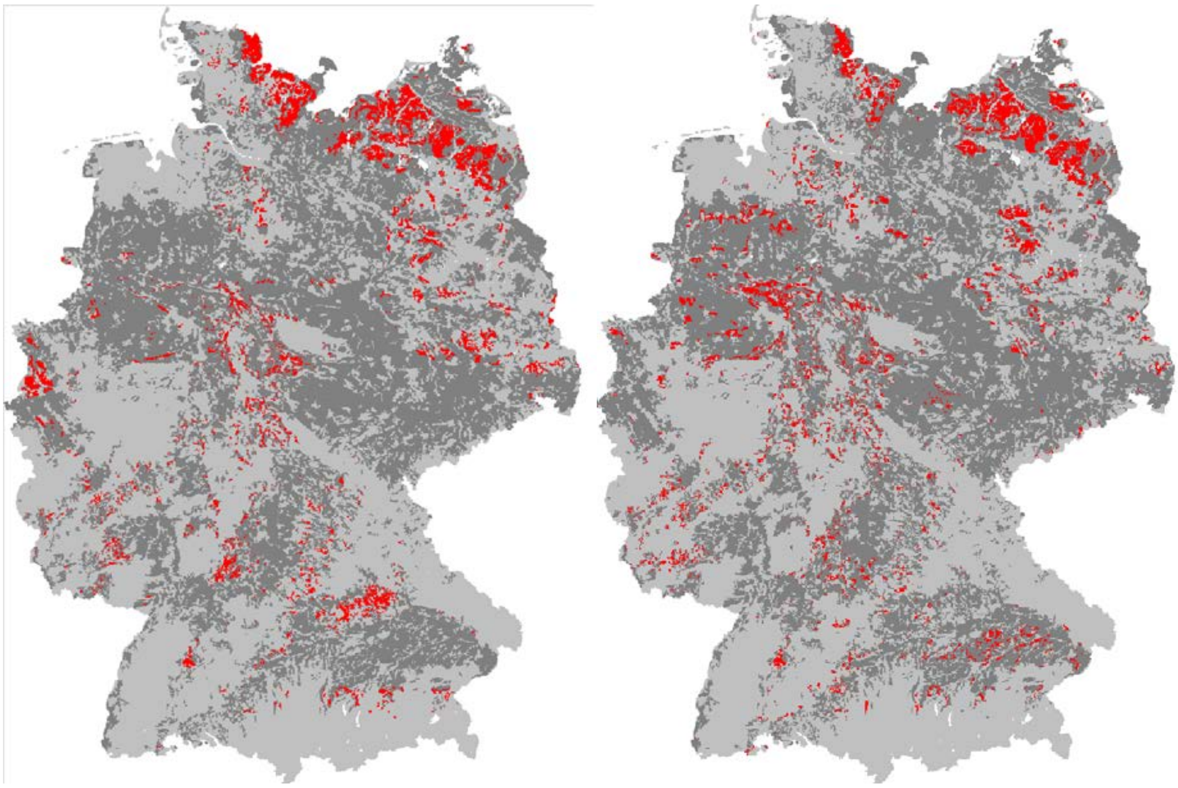


Figure 3-99: Distribution of the 80 +/- 5th spatial percentile of the 80th temporal percentiles of annual concentrations (Kf_{oc} 60 L/kg, $DegT_{50}$ 20 d, left: winter cereals, right: maize)

Obviously, there is some overlap between the two maps in Figure 3-99 indeed there are regions where only one of the crops has its 80th spatial percentile. This result is can be expected since applications in autumn usually lead to different leaching behaviour compared to spring applications and consequently also to difference in the vulnerability pattern for Germany. Similar leaching maps were calculated for all 18 crop-compound-combinations, too. The results are presented in appendix 6.

Figure 3-100 presents the aggregated results for all these calculations. Only few locations are marked in black representing 80th spatial percentiles for most of the tested compounds. All black raster cells (total area: 6 km^2) belong to two combinations of different soil profiles and weather stations. The more representative is BÜK profile 35 31 212 together with the DWD station Kassel in Hessen.

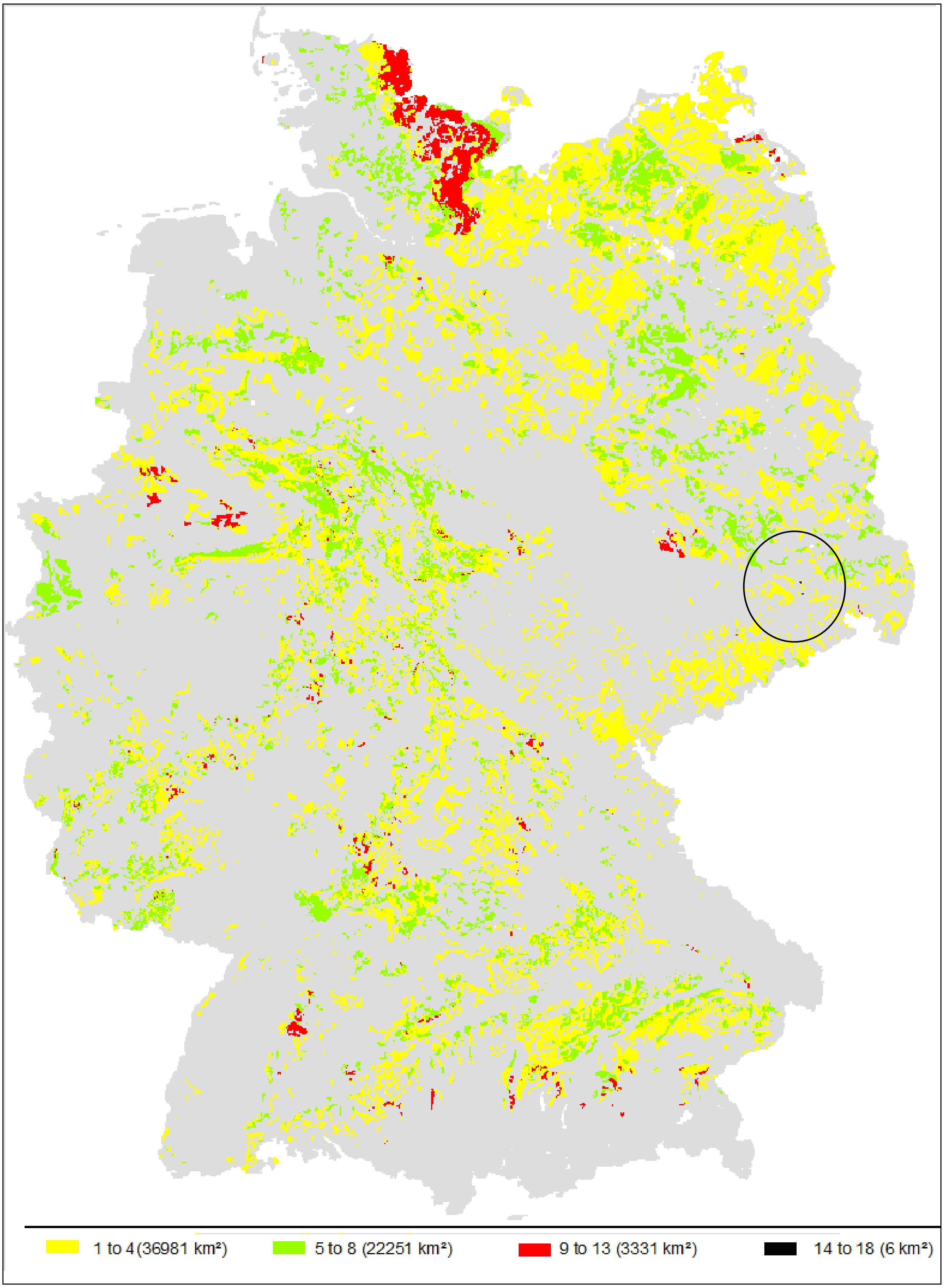


Figure 3-100: Overlap of 18 leaching maps showing the 80 +/- 5th spatial percentile of the 80th temporal percentiles of annual concentrations (The numbers in the legend show how often a location is represented in the percentile class 80+/- 5% of all different crop-compound-combinations)

In Table 3-34 and Table 3-35 soil and climate information about the selected alternative scenario are presented, respectively.

Table 3-34: Soil profile of the area with most overlaps in the 80th spatial percentile class (based on BÜK 1000 N profile: 35 31 212 – "Braunerde Podsol")

Soil horizon	Depth (cm)	Density (g/cm^3)	Field capacity (m^3/m^3)	Wilting point (m^3/m^3)	Sand content (%)	Clay content (%)	C_{org} (%)	pH (-)	Biodegradation factor (-)
1	30	1.28	0.27	0.09	76	6.5	0.90	5.05	1.0
2	20	1.36	0.21	0.05	80	2.5	0.31	5.05	0.5
3	10	1.36	0.21	0.05	80	2.5	0.31	5.05	0.5
4	40	1.46	0.23	0.06	76	6.5	0.31	5.05	0.3
5	20	1.46	0.23	0.06	76	6.5	0.31	5.05	0.3
6	80	1.55	0.17	0.02	93	2.5	0	5.05	0

Table 3-35: Climate information of the area with the most overlays in the 80th spatial percentile class (based on DWD weather station Kassel, Hessen)

	Temperature (°C)	Precipitation (mm)
Spring	9.2	166
Summer	17.5	210
Autumn	9.2	180
Winter	1.2	166
Summer half-year	14.8	378
Winter half-year	3.8	343
Year	9.3	721

Compared to the FOCUS Hamburg scenario there is less rainfall (e.g. annual precipitation of FOCUS Hamburg: 788 mm). However, the organic carbon contents with depth are significantly lower than for the official FOCUS Scenario (FOCUS Hamburg: 0.780 %, alternative scenario: 0.487 %). It is in line with previous results that the alternative scenario is overall based on less organic carbon in soil since the analysis presented earlier showed that FOCUS Hamburg does not represent the 80th spatial percentile for Germany.

3.5.2.1 Major leaching substances

For this analysis only the substances which Kf_{oc} values up to 60 L/kg were considered. In total 12 crop-compound combinations belong to this group. The minimum number of overlaps for a raster cell to be considered in the further analysis (= black colour) was set to 11. The total size of this area was again 4 km^2 and they are identical to the previously described Kassel weather station together with soil profile 35 31 212.

Further information about this scenario can be found in the previous section.

3.5.2.2 Less leaching compounds

For this analysis only the substances which Kf_{oc} values above 60 L/kg were considered. In total 6 crop-compound combinations belong to this group. The minimum number of overlaps for a raster cell to be considered in the further analysis (= black colour) was set to 6. Figure 3-101 shows a wide spread distribution of overlaps which represent 44 different possible soil-weather scenarios. The most representative of these scenarios were found to be the weather station Altomünster-Maisbrunn in Bavaria (1004 km^2) and Neuruppin in Brandenburg (759 km^2). The weather information for these two scenarios is presented in Table 3-36. The averaged weather parameters are quite different indeed GISPELMO simulated comparable percolate concentrations for both scenarios. Whereas the climate of Altomünster-Maisbrunn is characterised by high amounts of precipitation (similar as FOCUS Kremsmünster), Neuruppin represents one of the driest area in Germany. The reason for similar PEC estimations can be found when looking at the respective soil profiles (see Table 3-37 and Table 3-38). The dry weather of Neuruppin is combined with a soil profile characterised by very low organic carbon content (0.363 %) whereas the soil characteristics combined with the wetter climate in Bavaria is more similar with the FOCUS Hamburg scenario.

Table 3-36: Climate information of the two most representative locations with overlaps in the 80th spatial percentile class (Less leaching substances)

	Altomünster-Maisbrunn		Neuruppin	
	Temperature (°C)	Precipitation (mm)	Temperature (°C)	Precipitation (mm)
Spring	8.6	212	9.0	122
Summer	17.4	314	18.1	171
Autumn	8.4	194	9.4	130
Winter	-0.2	157	1.1	126
Summer half-year	14.5	527	15.2	301
Winter half-year	2.6	350	3.6	249
Year	8.6	877	9.4	549

Table 3-37: Soil profile of one of the two most representative locations in the 80th spatial percentile class for less-leaching compounds (based on BÜK N profile: 35 12 211 – “Braunerde-Gley” – in combination with DWD weather station Neuruppin)

Soil horizon	Depth (cm)	Density (g/cm³)	Field capacity (m³/m³)	Wilting point (m³/m³)	Sand content (%)	Clay content (%)	C_{org} (%)	pH (-)	Biodegradation factor (-)
1	30	1.28	0.27	0.09	76	6.5	0.90	5.05	1.0
2	10	1.50	0.23	0.06	76	6.5	0.31	5.05	0.5
2	10	1.40	0.21	0.06	80	2.5	0.31	5.05	0.5
3	10	1.40	0.21	0.05	80	2.5	0.31	5.05	0.3
4	40	1.40	0.21	0.05	80	2.5	0	5.05	0.3
5	100	1.55	0.16	0.03	93	2.5	0	5.75	0

Table 3-38: Soil profile of one of the two most representative locations in the 80th spatial percentile class for less leaching compounds (based on BÜK N profile: 34 42 211 – “Pseudogley-Parabraunerde” – in combination with DWD weather station Altomünster-Maisbrunn)

Soil horizon	Depth (cm)	Density (g/cm³)	Field capacity (m³/m³)	Wilting point (m³/m³)	Sand content (%)	Clay content (%)	C_{org} (%)	pH (-)	Biodegradation factor (-)
1	30	1.21	0.40	0.18	9	74	1.50	6.45	1.0
2	10	1.40	0.36	0.12	12	74	0.44	6.45	0.5
3	10	1.45	0.34	0.12	5	77	0.44	6.45	0.5
4	10	1.45	0.34	0.22	5	70	0.44	6.45	0.3
5	10	1.45	0.34	0.22	5	70	0	6.45	0.3
6	30	1.45	0.34	0.22	5	70	0	6.45	0.3
7	20	1.45	0.34	0.22	5	70	0	6.45	0.3
8	100	1.40	0.36	0.12	12	77	0	7.00	0

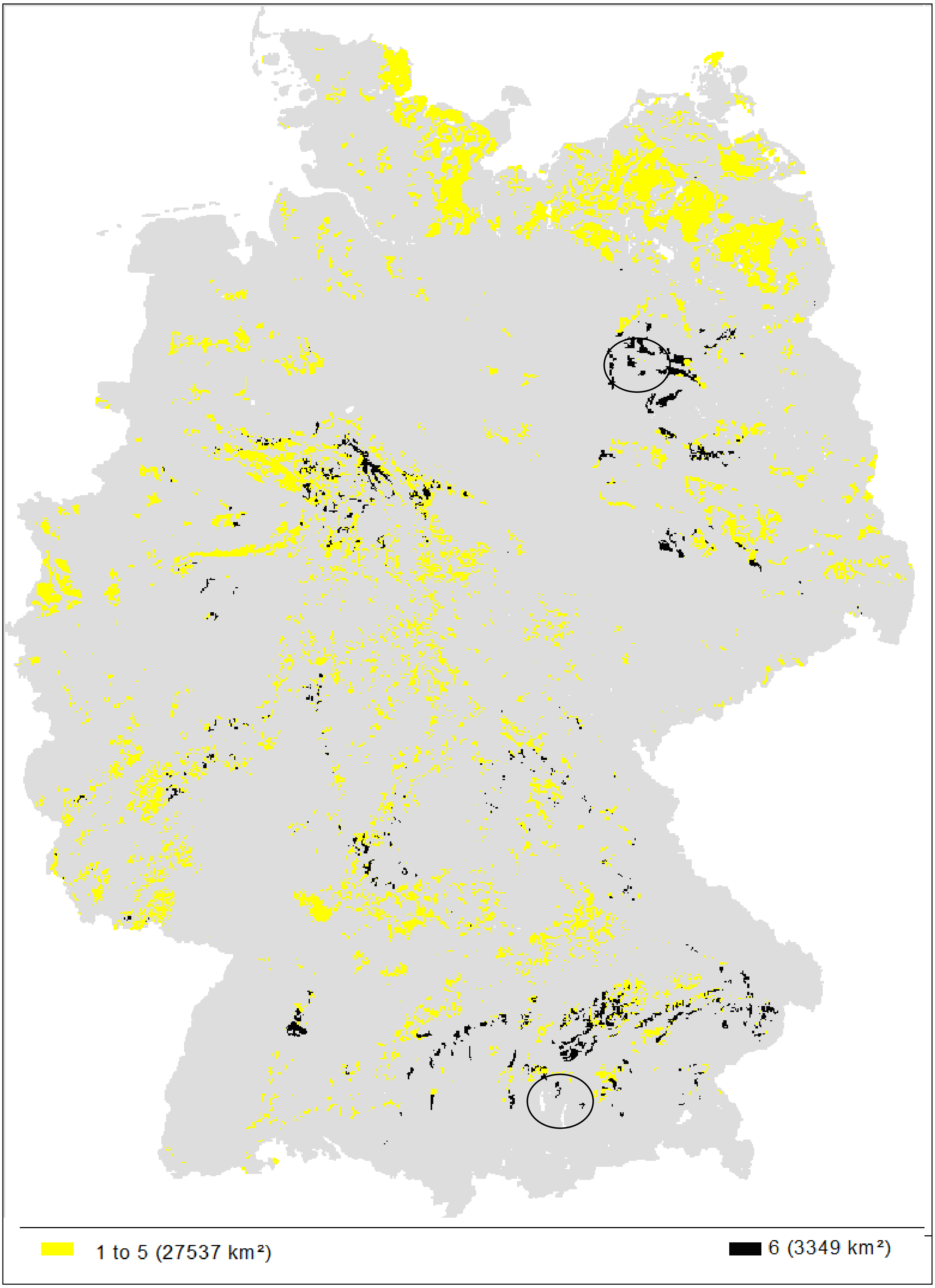


Figure 3-101: Overlap of 6 crop-compound combinations showing the 80 +/- 5th spatial percentile of the 80th temporal percentiles of annual concentrations for less leaching compounds (The numbers in the legend show how often a location is represented in the percentile class 80 +/- 5% for less leaching compounds)

3.5.2.3 Winter cereals

For this analysis only the 9 crop-compound combinations with winter cereals as typical crop for applications in autumn and winter were considered. The minimum number of overlaps for a raster cell to be considered in the further analysis (= black colour) was set to 9. Figure 3-102 presents the aggregated results for all these calculations. An area of 4 km^2 is marked in black representing the 80^{th} spatial percentile for all 9 compounds. The area is mainly located west of Göttingen (annual rainfall: 808 mm).

All black pixels in the map belong to one single combination of one soil profile and one weather station which is the BÜK profile 33 42 211 in combination with the DWD station Berus in the Saarland (average annual rainfall: 777 mm, average annual temperature: 9.6 °C). Although the real geographic distance of the weather station to the soil profile is rather big, the Euklidic distance with regard to seasonal temperature and rainfall at both locations are rather small. Detailed information about the scenarios is given in the following two tables.

Table 3-39: Soil profile of the area with most overlaps in the 80^{th} spatial percentile class for compounds applied in winter cereals (based on BÜK N profile: 33 42 211, “Normparabraunerde”)

Soil horizon	Depth (cm)	Density (g/cm³)	Field capacity (m³/m³)	Wilting point (m³/m³)	Sand content (%)	Clay content (%)	C_{org} (%)	pH (-)	Biodegradation factor (-)
1	30	1.21	0.40	0.18	9	9	1.30	6.45	1.0
2	20	1.40	0.36	0.12	12	12	0.44	6.45	0.5
3	10	1.40	0.36	0.16	9	9	0.44	6.45	0.3
4	40	1.40	0.34	0.16	9	9	0	6.45	0.3
5	10	1.40	0.36	0.12	12	12	0	6.45	0
6	90	1.40	0.36	0.12	12	12	0	7.00	0

Table 3-40: Climate information of the most representative location with overlaps in the 80th spatial percentile class (winter cereals)

Climate	Berus (4 km²)	
	Temp (°C)	Precipitation (mm)
Spring	5.0	174
Summer	8.0	189
Autumn	9.6	195
Winter	1.6	220
Summer half-year	15.0	359
Winter half-year	4.2	419
Year	9.6	777

The rainfall of this scenario is comparable to FOCUS Hamburg. However, the average organic carbon content in soil (0.522 %) is significant lower than the FOCUS scenario (0.780 %).

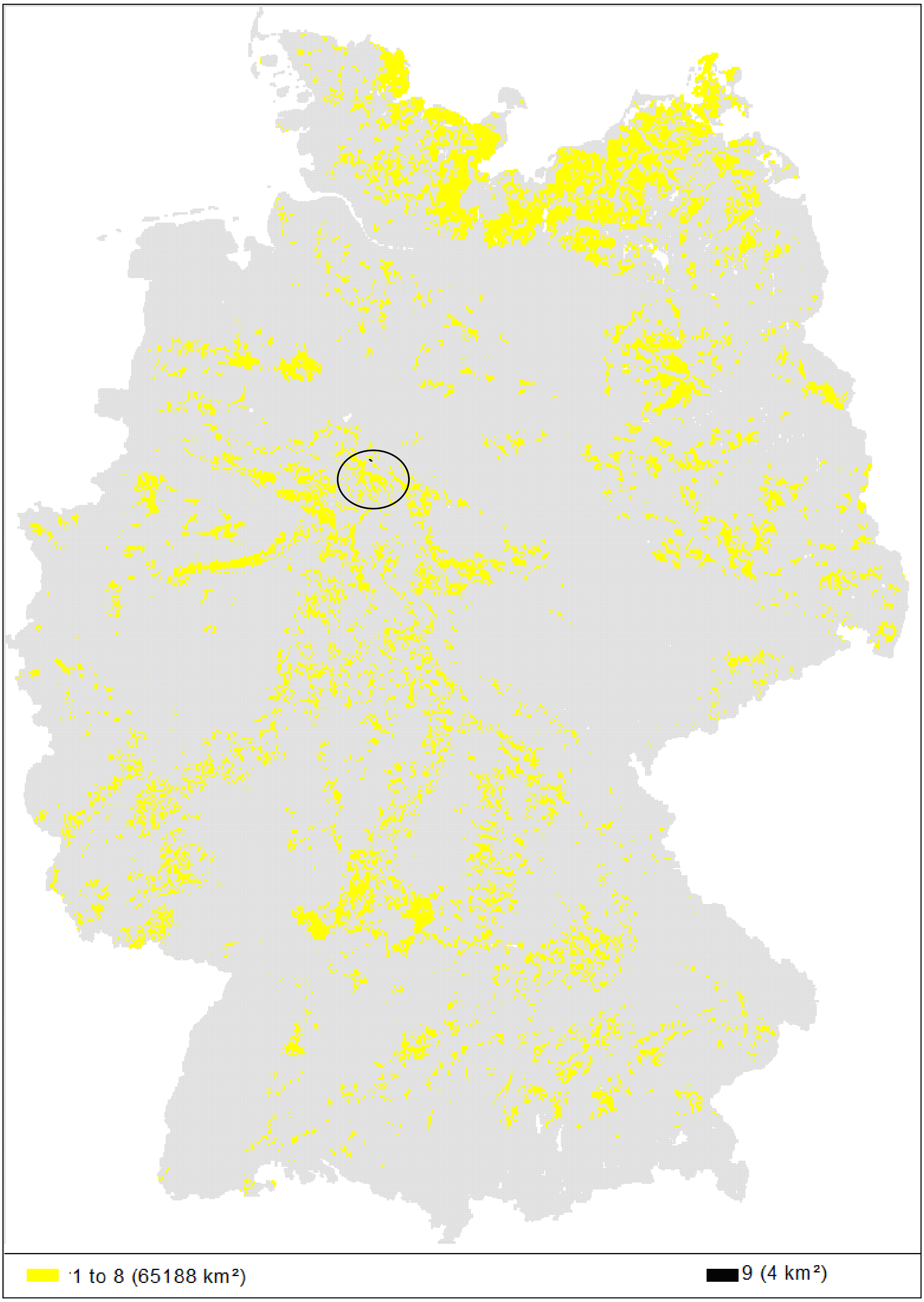


Figure 3-102: Overlap of 9 crop-compound combinations showing the 80 +/- 5th spatial percentile of the 80th temporal percentiles of annual concentrations for applications in winter cereals (The numbers in the legend show how often a location is represented in the percentile class 80 +/- 5% for winter cereals)

3.5.2.4 Maize

For this analysis only the 9 crop-compound combinations for maize were considered. The minimum number of overlaps for a pixel to be considered in the further analysis (= black colour) was set to 8. Figure 3-103 presents the aggregated results for all these calculations. 6 km^2 are marked in black representing 80th spatial percentiles for 8 of the 9 crop-compound combinations. The marked area is located close to Sankt Peter-Ording, where the average annual rainfall with 837 mm is slightly higher than in the FOCUS Hamburg scenario.

The soil profile which is combined with the DWD weather station was the BÜK profile 33 25 211. Detailed soil and climate information about the representative scenario for spring applications only is given in the following two tables.

Table 3-41: Soil profile of the area with most overlaps in the 80th spatial percentile class for compounds applied in maize (based on BÜK N profile: 33 25 211, “Pseudogley-Podsol”)

Soil horizon	Depth (cm)	Density (g/cm³)	Field capacity (m³/m³)	Wilting point (m³/m³)	Clay content (%)	Sand content (%)	C_{org} (%)	pH (-)	Biodegradation factor (-)
1	30	1.28	0.27	0.09	6.5	76	1.90	5.05	1.0
2	20	1.50	0.23	0.06	6.5	76	0.31	5.75	0.5
3	10	1.50	0.23	0.06	6.5	76	0.31	5.75	0.3
4	10	1.50	0.23	0.06	6.5	76	0	5.75	0.3
5	30	1.40	0.28	0.11	14.5	61	0	6.45	0
6	100	1.50	0.29	0.19	35.0	43	0	7.00	0

Table 3-42: Climate information of the most representative location with overlaps in the 80th spatial percentile class (maize)

	St Peter Ording (5 km²)	
	Temp (°C)	Precipitation (mm)
Spring	8.1	139
Summer	16.9	235
Autumn	10.2	266
Winter	2.2	198
Summer half-year	14.3	407
Winter half-year	4.5	431
Year	9.4	838

Although the average annual rainfall of this scenario is comparable to the FOCUS Hamburg scenario the average organic carbon content in soil (0.575 %) is much lower than in the FOCUS Hamburg scenario (0.780 %). Hence, the alternative scenario is more vulnerable than FOCUS Hamburg.

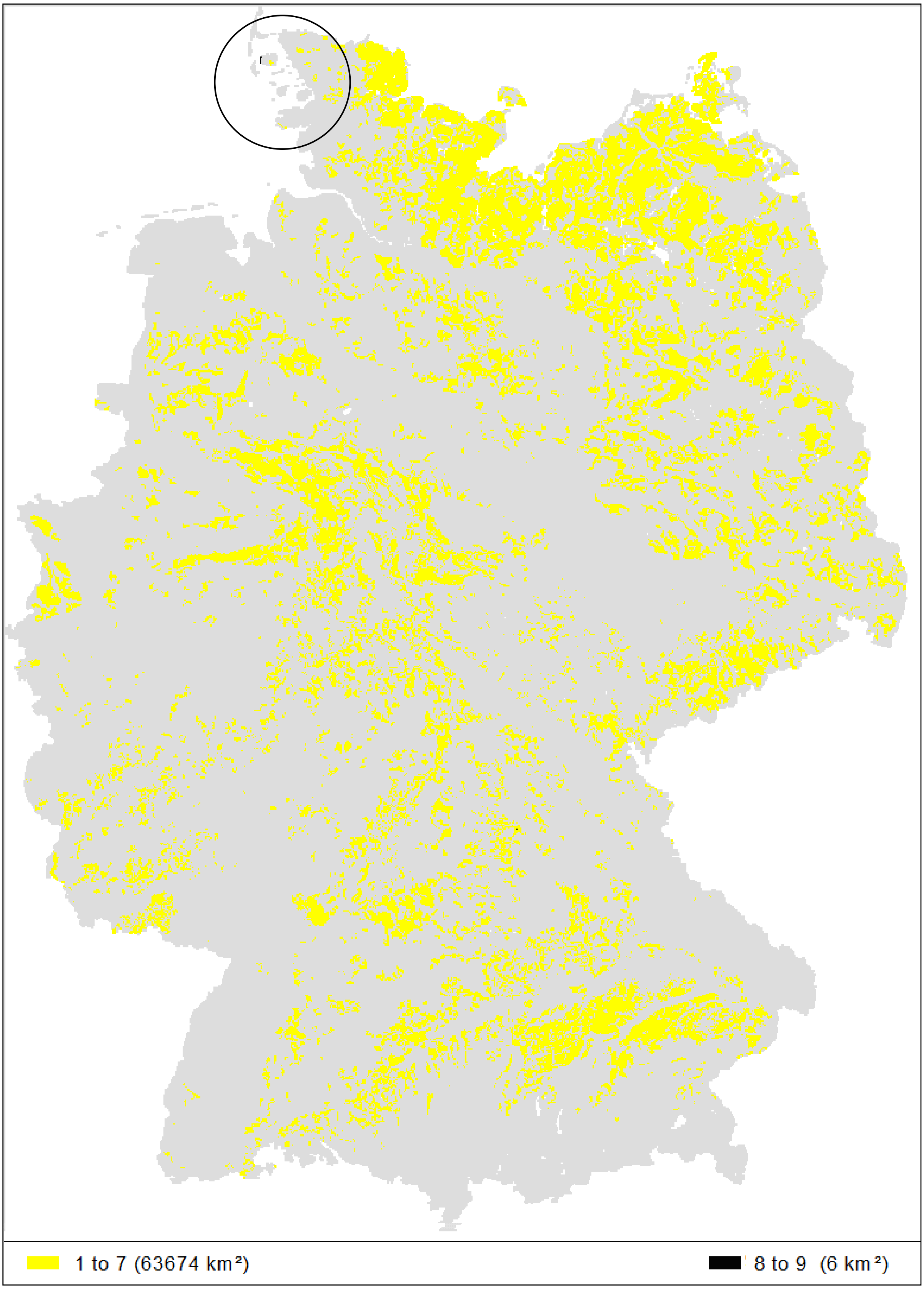


Figure 3-103: Overlap of 9 crop-compound combinations showing the 80 +/- 5th spatial percentile of the 80th temporal percentiles of annual concentrations for applications in maize (The numbers in the legend show how often a location is represented in the percentile class 80 +/- 5% for maize)

3.5.2.5 Special leaching scenario for alkaline soils

For this analysis all 18 crop-compound combinations were considered. The minimum number of overlaps for a raster cell to be considered in the further analysis was reduced to 10 in order to obtain a wider range of soil profiles. The most representative areas can be found in South Germany with Metten as typical DWD station in Bavaria. The average annual rainfall of 973 mm is about 200 mm higher than in the FOCUS Hamburg scenario.

The soil profile which was combined with the DWD weather station Metten was the BÜK profile 34 11 211. Detailed soil and climate information about the scenario is given in the following two tables. Figure 3-104 shows the areas with the same weather conditions like the station Metten and the areas where the soil profile 34 11 211 is located.

Table 3-43: Typical neutral to alkaline soil profile representative for the 80th spatial percentile class (based on BÜK 1000 N profile: 34 11 211, "Normkalkpaternia")

Soil horizon	Depth (cm)	Density (g/cm³)	Field capacity (m³/m³)	Wilting point (m³/m³)	Clay content (%)	Sand content (%)	C_{org} (%)	pH (-)	Biodegradation factor (-)
1	30	1.10	0.46	0.25	24	19	1.60	7.00	1.0
2	20	1.40	0.36	0.23	30	30	0.56	7.55	0.5
3	20	1.40	0.36	0.23	30	30	0.56	7.55	0.3
4	30	1.35	0.38	0.28	40	20	0	7.55	0.3
5	100	1.35	0.38	0.28	40	20	0	7.55	0

Table 3-44: Climate information of the most representative location with overlaps in the 80th spatial percentile class (alkaline soil pH)

	Metten (Bayern)	
	Temp (°C)	Precipitation (mm)
Spring	9.0	217.1
Summer	17.6	296.2
Autumn	8.5	222.7
Winter	-0.6	237.3
Summer half-year	14.9	508.7
Winter half-year	2.4	464.6
Year	9.4	973.3

Although the organic carbon content of this soil scenario is comparable to FOCUS Hamburg (33 25 211: 0.704 % C_{org}, FOCUS Hamburg: 0.780 % C_{org}) the rainfall is much higher which leads to a more vulnerable situation than in the FOCUS Hamburg scenario.

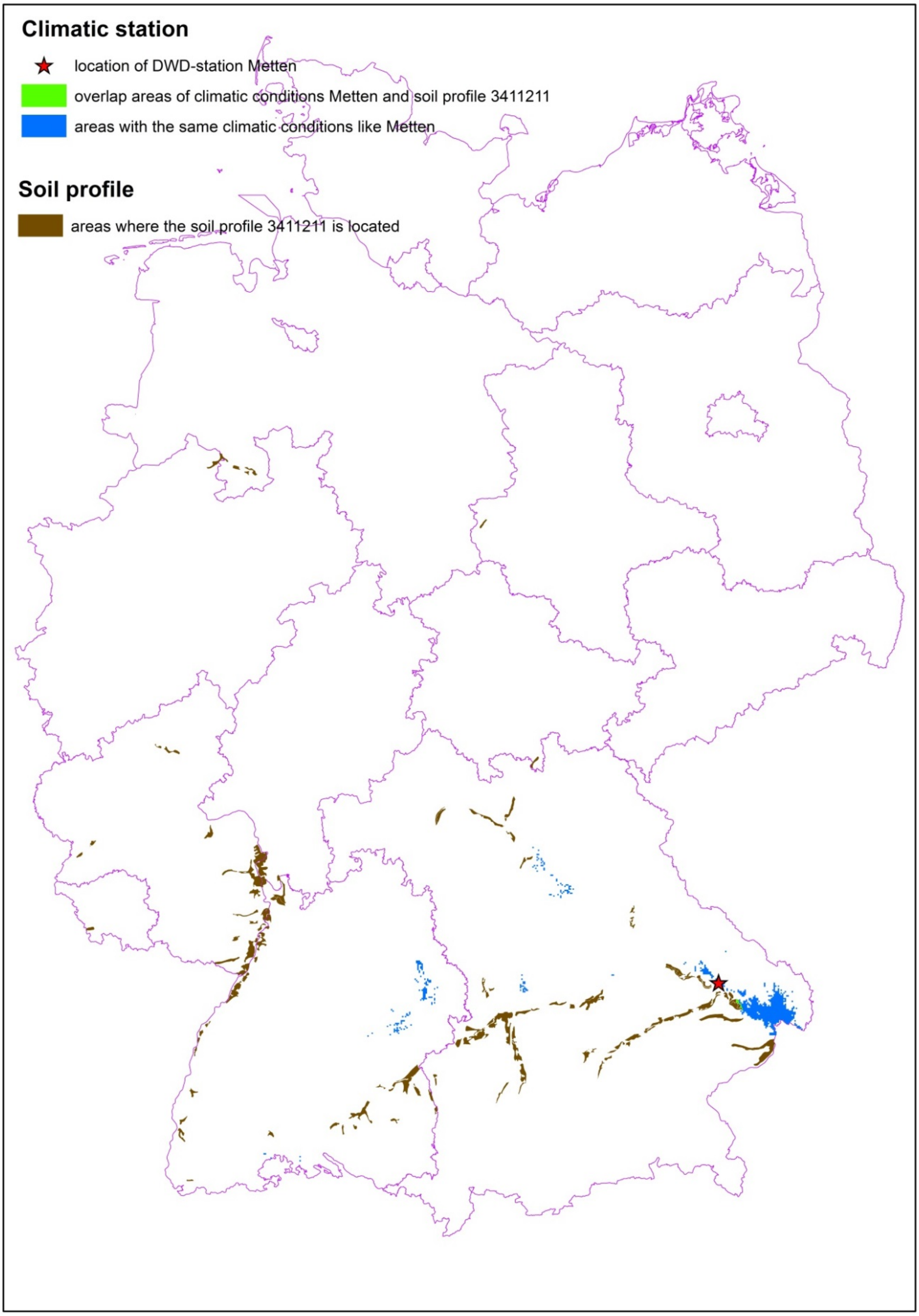


Figure 3-104: Map showing the areal distribution of soil profile 3411211 and areas with the same weather conditions as DWD station Metten which where identified to be most representative for the alkaline soil scenario

3.5.3 Descriptive statistics

For a more detailed characterisation of the soil and climate properties of regions which show a high number of overlaps boxplots for the 11 most important parameters were generated. These parameters with crucial influence on the leaching behaviour of PPP to groundwater are:

- temperature summer half-year (T Shy),
- temperature winter half-year (T Why),
- precipitation summer half-year (Prec Shy),
- precipitation winter half-year (Prec Why),
- percolate,
- potential evapotranspiration (PET),
- runoff,
- C_{org}-content over 1 m soil depth (C_{org}-1mdw),
- available water capacity (aWC; difference between field capacity and wilting point),
- biodegradation factor (BF),
- soil profile depth.

The charts for each parameter in the following sections contain the boxplots for the 75th-85th percentile overlapping areas of five different aggregation levels (i.e. overlap of all crop-compound combinations, overlap of all test compounds in combination with maize, overlap of all test compounds in combination with winter cereals, overlap of major leaching compounds and overlap of less leaching compounds), the boxplot for the distribution in the total agricultural area, the FOCUS Hamburg scenario parameter value and the parameter value of the five alternative scenarios. The boxplots for the different overlapping areas are based on different minimum numbers of overlaps:

- all crop/compound combinations: number of overlaps >=12
- all maize/compound combinations: number of overlaps >=7
- all winter cereals (wc)/compound combinations: number of overlaps >=7
- all major leaching compounds (mlc): number of overlaps >=9
- all less leaching compounds (llc): number of overlaps >=5

The next table shows the values of the climatic and soil properties of the identified alternative scenarios in comparison to the parameter in the FOCUS Hamburg scenario.

Table 3-45: Overview of climatic and soil properties of the alternative scenarios and Hamburg

scenario group	overlaps all and mlc	overlaps maize	overlaps wc	overlaps llc		overlaps alkaline pH	Hamburg
climatic station/ soil profile ID	Kassel/ 3531212	St.Peter-Ording/ 3325211	Berus/ 3342211	Neuruppin/ 3512211	Altomünster-Maisbrunn/ 3442211	Metten/ 3411211	
abbreviation	As1	As2	As3	As4a	As4b	As5	HH
parameter							
T-Shy [°C]	14.8	14.3	15.0	15.2	14.5	14.9	13.9
T-Why [°C]	3.8	4.5	4.2	3.6	2.6	2.4	4.0
T-annual [°C]	9.3	9.4	9.6	9.4	8.6	9.4	9.0
Prec Shy [mm]	377.9	406.8	358.6	300.7	527.4	508.7	393.0
Prec Why [mm]	343.4	430.7	418.8	248.7	350.1	464.6	377.0
Prec-annual [mm]	721	838	777	549	877	973	786
Percolate [mm]	219	325	185	95	281	424	284
PET [mm]	583	623	681	642	654	609	610
Runoff [mm]	9	11	80	4	13	17	0
C_{org} [%]	0.487	0.663	0.522	0.363	0.582	0.704	0.78
aWC [mm]	0.171	0.173	0.206	0.168	0.174	0.145	0.200
BF	0.55	0.55	0.55	0.55	0.55	0.55	0.57
soil profile depth [cm]	100	100	100	100	100	100	100

As shown in Table 3-45 apart from Neuruppin (549 mm) and Metten (973 mm) the annual precipitation amounts of the selected DWD weather stations don't deviate very much from each other (range of annual precipitation 721 mm to 838 mm) and are also comparable to the current FOCUS Hamburg weather scenario. Furthermore the analysis clearly demonstrated that all these alternative locations are characterised by lower organic carbon contents (range 0.522 % to 0.704 %) compared to the FOCUS Hamburg soil (0.780 %). However, one single alternative scenario was identified outside these ranges, which was found to represent a suitable spatial percentile for less leaching compounds. This scenario is characterised by an extremely low organic carbon content of 0.363 % in soil but on the same time also by very low annual precipitation amounts of 549 mm. For leaching substances with lower adsorption values the use of this scenario could be problematic as the respective result may be much more event driven than for the other alternative scenarios.

In the following some general observation concerning the statistical description of the areas with a high number of overlaps in comparison to the total distribution, the FOCUS Hamburg scenario and the alternative scenarios are described for each parameter.

- Temperature in the summer half-year:

The median of almost all 75th – 85th percentile overlapping groups concerning the average temperature in the summer half-year (T-Shy) is quite similar to the FOCUS Hamburg value (13.9 °C) and thereby lies distinctly below the median of the total distribution (14.5 °C). Only the “winter cereals-group” shows a slightly lower T-Shy of 13.6 °C.

In contrast, the T-Shy values of all the alternative scenarios lie above the Hamburg scenario and the majority (except As2 and As 4b) is even higher than the total median.

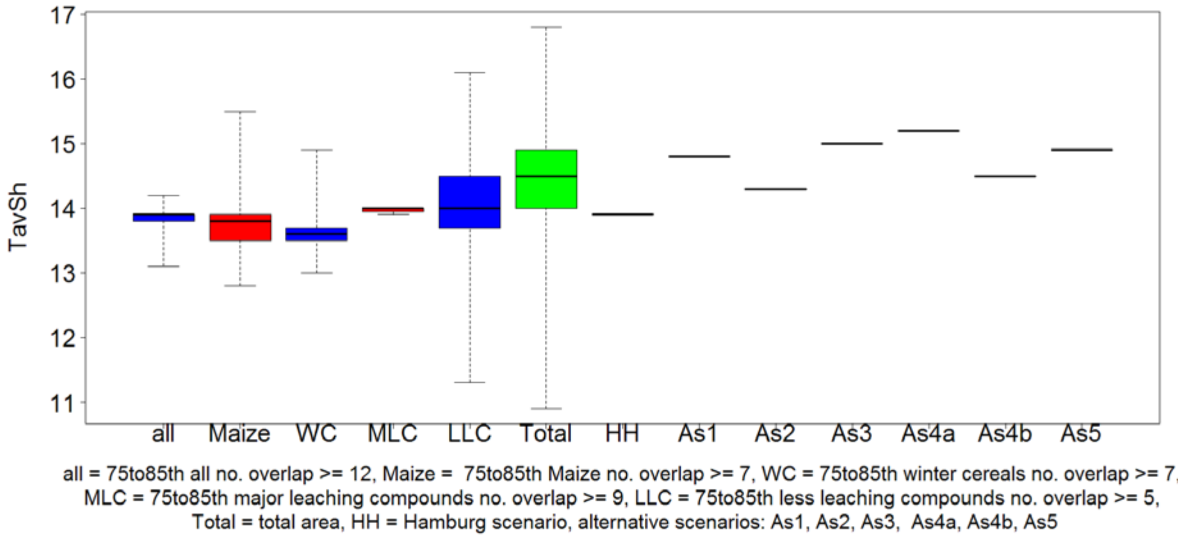


Figure 3-105: Summarizing chart containing boxplots for different overlapping groups and the total distribution in comparison to the FOCUS Hamburg scenario value and the values of the alternative scenarios concerning the parameter average temperature in the summer half-year

- Temperature in the winter half-year:

Only the median of the 75th-85th percentile overlapping areas of major leaching compounds concerning the temperature in the winter half-year lies on the same level of the FOCUS Hamburg value (4 °C). All the other medians of the overlapping groups are lower than the averaged winter temperature of the FOCUS Hamburg scenario and are around the same like the median of the total distribution (3.6 °C).

Looking at the T-Why values of the alternative scenarios two scenarios lie above the FOCUS Hamburg value (As2: 4.5 °C and As3: 4.2 °C), two scenarios lie slightly below (As1: 3.8 °C and As 4a: 3.6 °C) and two scenarios distinctly below it (As4b: 2.6 °C and As5: 2.4 °C).

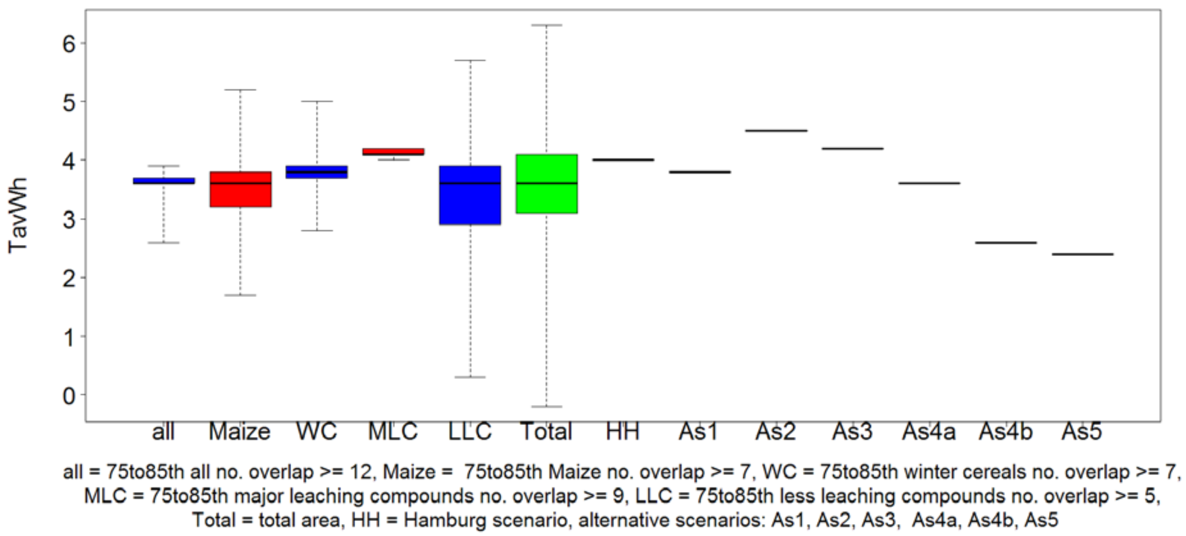


Figure 3-106: Summarizing chart containing boxplots for different overlapping groups and the total distribution in comparison to the FOCUS Hamburg scenario value and the values of the alternative scenarios concerning the parameter average temperature in the winter half-year

- Precipitation in the summer half-year:

The medians of the 75th – 85th percentile overlapping areas of the maize-, winter cereals- and less leaching compound-group concerning the precipitation in the summer half-year are on the same level like FOCUS Hamburg (393 mm). The major leaching compound-group shows a distinctly higher value (426 mm) and the group which considers all crop/compound combinations a distinctly lower value (357 mm). The median of the total distribution concerning this climatic parameter lies below the median of most of the overlapping groups (374 mm).

Two alternative scenarios show slightly different values to the FOCUS Hamburg scenario (As1: 378 mm and As2: 407 mm), two scenario values lie distinctly below the Hamburg value (As3: 359 mm and As4a: 301 mm) and two scenarios are remarkably higher (As4b: 527 mm and As5: 509 mm).

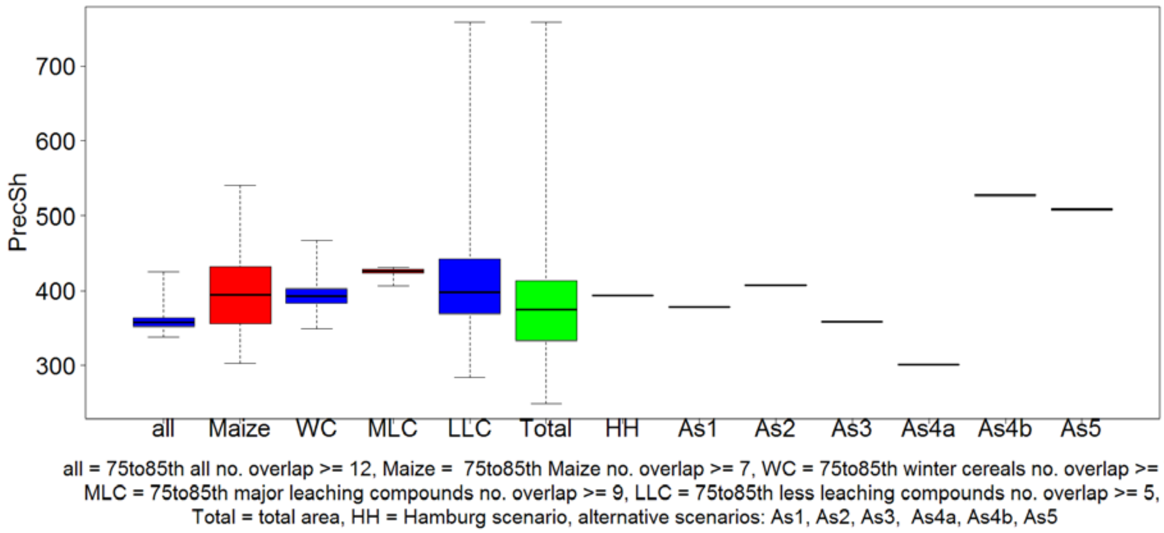


Figure 3-107: Summarizing chart containing boxplots for different overlapping groups and the total distribution in comparison to the FOCUS Hamburg scenario value and the values of the alternative scenarios concerning the parameter average precipitation in the summer half-year

- Precipitation in the winter half-year:

The 75th – 85th percentile overlapping areas of the major leaching-group show a distinct higher median value (415 mm) concerning the precipitation in the winter half-year than the FOCUS Hamburg value (377 mm). The median winter precipitation of the less leaching compounds and winter cereals-group is on the same level like FOCUS Hamburg and the values for the maize- (347 mm) and for the group which regarded all crop/compound combinations (316 mm) lie below. The median of the total distribution concerning Prec-Why lies below most of the medians of the different overlapping groups (332 mm).

Three of the alternative scenarios (As2, As3 and As5) show a higher value than FOCUS Hamburg concerning this climate parameter. The highest precipitation in the winter half-year (465 mm) can be observed at the station Metten (As5). The three other stations of the alternative scenarios show lower Prec-Why values whereby As4a shows the lowest (249 mm).

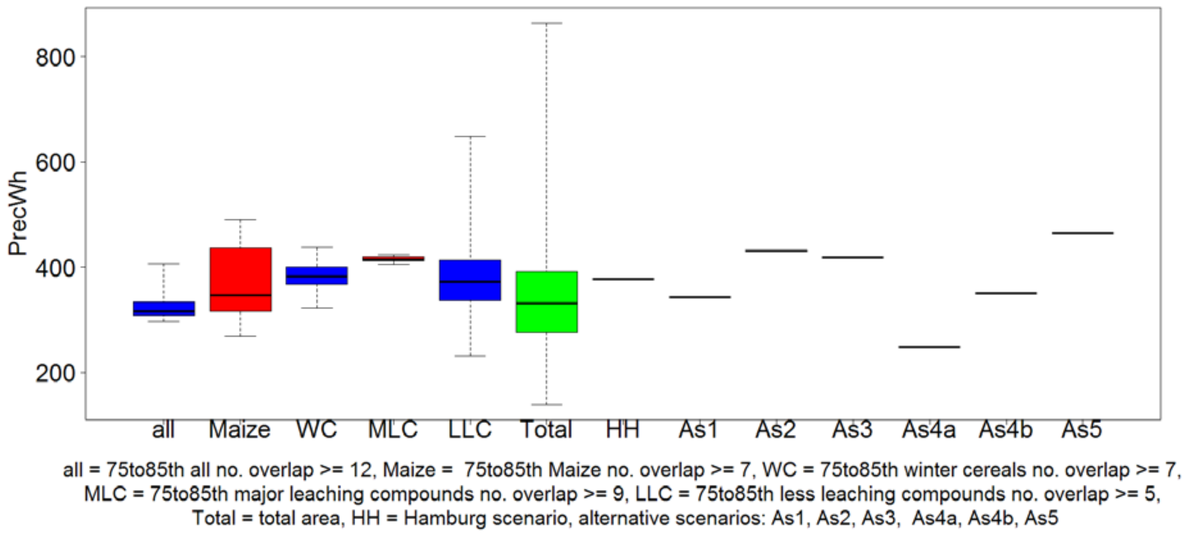


Figure 3-108: Summarizing chart containing boxplots for different overlapping groups and the total distribution in comparison to the FOCUS Hamburg scenario value and the values of the alternative scenarios concerning the parameter average precipitation in the winter half-year

- Percolate:

The median of the 75th – 85th percentile overlapping area of the group less leaching compounds concerning the percolate amount is around the same like the FOCUS Hamburg value (284 mm). The medians of the major leaching compounds, maize- and winter cereals-group are slightly lower (around 265 mm) and the median value for the group which considers all crop/compound combinations is distinctly lower (206 mm). The median of the total distribution is lower than the medians of all different overlapping groups (199 mm).

The percolate amounts of three of the alternative scenarios are distinctly lower than calculated with FOCUS Hamburg (As1, As3 and As4b) whereby As4a show the lowest percolate value (95 mm). Percolate amounts of two scenario lie above the FOCUS Hamburg results (As2: 325 mm and As5: 424 mm) and the As4b parameter value is quite similar to the FOCUS Hamburg scenario.

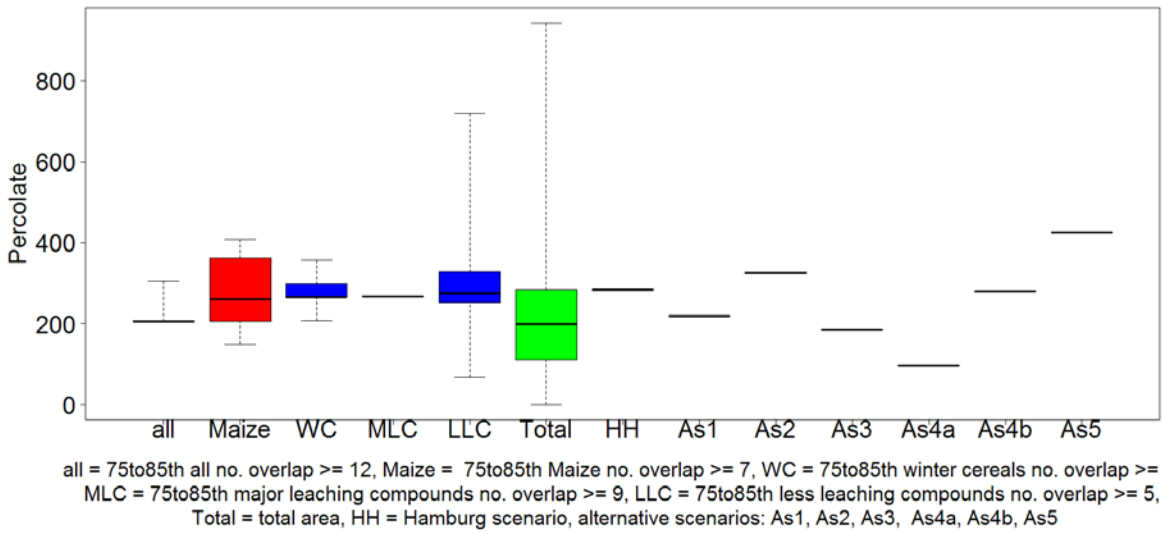


Figure 3-109: Summarizing chart containing boxplots for different overlapping groups and the total distribution in comparison to the FOCUS Hamburg scenario value and the values of the alternative scenarios concerning the parameter percolate amount

- Potential Evapotranspiration:

The medians for the 75th – 85th percentile overlapping areas concerning the Potential Evapotranspiration amount for the winter cereals-, major leaching compounds- and less leaching compounds-group lie on a slightly lower level (596 mm) than in the FOCUS Hamburg scenario (610 mm). The group which considers all crop/compound combinations and the maize-group show a remarkably lower median of 577 mm. The median of the total distribution concerning this climate parameter is around the same like the FOCUS Hamburg value (606 mm).

Regarding the PET amount values of the alternative scenarios, one scenario lies on the same level like FOCUS Hamburg (As5: 609 mm), one lies distinctly below (As1: 583 mm) and the others lie above the Hamburg value. As3 shows the highest PET value (681 mm).

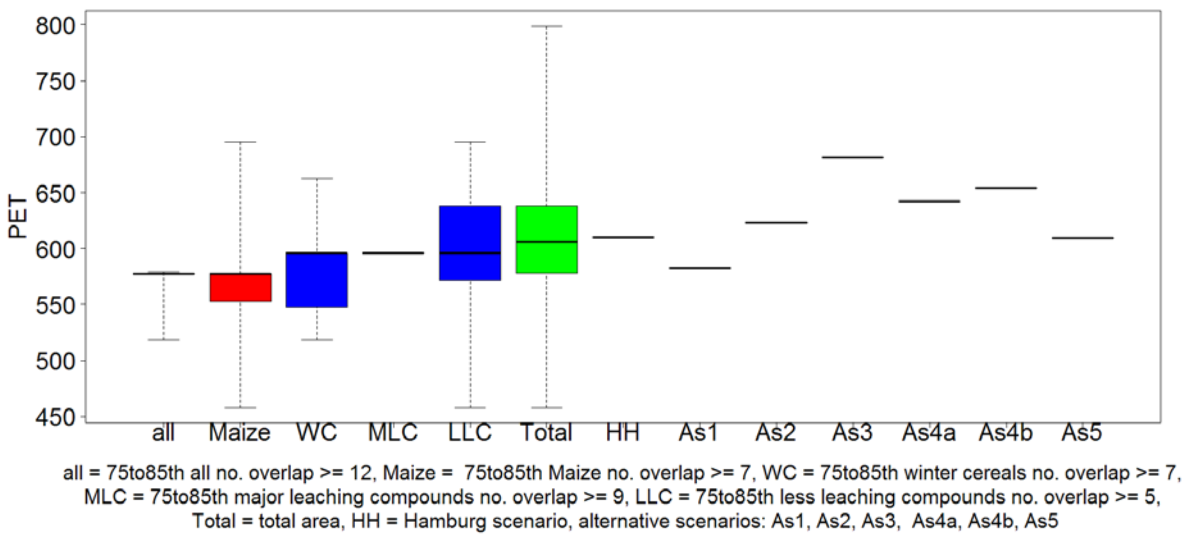


Figure 3-110: Summarizing chart containing boxplots for different overlapping groups and the total distribution in comparison to the FOCUS Hamburg scenario value and the values of the alternative scenarios concerning the parameter potential evapotranspiration amount

- Runoff:

Each median of the 75th – 85th percentile overlapping areas concerning the runoff amount for all different aggregation levels lie above the FOCUS Hamburg value since the standard scenario value is set 0. The median runoff amount of the maize- (15 mm), the major leaching compounds- (10 mm) and the less leaching compounds-group (24 mm) lie slightly above the FOCUS Hamburg value. The median of the winter cereals-group (44 mm) and the group which considers all crop/compound combinations (62 mm) are remarkably higher. The median of the total distribution (22 mm) is around as high as the median of the less leaching compounds-group.

The runoff amount of almost all alternative scenarios is relatively low (between 4 and 17 mm). Only As3 show a distinctly higher value (80 mm).

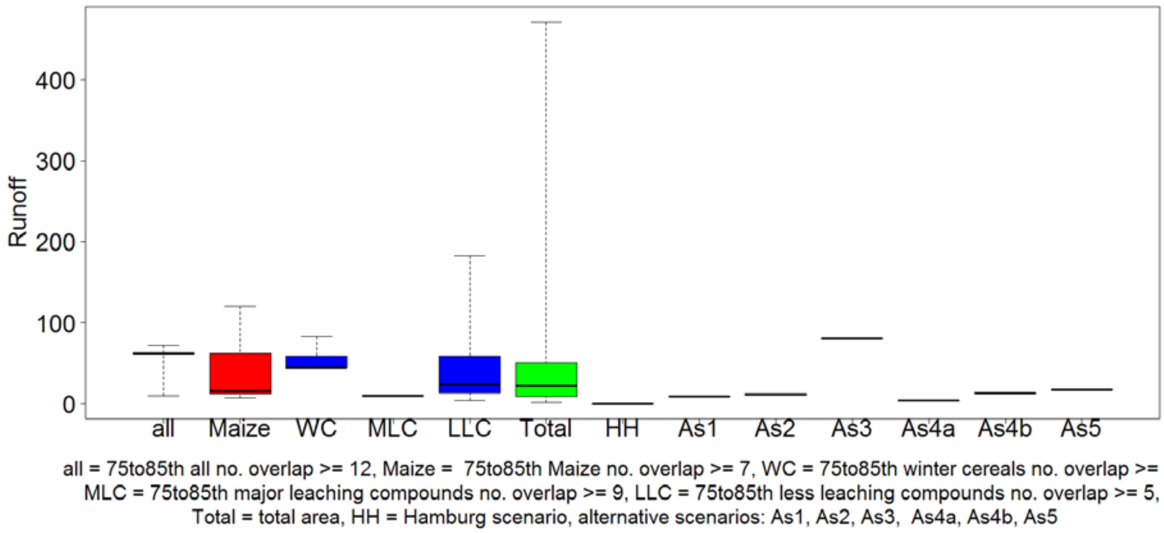


Figure 3-111: Summarizing chart containing boxplots for different overlapping groups and the total distribution in comparison to the FOCUS Hamburg scenario value and the values of the alternative scenarios concerning the parameter runoff amount

- C_{org}-content:

The medians of all 75th - 85th percentile overlapping groups concerning the C_{org}-content lie below the value in the FOCUS Hamburg scenario (0.78 %). The lowest C_{org}-value of the overlapping areas shows the group which considers all crop/compound combinations (0.487 %), the highest value can be observed for the major leaching compounds-group (0.725 %). The median of the total distribution is also lower than value in the FOCUS Hamburg scenario for this parameter (0.67 %).

Furthermore all C_{org}-values of the alternative scenarios are lower than the FOCUS Hamburg parameter value. The lowest C_{org} value of the alternative scenarios can be observed for the soil profile of As4a (0.363 %) and the highest for the profile of As5 (0.704 %).

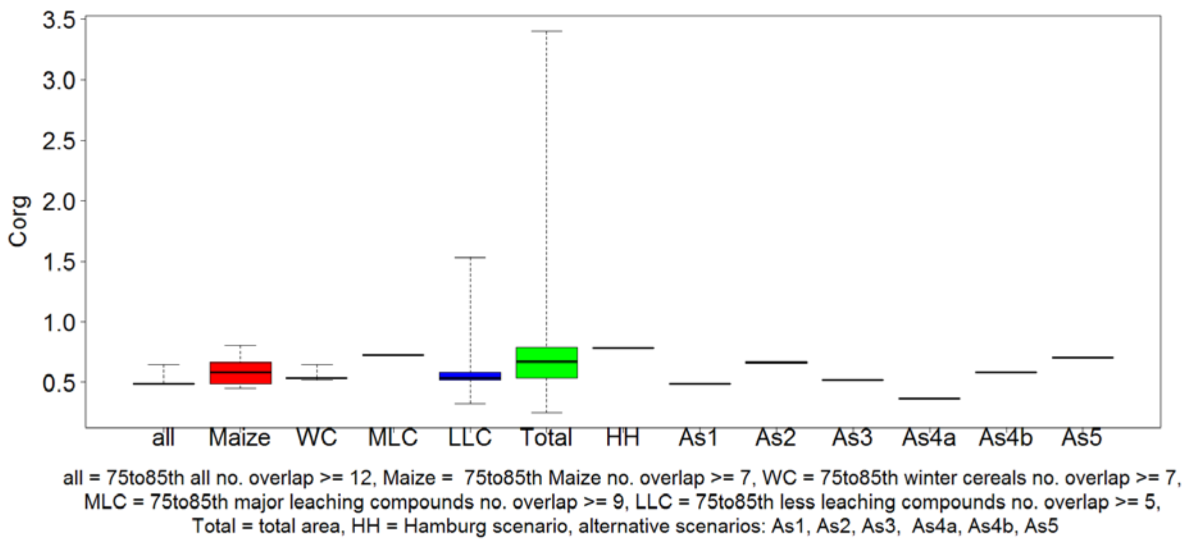
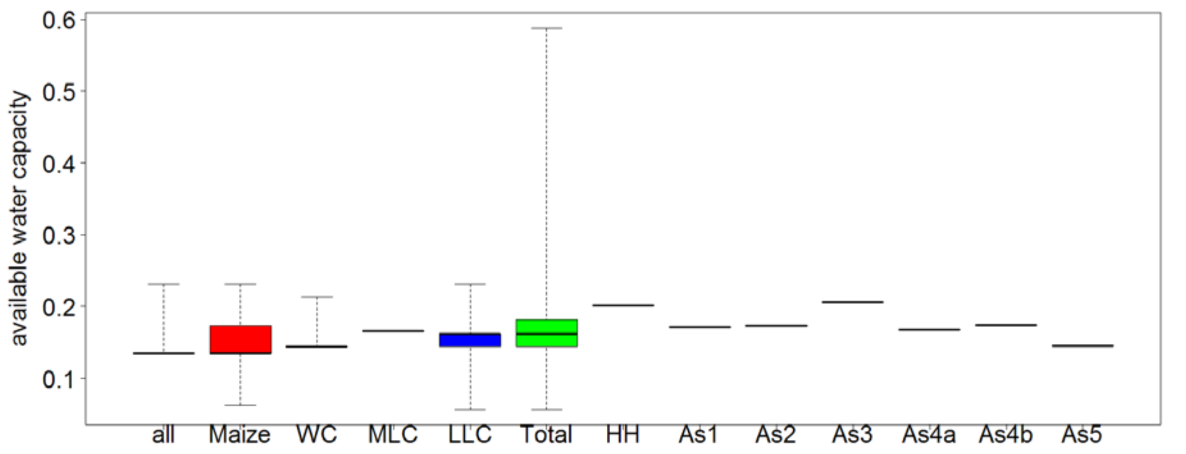


Figure 3-112: Summarizing chart containing boxplots for different overlapping groups and the total distribution in comparison to the FOCUS Hamburg scenario value and the values of the alternative scenarios concerning the parameter Corg-content

- Available water capacity**:**

The medians of all 75th – 85th percentile overlapping groups concerning the available water capacity lie below the FOCUS Hamburg value (0.20 m^3/m^3). The lowest median of the overlapping groups can be observed for the maize-group and the group which considers all crop/compound combinations (0.135 m^3/m^3). The medians of the major leaching compounds- and less leaching compounds-group are around the same like the median of the total distribution (0.16 m^3/m^3).

Except the soil profile of As3, which is around as high as the FOCUS Hamburg value (0.206 m^3/m^3), all the alternative scenarios lie below the German standard scenario concerning this soil hydrologic parameter. The available water capacity of the soil profiles of As1, As2, As4a and As4b lie all around a value of 0.17 m^3/m^3. The profile of As5 has an even lower available water capacity (0.145 m^3/m^3).



all = 75to85th all no. overlap >= 12, Maize = 75to85th Maize no. overlap >= 7, WC = 75to85th winter cereals no. overlap >= 7, MLC = 75to85th major leaching compounds no. overlap >= 9, LLC = 75to85th less leaching compounds no. overlap >= 5, Total = total area, HH = Hamburg scenario, alternative scenarios: As1, As2, As3, As4a, As4b, As5

Figure 3-113: Summarizing chart containing boxplots for different overlapping groups and the total distribution in comparison to the FOCUS Hamburg scenario value and the values of the alternative scenarios concerning the parameter available water capacity

- Biodegradation factor:

All medians of the different 75th – 85th percentile overlapping areas concerning the averaged biodegradation factor are represented by the same value of 0.55. Furthermore the same biodegradation factor of 0.55 was calculated of all the alternative scenarios. The biodegradation value of the FOCUS Hamburg scenario is slightly higher (0.57), since the thickness of the soil profile layers is not exactly parameterized according to the FOCUS convention. That means that the second soil horizon in the FOCUS Hamburg scenario is parameterized with a biodegradation factor of 0.5 from a depth of 30 cm down to 60 cm and not to 50 cm as predefined.

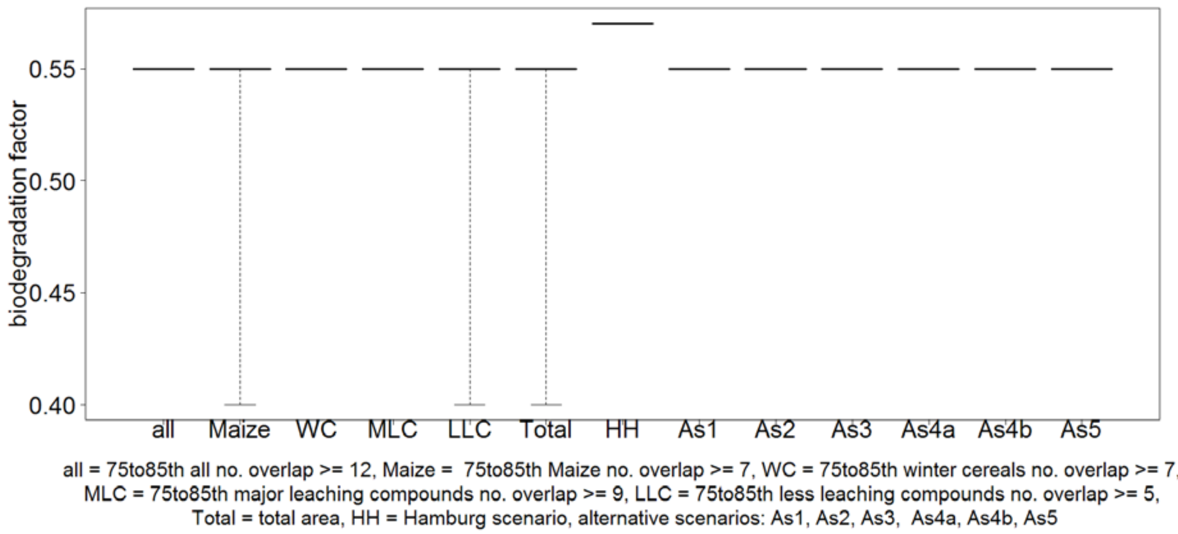


Figure 3-114: Summarizing chart containing boxplots for different overlapping groups and the total distribution in comparison to the FOCUS Hamburg scenario value and the values of the alternative scenarios concerning the parameter biodegradation factor

- Soil profile depth:

The median of all 75th – 85th percentile overlapping groups concerning the soil profile depth is 100 cm. The soil of the FOCUS Hamburg scenario has the same depth and the profiles of all alternative scenarios, too.

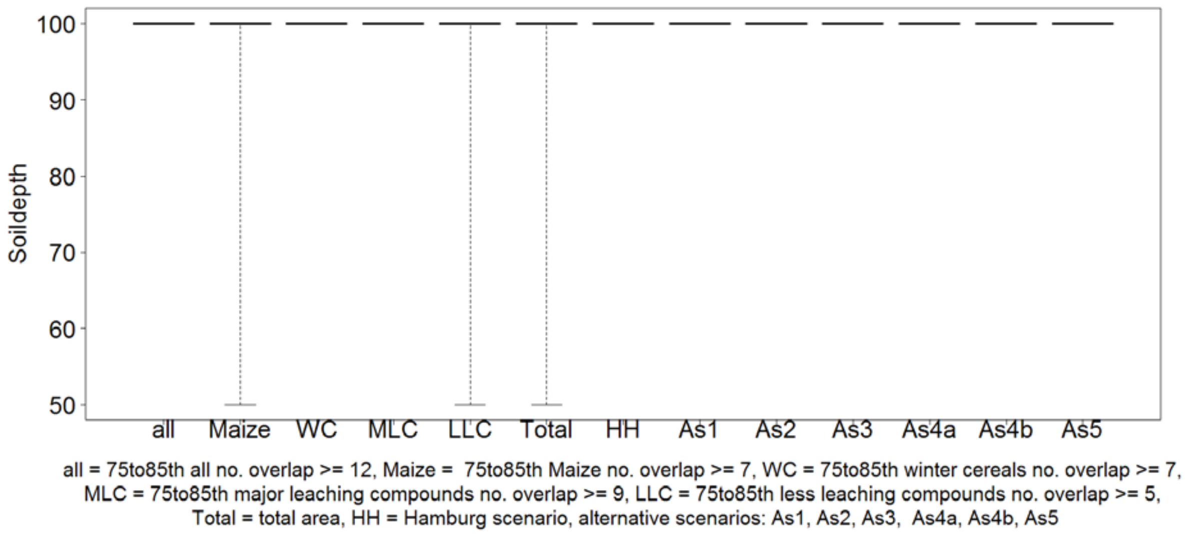


Figure 3-115: Summarizing chart containing boxplots for different overlapping groups and the total distribution in comparison to the FOCUS Hamburg scenario value and the values of the alternative scenarios concerning the parameter soil profile depth

3.6 Summary and Conclusions

In a first analysis (Step 1), a comparison of nationwide climate and soil properties in Germany with the corresponding properties in the FOCUS Hamburg scenario was conducted.

Referring to the climate conditions it turned out that Hamburg doesn't seem to represent a realistic worst-case. About 60 % of the arable land is characterised by lower yearly precipitation than the FOCUS scenario. In winter the spatial protection level is a bit higher (around 65 %) than in summer (around 56 %). For the parameter "average temperature" the relevant area covered by the Hamburg scenario is even lower (around 45 %), whereat the summer temperature shows a higher spatial protection level (76 %) than the temperature in winter (25 %).

The Step 1 analysis further showed that the FOCUS Hamburg soil profile with 1.5 % organic carbon content in the upper soil layer does represent a reasonable medium case scenario for the distribution of organic carbon contents in German agricultural soils. 44 % of the German soils show lower organic carbon contents in the upper soil layer compared to the FOCUS Hamburg scenario. Preliminary analysis further indicated, that in contrast to the FOCUS Hamburg scenario most of the agricultural soil profiles of the original BÜK 1000 N showed organic carbon contents of zero already in the second soil horizon. This conservative parametrisation in the BÜK 1000 N would have a significant impact on the estimated leaching behaviour. As it did not seem reasonable that the organic matter class h0 is widely found already at soil depths of about 50 cm the original C_{org}-contents were replaced by more recent results of Düwel et al. (2007) and Utermann et al. (2009). Finally, the results referring to the depth weighted organic carbon content down to 1 m soil depth additionally confirm that the FOCUS Hamburg soil was found to be far away from being a realistic worst case. 73 % of agricultural soils in Germany according to Düwel et al. (2007) and Utermann et al. (2009) showed lower averaged organic carbon contents than the FOCUS Hamburg soil scenario and hence a lower potential for adsorption of plant protection products.

Finally, a quantitative protection level of the FOCUS Hamburg scenario for Germany can only be derived if other important model parameters beside climate and soil such as application pattern, substance properties or crop type are also taken into account. Therefore and in addition to the initial model independent analysis a Step 2 evaluation was performed where the leaching model PELMO was combined with geo-referenced data in order to calculate the spatial protection level of the FOCUS Hamburg scenario for the agricultural area in Germany dependent on spring/summer and autumn/winter application times and important pesticide parameters such as degradation and sorption in soil. In order to combine PELMO with geographic information from different thematic maps a process-based modelling approach was applied similar as the methodology realised in GeoPEARL (Tiktal et al., 2003) and GeoPEARL_DE (Bangert, 2007). The new development of the leaching model "GISPELMO" for Germany resulted in 3348 different combinations of soil profiles (BGR, 2007) and DWD weather stations (DWD, 2012) for which the geographic data was available based on a raster map with a resolution of 1 km^2.

In order to cover a reasonable range of typical properties from plant protection products in total 9 different fictive compounds were considered and simulated as active substances. Their properties differed in their sorption constants (Kf_{oc}) and their degradation times in soil

($DegT_{50}$) because these are normally the most important substance related driving factors for leaching in soil. All simulations were performed in maize and winter cereals over a period of 26 years including a warming up period of 6 years and with annual applications one day before emergence of the crop. Maize and winter cereals were chosen as typical crops to cover both spring/summer and autumn/winter application dates. A general application rate of 200 g/ha was defined. However, for some compounds the rate was adapted to achieve a range of leaching concentrations which do not exceed one order of magnitude above or below the trigger value of 0.1 µg/L for active substances. During the development of the GISPELMO in this project it was decided to use the 80th temporal percentile of the PELMO percolate concentrations in 1 m soil depth from 20 sequent weather years as relevant PEC in groundwater for each raster cell and therefore to be consistent with the FOCUS scenario approach in the EU (FOCUS 2009/2014) and with the currently applied regulatory groundwater assessment scheme in Germany (Holdt et al., 2011).

In contrast to regulatory accepted standard FOCUS PELMO simulation the runoff process was considered as relevant for PEC calculation because it is obviously occurring as process on major areas in Germany and therefore may have an impact on the result of the evaluation of nationwide leachate amounts and leachate concentrations. The annual runoff amounts averaged over 20 years simulated with GISPELMO were in the range of 5 L/m^2 up to 250 L/m^2 with significantly higher amounts of runoff in maize than in winter cereals due to fallow conditions in the autumn and winter periods. The regions with the lowest estimated annual runoff amounts are located mainly in North-East-Germany due to a high occurrence of sandy soils and the low annual precipitation whereas maximum runoff amounts were calculated to be in areas of the low mountain range especially in the Sauerland in North Rhine-Westphalia.

The spatial distribution of the calculated percolate amounts in Germany gave evidence, that the regions with the lowest annual percolate averaged over 20 years are located mainly in North-East-Germany due to the low annual precipitation whereas maximum percolate amounts were calculated to be in the low mountain range, where normally higher precipitation occurs. Both the absolute percolate amounts as well as the nationwide distribution calculated with GISPELMO are comparable with the percolate amounts according to the HAD (Hydrologischer Atlas Deutschlands; Duijisveld et al., 2003). It was concluded from a statistical analysis, that the calculated percolate amount is an important parameter which influences the simulated leachate concentration. A positive correlation was rather discussed for leaching substances with low adsorption values and short $DegT_{50}$ and might be stronger for autumn and winter applications. Finally, the percolate amount of the FOCUS Hamburg Scenario of about 284 mm (80th temporal percentile) corresponds with the overall 75th spatial percentile of the percolate amounts for the entire agricultural area in Germany. And most of the median percolate amounts from the 75th-85th spatial percentile classes for all selected crop-compound combinations are in the same range. This provides evidence, that the FOCUS Hamburg scenario represents a rather conservative leaching scenario and a high spatial percentile according to the estimated soil water fluxes in 1 m soil depth.

However, as a future option the groundwater recharge could be used to simulate the soil water balance more realistically because in contrast to the percolate amount it considers also the interflow (see chapter 3.4.1.2; Neumann & Wycisk, 2003). As it is rather complicated to include lateral interflow processes in 1-dimensional leaching models only few models are available (e.g. the GeoPEARL model for the Netherlands; Tiktak et al, 2003). Lateral processes were implemented in GeoPEARL by coupling it with a separate model calculating the interflow. In general it is difficult to estimate the influence of a possible consideration of the groundwater recharge for PEC calculations compared to the results based on the assumptions made in this project. Less groundwater recharge to the saturated zone may not generally result in lower PECs for all substances since also an opposed concentration effect seems possible. Furthermore the possible effect of the interflow on the substance concentration depends on the depth of the soil layer in which the interflow occurs. The extend of the lateral water flow further strongly depends on the soil type. On sandy soils lower values are expected to be observed than on loamy soils for example.

To consider all of the most relevant processes of the water balance in soil the preferential flow could be integrated as additional process in the modelling, too. It can be expected, that this would tendentially lead to higher PECs on clay or loamy soils since more water with higher pesticide concentrations in the upper soil zone could be directly and fast transported through macropores to the lower soil layers and subsequent to the groundwater. But without calculation runs and/or suitable monitoring data it is difficult to decide whether the effect of preferential flow would be stronger than the consideration of the interflow for a nationwide analysis of the percolate amounts and subsequent pesticide leaching. Therefore, it is also difficult to estimate how a possible consideration of both additional soil water transport processes would influence the protection level analysis of the FOCUS Hamburg scenario for German agriculture conditions. The protection level analysis is described in the following passage according to the more basic but widely accepted FOCUS assumptions. This basic approach does also not consider transport in makropores, which in reality is increasing the leaching potential of different soil types considerably.

The results of the step 2 simulations with 18 different crop-compound combinations generally showed higher leachate concentrations for autumn/winter applications (winter cereals) than for spring/summer applications (maize). Furthermore, the GISPELMO analysis showed that the FOCUS Hamburg scenario only represents a spatial percentile in the range of 31 % up to 65 % for the agricultural area in Germany when an 80^{th} temporal percentile was preselected from a 20 years simulation period. The arithmetic mean of the spatial percentiles for all calculated crop-compound combinations was finally 44 % for the FOCUS Hamburg scenario. It was concluded that FOCUS Hamburg is not representing an 80^{th} spatial percentile for the agricultural area in Germany although the simulated concentrations in the percolate of the FOCUS Hamburg scenario do often not extremely differ with the 80^{th} spatial percentile as calculated with GISPELMO. An average factor of 3.23 would describe the averaged ratio between the FOCUS Hamburg scenario and the 80^{th} percentile of GISPELMO, respectively.

Assuming that the percolate amount in 1 m soil depth represents an important sum parameter for pesticide transport in soil, because it considers already soil conditions and precipitations in a certain area, the results referring to the leachate concentrations seem to be quite contrary to the results of the calculated percolate amounts in 1 m soil depth. Concerning the latter parameter a higher spatial percentile of the agricultural area in Germany was met for the FOCUS Hamburg scenario than for the leachate concentration.

However, in contrast to the volume of the percolate at 1 m soil depth the related pesticide concentrations are highly influenced by the organic carbon content in the soil profile. With 27.2 % the FOCUS Hamburg scenario shows a relatively low level of spatial protection regarding the 1 m depth weighted C_{org}-content in German agricultural soils. That is probably the dominant factor which finally leads to the contrary results for the percolate amount and the concentrations in the percolate for the FOCUS Hamburg scenario.

With the analysis and based on the selected 80th temporal percentile some vulnerable areas for leaching were identified which appeared to be nearly independent on the chosen pesticide and crop properties. This observation was the base for the selection and evaluation of alternative scenarios which may better represent the 80th spatial percentile for the agricultural area in Germany than the FOCUS Hamburg scenario.

The following principles were applied for the selection of alternative realistic worst case scenarios for the agricultural area in Germany:

- GISPELMO results of all chosen crop-substance combinations were considered.
- The combination of the 80th spatial and the 80th temporal percentile was the target as recommended by FOCUS (2009/2014).
- As the target spatial percentile would technically speaking only be represented by a very small area (single raster cell relating to the GISPELMO model) in Germany a wider percentile range of 80 ± 5 % was considered to identify a reasonable area for the selection of scenarios.
- The selection of one main alternative scenario is based on an overlap of 18 crop-compound combination each with the 80th spatial and temporal percentile and therefore independent on the crops and pesticide properties.
- As the total overlap of all 18 crop-compound combinations was only reached for a very small area further scenarios were suggested based on subclasses of the 18 combinations (e.g. only winter crops, only major leaching substances).

The alternative scenarios determined in this evaluation, which would better represent an 80th spatial percentile for the risk assessment of pesticide leaching for the agricultural area in Germany, are summarised in Table 3-45. They are characterised by different seasonal averaged temperatures and precipitation amounts, which reflect typical and geographicly justified climate and weather deviations in Germany. Overall, the averaged temperatures and precipitations are in most of this selected DWD stations quite comparable to the FOCUS Hamburg weather. Clear distinctions compared to the FOCUS Hamburg weather may exist for some climate parameters in some stations, whereat those distinctions can be identified both below and above the typical FOCUS Hamburg weather values. However, the analysis also clearly demonstrated that all these alternative areas are characterised by typical soil profiles with lower averaged organic carbon contents until 1 m soil depth (range of 0.52 % to 0.70 %) compared to the FOCUS Hamburg soil (0.78 %). The results of the step 2 analysis further showed that it could be problematic to base all decisions on a single or a small number of scenarios because according to the GISPELMO simulations there is no fixed scenario which always guarantees a certain spatial percentile for the entire agricultural area in Germany.

Furthermore, the available simulations only consider few application pattern and crops. Only a spatially distributed tool like GISPELMO is able to always calculate an exact spatial percentile dependent on pesticide properties, crops and application time. Additionally, such a GIS based tool could also consider the real distribution of crop cover or specific conditions (e.g. additional geographic information about soil types, climate or slope) to enable case by case decisions. Especially when risk assessment has to be performed for special situations (e.g. permanent crops like vines) and simulations of the whole agricultural area don't seem meaningful, GISPELMO could be a suitable alternative.

It is therefore recommended to consider GISPELMO as an additional higher tier option in the registration procedure. Additional model extensions, which for example would consider interflow and preferential flow as additional processes in the soil water balance, need further investigations and validations.

3.7 References

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4 Appendices

4.1 Appendix 1: Soil profiles used for the Step 2 analysis

The following table shows the soil profiles as used in GISPELMO based on BÜK 1000 N but using the C_{org} modifications of Düwel et al. (2007)/Utermann et al. (2009). The classification of the Hydrologic soil group (HSG) in the table is based on Bach et al. (2016) (1 stands for HSG A, 2 stands for HSG B, 3 stands for HSG BC, 4 stands for HSG C, 5 stands for HSG D; HSG D does not occur on arable soils in Germany).

Table 4-1: Soil profiles considered for the GISPELMO simulations

Soil no.	Horizon no.	Depth (cm)	Density (kg/L)	Field capacity (m^3/m^3)	Wilting point (m^3/m^3)	C_{org} (%)	pH (-)	Hydrologic soil group
3301211	1	30	1.32	0.23	0.05	1.9	5.05	1
3301211	2	20	1.51	0.2	0.04	0.31	5.05	1
3301211	3	30	1.55	0.15	0.03	0.31	5.05	1
3301211	4	20	1.55	0.15	0.03	0	5.05	1
3301211	5	100	1.55	0.15	0.03	0	5.05	1
3303211	1	30	1.1	0.46	0.25	1.9	6.45	1
3303211	2	20	1.4	0.28	0.06	0.85	7	1
3303211	3	50	1.4	0.29	0.11	0.85	7.55	1
3303211	4	100	1.4	0.27	0.09	0	7.55	1
3304211	1	30	1.21	0.42	0.28	1.9	5.75	1
3304211	2	20	1.36	0.38	0.27	0.85	6.45	1
3304211	3	50	1.36	0.33	0.27	0.85	6.45	1
3304211	4	50	1.45	0.34	0.22	0	6.45	1
3304211	5	50	1.4	0.34	0.28	0	7	1
3305211	1	30	1.1	0.37	0.13	1.9	6.45	1
3305211	2	20	1.22	0.36	0.2	0.85	7	1
3305211	3	50	1.22	0.36	0.2	0.85	7	1
3305211	4	100	1.4	0.4	0.31	0	7	1
3306211	1	30	0.54	0.59	0.3	2.5	3.65	1
3306211	2	20	0.54	0.62	0.3	2.5	3.65	1
3306211	3	50	0.54	0.62	0.3	2.5	4.35	1

Soil no.	Horizon no.	Depth (cm)	Density (kg/L)	Field capacity (m^3/m^3)	Wilting point (m^3/m^3)	C_{org} (%)	pH (-)	Hydrologic soil group
3306211	4	100	1.5	0.24	0.06	0	4.35	1
3307211	1	30	0.45	0.83	0.28	2.5	3.65	1
3307211	2	20	0.54	0.73	0.13	2.5	4.35	1
3307211	3	50	0.54	0.73	0.13	2.5	4.35	1
3307211	4	100	1.5	0.24	0.06	0	3.65	1
3308211	1	30	1.17	0.36	0.2	1.6	5.05	1
3308211	2	20	1.32	0.32	0.1	0.56	5.75	1
3308211	3	50	1.5	0.24	0.06	0.56	6.45	1
3308211	4	100	1.5	0.24	0.06	0	6.45	1
3309211	1	30	0.98	0.52	0.28	1.6	6.45	1
3309211	2	20	1.21	0.4	0.18	0.56	7	1
3309211	3	30	1.3	0.38	0.14	0.56	7	1
3309211	4	20	1.4	0.36	0.16	0	7	1
3309211	5	100	1.4	0.21	0.05	0	7	1
3310211	1	30	1.28	0.28	0.1	1.6	5.05	1
3310211	2	20	1.46	0.23	0.06	0.56	5.75	1
3310211	3	20	1.5	0.23	0.06	0.56	6.45	1
3310211	4	30	1.5	0.23	0.06	0	6.45	1
3310211	5	100	1.5	0.23	0.06	0	6.45	1
3311211	1	30	1.17	0.36	0.14	1.6	5.05	1
3311211	2	20	1.32	0.32	0.1	0.56	5.75	1
3311211	3	20	1.25	0.36	0.2	0.56	5.75	1
3311211	4	30	1.4	0.29	0.11	0	5.75	1
3311211	5	100	1.4	0.27	0.09	0	5.75	1
3312211	1	30	1.28	0.27	0.09	1.9	5.05	1
3312211	2	20	1.5	0.23	0.06	0.31	5.05	1
3312211	3	10	1.4	0.21	0.05	0.31	5.05	1
3312211	4	40	1.4	0.21	0.05	0	5.05	1
3312211	5	100	1.55	0.16	0.03	0	5.75	1
3315211	1	30	1.3	0.38	0.17	0.87	5.75	3

Soil no.	Horizon no.	Depth (cm)	Density (kg/L)	Field capacity (m^3/m^3)	Wilting point (m^3/m^3)	C_{org} (%)	pH (-)	Hydrologic soil group
3315211	2	20	1.4	0.36	0.12	0.53	6.45	3
3315211	3	20	1.4	0.36	0.12	0.53	6.45	3
3315211	4	30	1.4	0.33	0.27	0	6.45	3
3315211	5	40	1.4	0.36	0.16	0	6.45	3
3315211	6	60	1.25	0.27	0.15	0	7	3
3316211	1	30	1.21	0.29	0.11	1.74	5.05	1
3316211	2	20	1.5	0.23	0.06	0.53	5.75	1
3316211	3	10	1.5	0.23	0.06	0.53	5.75	1
3316211	4	40	1.4	0.2	0.06	0	5.75	1
3316211	5	100	1.4	0.17	0.05	0	5.75	1
3317211	1	30	1.28	0.28	0.1	1.9	5.05	1
3317211	2	20	1.46	0.24	0.06	0.31	5.75	1
3317211	3	50	1.46	0.22	0.05	0.31	5.75	1
3317211	4	100	1.4	0.28	0.11	0	6.45	1
3319211	1	30	1.3	0.29	0.12	1.3	6.45	2
3319211	2	20	1.4	0.28	0.11	0.29	6.45	2
3319211	3	30	1.5	0.27	0.15	0.29	6.45	2
3319211	4	10	1.35	0.28	0.1	0	7	2
3319211	5	110	1.55	0.29	0.19	0	7.55	2
3320211	1	30	1.14	0.4	0.22	1.3	7	2
3320211	2	20	1.28	0.38	0.25	0.29	7	2
3320211	3	50	1.46	0.29	0.19	0.29	7	2
3320211	4	100	1.4	0.3	0.2	0	7.55	2
3322211	1	30	1.3	0.29	0.12	1.9	5.05	3
3322211	2	20	1.36	0.28	0.11	0.31	5.75	3
3322211	3	50	1.5	0.29	0.19	0.31	5.75	3
3322211	4	100	1.5	0.29	0.19	0	5.75	3
3324211	1	30	1.21	0.32	0.14	1.3	7	1
3324211	2	20	1.3	0.3	0.12	0.29	7.55	1
3324211	3	30	1.3	0.27	0.09	0.29	7.55	1

Soil no.	Horizon no.	Depth (cm)	Density (kg/L)	Field capacity (m^3/m^3)	Wilting point (m^3/m^3)	C_{org} (%)	pH (-)	Hydrologic soil group
3324211	4	20	1.36	0.28	0.11	0.29	7.55	1
3324211	5	10	1.35	0.31	0.17	0	7.55	1
3324211	6	40	1.5	0.29	0.19	0	7.55	1
3324211	7	50	1.5	0.29	0.19	0	7.55	1
3325211	1	30	1.28	0.27	0.09	1.9	5.05	1
3325211	2	20	1.5	0.23	0.06	0.31	5.75	1
3325211	3	10	1.5	0.23	0.06	0.31	5.75	1
3325211	4	10	1.5	0.23	0.06	0	5.75	1
3325211	5	30	1.4	0.28	0.11	0	6.45	1
3325211	6	100	1.5	0.29	0.19	0	7	1
3326211	1	30	1.38	0.25	0.08	0.7	5.05	2
3326211	2	10	1.5	0.23	0.06	0.13	5.75	2
3326211	3	10	1.5	0.23	0.06	0.13	5.75	2
3326211	4	10	1.4	0.28	0.11	0.13	5.75	2
3326211	5	40	1.5	0.23	0.06	0	6.45	2
3326211	6	100	1.5	0.27	0.15	0	7	2
3327211	1	30	1.3	0.28	0.07	1.3	5.05	2
3327211	2	20	1.4	0.27	0.06	0.29	5.75	2
3327211	3	50	1.25	0.29	0.06	0.29	5.75	2
3327211	4	100	1.5	0.29	0.19	0	7	2
3328211	1	30	1.21	0.3	0.08	1.9	5.05	3
3328211	2	20	1.4	0.27	0.06	0.31	5.75	3
3328211	3	50	1.25	0.27	0.07	0.31	5.75	3
3328211	4	100	1.5	0.24	0.13	0	7	3
3329211	1	30	1.3	0.28	0.07	1.9	5.75	1
3329211	2	20	1.4	0.27	0.06	0.31	5.75	1
3329211	3	20	1.4	0.26	0.08	0.31	5.75	1
3329211	4	30	1.4	0.22	0.1	0	7	1
3329211	5	100	1.4	0.22	0.1	0	7	1
3331211	1	30	1.28	0.27	0.09	1.9	5.05	1

Soil no.	Horizon no.	Depth (cm)	Density (kg/L)	Field capacity (m³/m³)	Wilting point (m³/m³)	C_{org} (%)	pH (-)	Hydrologic soil group
3331211	2	20	1.36	0.21	0.05	0.31	5.05	1
3331211	3	50	1.46	0.23	0.06	0.31	5.05	1
3331211	4	100	1.55	0.17	0.02	0	5.05	1
3332211	1	30	1.38	0.26	0.08	1.9	5.05	1
3332211	2	20	1.5	0.24	0.06	0.31	5.75	1
3332211	3	10	1.5	0.24	0.06	0.31	5.75	1
3332211	4	40	1.5	0.24	0.06	0	5.75	1
3332211	5	100	1.5	0.24	0.06	0	5.75	1
3333211	1	30	1.21	0.26	0.08	1.9	5.05	1
3333211	2	20	1.36	0.22	0.06	0.31	5.05	1
3333211	3	30	1.36	0.22	0.06	0.31	5.05	1
3333211	4	20	1.55	0.18	0.02	0	5.05	1
3333211	5	100	1.55	0.18	0.02	0	5.05	1
3334211	1	30	1.42	0.21	0.04	1.9	5.05	1
3334211	2	20	1.55	0.2	0.04	0.31	5.05	1
3334211	3	50	1.55	0.22	0.03	0.31	5.05	1
3334211	4	100	1.55	0.22	0.03	0.31	5.05	1
3338211	1	30	1.21	0.4	0.18	1.3	7	2
3338211	2	20	1.4	0.38	0.12	0.44	7	2
3338211	3	20	1.4	0.38	0.12	0.44	7	2
3338211	4	30	1.35	0.36	0.1	0	7	2
3338211	5	50	1.4	0.36	0.12	0	7.55	2
3338211	6	50	1.4	0.3	0.2	0	7.55	2
3340211	1	30	1.1	0.4	0.22	1.3	6.45	3
3340211	2	20	1.1	0.4	0.22	0.44	6.45	3
3340211	3	30	1.36	0.36	0.23	0.44	6.45	3
3340211	4	20	1.4	0.36	0.16	0	7	3
3340211	5	100	1.4	0.38	0.16	0	7	3
3342211	1	30	1.21	0.4	0.18	1.3	6.45	3
3342211	2	20	1.4	0.36	0.12	0.44	6.45	3

Soil no.	Horizon no.	Depth (cm)	Density (kg/L)	Field capacity (m^3/m^3)	Wilting point (m^3/m^3)	C_{org} (%)	pH (-)	Hydrologic soil group
3342211	3	10	1.4	0.36	0.16	0.44	6.45	3
3342211	4	40	1.4	0.34	0.16	0	6.45	3
3342211	5	10	1.4	0.36	0.12	0	6.45	3
3342211	6	90	1.4	0.36	0.12	0	7	3
3346211	1	30	1.1	0.37	0.13	1.2	6.45	2
3346211	2	20	1.25	0.34	0.12	0.22	6.45	2
3346211	3	30	1.25	0.32	0.12	0.22	6.45	2
3346211	4	20	1.2	0.3	0.08	0	7	2
3346211	5	100	1.35	0.28	0.16	0	7	2
3348211	1	25	1.21	0.38	0.14	1.3	6.45	3
3348211	2	5	1.35	0.33	0.11	0.44	7	3
3348211	3	20	1.25	0.27	0.15	0.44	7	3
3348211	4	10	1.25	0.27	0.15	0.44	7	3
3348211	5	140	1.35	0.28	0.21	0	7	3
3349212	1	30	1.21	0.3	0.2	1.74	7	1
3349212	2	20	1.3	0.29	0.2	0.69	7.55	1
3349212	3	10	1.3	0.29	0.2	0.69	7.55	1
3351211	1	25	1.21	0.48	0.3	1.74	6.45	2
3351211	2	5	1.32	0.38	0.28	0.5	7	2
3351211	3	50	1.4	0.36	0.28	0.5	7	2
3351211	4	20	1.35	0.37	0.27	0	7.55	2
3351211	5	100	1.35	0.37	0.27	0	7.55	2
3352211	1	30	1.28	0.38	0.25	1.74	6.45	2
3352211	2	20	1.4	0.27	0.18	0.5	7	2
3352211	3	20	1.25	0.21	0.12	0.5	7.55	2
3352211	4	30	1.25	0.13	0.07	0	7.55	2
3352211	5	100	1.25	0.13	0.07	0	7.55	2
3358211	1	30	1.17	0.35	0.2	1.74	6.45	2
3358211	2	20	1.35	0.28	0.1	0.46	7	2
3358211	3	20	1.35	0.25	0.09	0.46	7	2

Soil no.	Horizon no.	Depth (cm)	Density (kg/L)	Field capacity (m^3/m^3)	Wilting point (m^3/m^3)	C_{org} (%)	pH (-)	Hydrologic soil group
3361212	1	30	1.26	0.34	0.12	0.87	5.05	1
3361212	2	20	1.4	0.27	0.09	0.46	5.75	1
3361212	3	20	1.5	0.21	0.05	0.46	5.75	1
3363211	1	30	1.17	0.31	0.07	0.87	5.05	1
3363211	2	20	1.4	0.24	0.06	0.46	5.75	1
3363211	3	20	1.55	0.12	0.03	0.46	5.75	1
3365211	1	30	1.21	0.4	0.15	1.74	6.45	2
3365211	2	20	1.4	0.36	0.16	0.5	6.45	2
3365211	3	20	1.4	0.36	0.16	0.5	6.45	2
3365211	4	40	1.45	0.32	0.21	0	7	2
3366211	1	30	1.26	0.33	0.19	0.87	6.45	2
3366211	2	20	1.35	0.3	0.1	0.69	6.45	2
3366211	3	10	1.35	0.28	0.16	0.69	6.45	2
3366211	4	40	1.4	0.3	0.2	0	7	2
3366211	5	10	1.35	0.28	0.21	0	7	2
3406211	1	30	0.66	0.37	0.15	3.4	6.45	1
3406211	2	20	0.91	0.34	0.13	3.4	7	1
3406211	3	10	0.91	0.34	0.13	3.4	7	1
3406211	4	40	1.5	0.24	0.06	0	7	1
3406211	5	100	1.5	0.24	0.06	0	7	1
3407211	1	30	0.45	0.83	0.28	3.4	4.35	1
3407211	2	20	0.54	0.73	0.13	3.4	4.35	1
3407211	3	50	0.54	0.73	0.13	3.4	4.35	1
3407211	4	100	1.5	0.24	0.06	0	3.65	1
3408211	1	30	1.17	0.36	0.2	1.6	5.05	3
3408211	2	20	1.32	0.32	0.1	0.56	5.75	3
3408211	3	10	1.32	0.32	0.1	0.56	5.75	3
3408211	4	40	1.5	0.24	0.06	0	6.45	3
3408211	5	100	1.5	0.24	0.06	0	6.45	3
3409211	1	30	0.98	0.52	0.28	1.6	6.45	1

Soil no.	Horizon no.	Depth (cm)	Density (kg/L)	Field capacity (m^3/m^3)	Wilting point (m^3/m^3)	C_{org} (%)	pH (-)	Hydrologic soil group
3409211	2	30	1.21	0.4	0.18	0.56	7	1
3409211	3	20	1.3	0.38	0.14	0.56	7	1
3409211	4	40	1.4	0.36	0.16	0	7	1
3409211	5	80	1.4	0.21	0.05	0	7	1
3410211	1	30	1.28	0.28	0.1	1.6	5.05	1
3410211	2	20	1.46	0.23	0.06	0.56	5.75	1
3410211	3	20	1.5	0.23	0.06	0.56	6.45	1
3410211	4	30	1.5	0.23	0.06	0	6.45	1
3410211	5	100	1.5	0.23	0.06	0	6.45	1
3411211	1	30	1.1	0.46	0.25	1.6	7	1
3411211	2	20	1.4	0.36	0.23	0.56	7.55	1
3411211	3	20	1.4	0.36	0.23	0.56	7.55	1
3411211	4	30	1.35	0.38	0.28	0	7.55	1
3411211	5	100	1.35	0.38	0.28	0	7.55	1
3413211	1	30	1.1	0.35	0.13	1.6	6.45	1
3413211	2	20	1.25	0.27	0.15	0.53	7.55	1
3413211	3	30	1.25	0.27	0.15	0.53	7.55	1
3413211	4	20	1.25	0.27	0.15	0	7.55	1
3413211	5	100	1.25	0.27	0.15	0	7.55	1
3414211	1	30	1.21	0.4	0.18	1.6	5.75	3
3414211	2	20	1.36	0.36	0.12	0.53	6.45	3
3414211	3	10	1.36	0.36	0.12	0.53	6.45	3
3414211	4	40	1.4	0.33	0.27	0	6.45	3
3414211	5	40	1.4	0.3	0.2	0	7	3
3414211	6	60	1.4	0.2	0.06	0	7	3
3415211	1	30	1.3	0.38	0.17	1.6	5.75	3
3415211	2	20	1.4	0.36	0.12	0.53	6.45	3
3415211	3	20	1.4	0.36	0.12	0.53	6.45	3
3415211	4	30	1.4	0.33	0.27	0	6.45	3
3415211	5	40	1.4	0.36	0.16	0	6.45	3

Soil no.	Horizon no.	Depth (cm)	Density (kg/L)	Field capacity (m^3/m^3)	Wilting point (m^3/m^3)	C_{org} (%)	pH (-)	Hydrologic soil group
3415211	6	60	1.25	0.27	0.15	0	7	3
3416211	1	30	1.21	0.29	0.11	1.6	5.05	1
3416211	2	20	1.5	0.23	0.06	0.53	5.75	1
3416211	3	10	1.5	0.23	0.06	0.53	5.75	1
3416211	4	40	1.4	0.2	0.06	0	5.75	1
3416211	5	100	1.4	0.17	0.05	0	5.75	1
3417211	1	30	1.28	0.28	0.1	1.4	5.05	1
3417211	2	20	1.46	0.24	0.06	0.31	5.75	1
3417211	3	50	1.46	0.22	0.05	0.31	5.75	1
3417211	4	100	1.4	0.28	0.11	0	6.45	1
3418211	1	30	1.1	0.38	0.21	1.5	7	3
3418211	2	20	1.25	0.34	0.19	0.44	7.55	3
3418211	3	30	1.25	0.34	0.19	0.44	7.55	3
3418211	4	120	1.65	0.17	0.07	0	7.55	3
3421211	1	30	1.17	0.35	0.2	2.6	6.45	2
3421211	2	20	1.32	0.38	0.19	0.29	7	2
3421211	3	30	1.4	0.3	0.2	0.29	7.55	2
3421211	4	20	1.5	0.29	0.19	0	7.55	2
3421211	5	80	1.5	0.29	0.19	0	7.55	2
3421211	6	20	1.5	0.06	0.04	0	7.55	2
3422211	1	30	1.3	0.29	0.12	1.4	5.05	3
3422211	2	20	1.36	0.28	0.11	0.31	5.75	3
3422211	3	50	1.5	0.29	0.19	0.31	5.75	3
3422211	4	100	1.5	0.29	0.19	0	5.75	3
3428211	1	30	1.21	0.3	0.08	1.4	5.05	3
3428211	2	20	1.4	0.27	0.06	0.31	5.75	3
3428211	3	50	1.25	0.27	0.07	0.31	5.75	3
3428211	4	100	1.5	0.24	0.13	0	7	3
3430211	1	30	1.1	0.38	0.21	2.6	7	2
3430211	2	20	1.35	0.3	0.1	0.29	7	2

Soil no.	Horizon no.	Depth (cm)	Density (kg/L)	Field capacity (m^3/m^3)	Wilting point (m^3/m^3)	C_{org} (%)	pH (-)	Hydrologic soil group
3430211	3	50	1.25	0.27	0.15	0.29	7	2
3430211	4	20	1.35	0.25	0.09	0	7.55	2
3430211	5	80	1.35	0.19	0.07	0	7.55	2
3431211	1	30	1.28	0.27	0.09	1.4	5.05	1
3431211	2	20	1.36	0.21	0.05	0.31	5.05	1
3431211	3	10	1.36	0.21	0.05	0.31	5.05	1
3431211	4	40	1.46	0.23	0.06	0	5.05	1
3431211	5	100	1.55	0.17	0.02	0	5.05	1
3435211	1	30	1.1	0.4	0.22	1.5	7	3
3435211	2	20	1.25	0.36	0.2	0.44	7.55	3
3435211	3	50	1.25	0.36	0.2	0.44	7.55	3
3435211	4	100	1.25	0.36	0.2	0.44	7.55	3
3439211	1	30	1.21	0.4	0.18	1.5	7	2
3439211	2	20	1.4	0.38	0.12	0.44	7	2
3439211	3	20	1.4	0.38	0.12	0.44	7	2
3439211	4	30	1.35	0.36	0.1	0	7	2
3439211	5	50	1.4	0.36	0.12	0	7.55	2
3439211	6	50	1.4	0.3	0.2	0	7.55	2
3440211	1	30	1.1	0.4	0.22	1.5	6.45	3
3440211	2	20	1.1	0.4	0.22	0.44	6.45	3
3440211	3	40	1.36	0.38	0.27	0.44	6.45	3
3440211	4	10	1.25	0.36	0.2	0	6.45	3
3440211	5	100	1.25	0.36	0.2	0	7	3
3442211	1	30	1.21	0.4	0.18	1.5	6.45	1
3442211	2	10	1.4	0.36	0.12	0.44	6.45	1
3442211	3	10	1.4	0.36	0.12	0.44	6.45	1
3442211	4	10	1.45	0.34	0.22	0.44	6.45	1
3442211	5	40	1.45	0.34	0.22	0	6.45	1
3442211	6	100	1.4	0.36	0.12	0	7	1
3443211	1	30	1.21	0.4	0.15	1.5	6.45	1

Soil no.	Horizon no.	Depth (cm)	Density (kg/L)	Field capacity (m^3/m^3)	Wilting point (m^3/m^3)	C_{org} (%)	pH (-)	Hydrologic soil group
3443211	2	20	1.32	0.36	0.1	0.44	6.45	1
3443211	3	10	1.32	0.36	0.1	0.44	6.45	1
3443211	4	40	1.4	0.34	0.16	0	6.45	1
3443211	5	50	1.4	0.36	0.12	0	7	1
3443211	6	50	1.4	0.36	0.12	0	7	1
3444211	1	30	1.21	0.4	0.15	1.5	6.45	3
3444211	2	10	1.4	0.36	0.12	0.44	6.45	3
3444211	3	10	1.4	0.36	0.12	0.44	6.45	3
3444211	4	10	1.45	0.34	0.22	0.44	6.45	3
3444211	5	20	1.45	0.34	0.22	0	6.45	3
3444211	6	20	1.35	0.34	0.1	0	6.45	3
3444211	7	100	1.25	0.24	0.06	0	7	3
3445211	1	30	1.21	0.4	0.15	1.5	6.45	3
3445211	2	20	1.35	0.36	0.1	0.44	6.45	3
3445211	3	10	1.45	0.34	0.22	0.44	6.45	3
3445211	4	20	1.45	0.34	0.22	0	7	3
3445211	5	20	1.4	0.34	0.11	0	7	3
3445211	6	100	1.35	0.28	0.1	0	7	3
3446211	1	30	1.1	0.37	0.13	1.74	6.45	2
3446211	2	20	1.25	0.34	0.12	0.22	6.45	2
3446211	3	30	1.25	0.32	0.12	0.22	6.45	2
3446211	4	20	1.2	0.3	0.08	0	7	2
3446211	5	100	1.35	0.28	0.16	0	7	2
3447211	1	30	1.3	0.38	0.14	1.7	6.45	2
3447211	2	20	1.35	0.36	0.1	0.54	7	2
3447211	3	30	1.4	0.34	0.14	0.54	6.45	2
3447211	4	10	1.35	0.25	0.09	0	7	2
3448211	1	25	1.21	0.38	0.14	1.5	6.45	3
3448211	2	5	1.35	0.33	0.11	0.44	7	3
3448211	3	20	1.25	0.27	0.15	0.44	7	3

Soil no.	Horizon no.	Depth (cm)	Density (kg/L)	Field capacity (m³/m³)	Wilting point (m³/m³)	C_{org} (%)	pH (-)	Hydrologic soil group
3448211	4	10	1.25	0.27	0.15	0.44	7	3
3448211	5	40	1.35	0.28	0.21	0	7	3
3448211	6	100	1.35	0.28	0.21	0	7	3
3449212	1	30	1.21	0.3	0.2	1.6	7	1
3449212	2	30	1.3	0.29	0.2	0.69	7.55	1
3450212	1	20	0.98	0.4	0.23	1.6	6.45	3
3450212	2	30	1.22	0.27	0.15	0.69	7	3
3450212	3	40	1.4	0.28	0.22	0.69	7.55	3
3451211	1	30	1.21	0.48	0.3	1.7	6.45	2
3451211	2	5	1.32	0.38	0.28	0.5	7	2
3451211	3	15	1.4	0.36	0.28	0.5	7	2
3451211	4	30	1.4	0.36	0.28	0.5	7	2
3451211	5	20	1.35	0.37	0.27	0	7.55	2
3451211	6	100	1.35	0.37	0.27	0	7.55	2
3452211	1	30	1.17	0.34	0.13	1.7	5.05	1
3452211	2	5	1.17	0.34	0.13	1.7	5.05	1
3452211	3	15	1.25	0.27	0.1	0.5	6.45	1
3452211	4	20	1.35	0.19	0.07	0.5	5.75	1
3452211	5	30	1.4	0.08	0.02	0	7.55	1
3452211	6	100	1.4	0.08	0.02	0	7.55	1
3453211	1	30	1.17	0.36	0.2	1.7	6.45	2
3453211	2	20	1.25	0.27	0.15	0.54	7	2
3453211	3	20	1.35	0.19	0.11	0.54	7	2
3454212	1	30	1.17	0.34	0.13	1.74	5.75	2
3454212	2	20	1.35	0.25	0.09	0.4	6.45	2
3454212	3	40	1.4	0.13	0.04	0.4	6.45	2
3455211	1	30	1.21	0.38	0.14	1.74	6.45	2
3455211	2	20	1.36	0.33	0.12	0.56	6.45	2
3455211	3	10	1.36	0.33	0.12	0.56	6.45	2
3455211	4	40	1.35	0.19	0.11	0	6.45	2

Soil no.	Horizon no.	Depth (cm)	Density (kg/L)	Field capacity (m^3/m^3)	Wilting point (m^3/m^3)	C_{org} (%)	pH (-)	Hydrologic soil group
3456211	1	30	1.1	0.35	0.13	1.74	6.45	1
3456211	2	20	1.35	0.28	0.1	0.56	7	1
3456211	3	20	1.4	0.2	0.06	0.56	7	1
3458211	1	30	1.17	0.35	0.2	1.6	6.45	2
3458211	2	20	1.35	0.28	0.1	0.46	7	2
3458211	3	20	1.35	0.25	0.09	0.46	7	2
3459211	1	30	1.1	0.38	0.21	1.7	6.45	3
3459211	2	20	1.25	0.3	0.17	0.5	7	3
3459211	3	10	1.25	0.3	0.17	0.5	7	3
3459211	4	10	1.4	0.3	0.24	0	7	3
3460211	1	20	1.17	0.35	0.2	1.7	6.45	4
3460211	2	15	1.25	0.3	0.17	0.5	7	4
3460211	3	15	1.4	0.27	0.18	0.5	7	4
3461212	1	30	1.26	0.34	0.12	1.6	5.05	1
3461212	2	20	1.4	0.27	0.09	0.46	5.75	1
3461212	3	20	1.5	0.21	0.05	0.46	5.75	1
3463211	1	30	1.17	0.31	0.07	1.6	5.05	1
3463211	2	20	1.4	0.24	0.06	0.46	5.75	1
3463211	3	20	1.55	0.12	0.03	0.46	5.75	1
3464211	1	30	1.1	0.38	0.21	1.6	6.45	1
3464211	2	20	1.25	0.27	0.1	0.46	7	1
3465211	1	30	1.21	0.4	0.15	1.7	6.45	2
3465211	2	20	1.4	0.36	0.16	0.5	6.45	2
3465211	3	20	1.4	0.36	0.16	0.5	6.45	2
3465211	4	30	1.45	0.32	0.21	0	7	2
3466211	1	30	1.26	0.33	0.19	1.6	6.45	2
3466211	2	20	1.35	0.3	0.1	0.69	6.45	2
3466211	3	10	1.35	0.28	0.16	0.69	6.45	2
3466211	4	40	1.4	0.3	0.2	0	7	2
3466211	5	10	1.35	0.28	0.21	0	7	2

Soil no.	Horizon no.	Depth (cm)	Density (kg/L)	Field capacity (m^3/m^3)	Wilting point (m^3/m^3)	C_{org} (%)	pH (-)	Hydrologic soil group
3467211	1	30	1.1	0.4	0.22	1.7	6.45	3
3467211	2	20	1.25	0.36	0.2	0.5	7	3
3467211	3	20	1.4	0.4	0.31	0.5	7	3
3467211	4	30	1.4	0.4	0.31	0	7	3
3467211	5	100	1.4	0.4	0.31	0	7	3
3501211	1	30	1.32	0.23	0.05	0.9	5.05	1
3501211	2	5	1.32	0.23	0.05	0.9	5.05	1
3501211	3	15	1.51	0.2	0.04	0.31	5.05	1
3501211	4	30	1.55	0.15	0.03	0.31	5.05	1
3501211	5	20	1.55	0.15	0.03	0	5.05	1
3501211	6	100	1.55	0.15	0.03	0	5.05	1
3506211	1	30	0.54	0.59	0.3	0.8	4.35	1
3506211	2	20	0.54	0.62	0.3	0.8	5.05	1
3506211	3	60	0.45	0.8	0.22	0.8	5.05	1
3506211	4	90	1.5	0.24	0.06	0	5.05	1
3508211	1	30	1.17	0.36	0.14	1.5	5.05	1
3508211	2	20	1.32	0.32	0.1	0.56	5.75	1
3508211	3	25	1.32	0.32	0.1	0.56	5.75	1
3508211	4	25	1.35	0.32	0.1	0	6.45	1
3508211	5	100	1.35	0.32	0.1	0	6.45	1
3509211	1	30	0.98	0.52	0.28	1.5	6.45	1
3509211	2	20	1.21	0.4	0.18	0.56	7	1
3509211	3	30	1.3	0.38	0.14	0.56	7	1
3509211	4	20	1.4	0.36	0.16	0	7	1
3509211	5	100	1.4	0.21	0.05	0	7	1
3511211	1	30	1.17	0.36	0.14	1.5	5.05	1
3511211	2	20	1.4	0.29	0.11	0.56	5.75	1
3511211	3	20	1.4	0.29	0.11	0.56	5.75	1
3511211	4	30	1.4	0.29	0.11	0	5.75	1
3511211	5	100	1.4	0.29	0.11	0	5.75	1

Soil no.	Horizon no.	Depth (cm)	Density (kg/L)	Field capacity (m^3/m^3)	Wilting point (m^3/m^3)	C_{org} (%)	pH (-)	Hydrologic soil group
3512211	1	30	1.28	0.27	0.09	0.9	5.05	1
3512211	2	20	1.5	0.23	0.06	0.31	5.05	1
3512211	3	10	1.4	0.21	0.05	0.31	5.05	1
3512211	4	40	1.4	0.21	0.05	0	5.05	1
3512211	5	100	1.55	0.16	0.03	0	5.75	1
3513211	1	30	1.1	0.35	0.13	1.74	6.45	1
3513211	2	20	1.25	0.27	0.15	0.53	7.55	1
3513211	3	30	1.25	0.27	0.15	0.53	7.55	1
3513211	4	20	1.25	0.27	0.15	0	7.55	1
3513211	5	100	1.25	0.27	0.15	0	7.55	1
3515211	1	30	1.3	0.38	0.17	0.87	5.75	3
3515211	2	20	1.4	0.36	0.12	0.53	6.45	3
3515211	3	20	1.4	0.36	0.12	0.53	6.45	3
3515211	4	30	1.4	0.33	0.27	0	6.45	3
3515211	5	40	1.4	0.36	0.16	0	6.45	3
3515211	6	60	1.25	0.27	0.15	0	7	3
3517211	1	30	1.38	0.26	0.08	0.9	5.05	1
3517211	2	20	1.46	0.24	0.06	0.31	5.75	1
3517211	3	30	1.46	0.24	0.06	0.31	5.75	1
3517211	4	20	1.4	0.27	0.09	0	5.75	1
3517211	5	100	1.4	0.27	0.09	0	5.75	1
3519211	1	30	1.3	0.34	0.14	0.8	6.45	2
3519211	2	20	1.4	0.28	0.11	0.29	6.45	2
3519211	3	20	1.5	0.31	0.17	0.29	6.45	2
3519211	4	10	1.5	0.27	0.15	0	7	2
3519211	5	20	1.4	0.24	0.1	0	7	2
3519211	6	100	1.5	0.29	0.19	0	7.55	2
3520211	1	30	1.14	0.4	0.22	0.8	7	2
3520211	2	20	1.28	0.38	0.25	0.29	7	2
3520211	3	50	1.46	0.29	0.19	0.29	7	2

Soil no.	Horizon no.	Depth (cm)	Density (kg/L)	Field capacity (m³/m³)	Wilting point (m³/m³)	C_{org} (%)	pH (-)	Hydrologic soil group
3520211	4	100	1.4	0.3	0.2	0	7.55	2
3522211	1	30	1.3	0.29	0.12	0.9	5.05	3
3522211	2	20	1.36	0.28	0.11	0.31	5.75	3
3522211	3	50	1.5	0.29	0.19	0.31	5.75	3
3522211	4	100	1.5	0.29	0.19	0	5.75	3
3523211	1	30	1.3	0.27	0.09	0.8	5.75	1
3523211	2	20	1.5	0.23	0.06	0.29	7	1
3523211	3	10	1.5	0.23	0.06	0.29	7	1
3523211	4	20	1.4	0.24	0.1	0	7.55	1
3523211	5	20	1.5	0.29	0.19	0	7.55	1
3523211	6	30	1.5	0.29	0.19	0	7.55	1
3523211	7	70	1.5	0.29	0.19	0	7.55	1
3524211	1	30	1.21	0.32	0.14	0.8	7	1
3524211	2	20	1.3	0.3	0.12	0.29	7.55	1
3524211	3	30	1.3	0.27	0.09	0.29	7.55	1
3524211	4	20	1.36	0.28	0.11	0.29	7.55	1
3524211	5	10	1.35	0.31	0.17	0	7.55	1
3524211	6	40	1.5	0.29	0.19	0	7.55	1
3524211	7	50	1.5	0.29	0.19	0	7.55	1
3526211	1	30	1.38	0.25	0.08	0.8	5.05	2
3526211	2	10	1.5	0.23	0.06	0.13	5.75	2
3526211	3	10	1.5	0.23	0.06	0.13	5.75	2
3526211	4	10	1.4	0.28	0.11	0.13	5.75	2
3526211	5	40	1.5	0.23	0.06	0	6.45	2
3526211	6	100	1.5	0.27	0.15	0	7	2
3527211	1	30	1.3	0.28	0.07	0.8	5.05	2
3527211	2	20	1.4	0.27	0.06	0.29	5.75	2
3527211	3	50	1.25	0.29	0.06	0.29	5.75	2
3527211	4	100	1.5	0.29	0.19	0	7	2
3528212	1	30	1.21	0.3	0.08	0.9	5.05	3

Soil no.	Horizon no.	Depth (cm)	Density (kg/L)	Field capacity (m^3/m^3)	Wilting point (m^3/m^3)	C_{org} (%)	pH (-)	Hydrologic soil group
3528212	2	20	1.4	0.27	0.06	0.31	5.75	3
3528212	3	50	1.25	0.27	0.07	0.31	5.75	3
3528212	4	100	1.5	0.24	0.13	0	7	3
3529211	1	30	1.3	0.28	0.07	0.9	5.75	1
3529211	2	20	1.4	0.27	0.06	0.31	5.75	1
3529211	3	20	1.4	0.26	0.08	0.31	5.75	1
3529211	4	30	1.4	0.22	0.1	0	7	1
3531212	1	30	1.28	0.27	0.09	0.9	5.05	1
3531212	2	20	1.36	0.21	0.05	0.31	5.05	1
3531212	3	50	1.46	0.23	0.06	0.31	5.05	1
3531212	4	20	1.46	0.23	0.06	0.31	5.05	1
3531212	5	80	1.55	0.17	0.02	0	5.05	1
3532211	1	30	1.38	0.26	0.08	0.9	5.05	1
3532211	2	20	1.5	0.24	0.06	0.31	5.75	1
3532211	3	10	1.5	0.24	0.06	0.31	5.75	1
3532211	4	40	1.5	0.24	0.06	0	5.75	1
3532211	5	100	1.5	0.24	0.06	0	5.75	1
3534211	1	30	1.42	0.21	0.04	0.9	5.05	1
3534211	2	20	1.55	0.2	0.04	0.31	5.05	1
3534211	3	50	1.55	0.22	0.03	0.31	5.05	1
3534211	4	100	1.55	0.22	0.03	0.31	5.05	1
3536211	1	30	1.21	0.42	0.18	2.24	7	3
3536211	2	20	1.21	0.4	0.18	0.44	7.55	3
3536211	3	50	1.3	0.38	0.17	0.44	7.55	3
3536211	4	100	1.4	0.36	0.15	0	7.55	3
3537211	1	30	1.21	0.4	0.18	2.24	7	3
3537211	2	20	1.21	0.4	0.18	0.44	7.55	3
3537211	3	50	1.3	0.38	0.17	0.44	7.55	3
3537211	4	100	1.5	0.29	0.19	0	7.55	3
3538211	1	30	1.21	0.4	0.18	2.24	7	2

Soil no.	Horizon no.	Depth (cm)	Density (kg/L)	Field capacity (m^3/m^3)	Wilting point (m^3/m^3)	C_{org} (%)	pH (-)	Hydrologic soil group
3538211	2	20	1.4	0.38	0.12	0.44	7	2
3538211	3	20	1.4	0.38	0.12	0.44	7	2
3538211	4	30	1.35	0.36	0.1	0	7	2
3538211	5	50	1.4	0.36	0.12	0	7.55	2
3538211	6	50	1.4	0.3	0.2	0	7.55	2
3540211	1	30	1.1	0.4	0.22	2.24	6.45	3
3540211	2	20	1.1	0.4	0.22	0.44	6.45	3
3540211	3	30	1.36	0.36	0.23	0.44	6.45	3
3540211	4	20	1.4	0.36	0.16	0	7	3
3540211	5	100	1.4	0.38	0.16	0	7	3
3541211	1	30	1.1	0.46	0.25	2.24	6.45	2
3541211	2	20	1.1	0.4	0.22	0.44	6.45	2
3541211	3	30	1.17	0.38	0.22	0.44	7	2
3541211	4	20	1.22	0.36	0.2	0.44	7	2
3541211	5	10	1.25	0.36	0.2	0	7.55	2
3541211	6	40	1.25	0.36	0.2	0	7.55	2
3541211	7	50	1.4	0.27	0.18	0	7.55	2
3542211	1	30	1.21	0.4	0.18	2.24	6.45	3
3542211	2	20	1.4	0.36	0.12	0.44	6.45	3
3542211	3	10	1.45	0.36	0.21	0.44	6.45	3
3542211	4	10	1.4	0.36	0.12	0	6.45	3
3542211	5	30	1.4	0.34	0.11	0	7	3
3542211	6	100	1.4	0.31	0.11	0	7	3
3543211	1	30	1.21	0.4	0.15	2.24	6.45	1
3543211	2	20	1.32	0.36	0.1	0.44	6.45	1
3543211	3	10	1.32	0.36	0.1	0.44	6.45	1
3543211	4	40	1.4	0.34	0.16	0	6.45	1
3543211	5	100	1.4	0.36	0.12	0	7	1
3544211	1	30	1.21	0.4	0.15	2.24	6.45	3
3544211	2	10	1.4	0.36	0.12	0.44	6.45	3

Soil no.	Horizon no.	Depth (cm)	Density (kg/L)	Field capacity (m^3/m^3)	Wilting point (m^3/m^3)	C_{org} (%)	pH (-)	Hydrologic soil group
3544211	3	10	1.4	0.36	0.12	0.44	6.45	3
3544211	4	10	1.45	0.34	0.22	0.44	6.45	3
3544211	5	20	1.45	0.34	0.22	0	6.45	3
3544211	6	20	1.35	0.34	0.1	0	6.45	3
3544211	7	100	1.25	0.24	0.06	0	7	3
3545211	1	30	1.21	0.4	0.15	2.24	6.45	3
3545211	2	20	1.35	0.36	0.1	0.44	6.45	3
3545211	3	10	1.45	0.34	0.22	0.44	6.45	3
3545211	4	20	1.45	0.34	0.22	0	7	3
3545211	5	20	1.4	0.34	0.11	0	7	3
3545211	6	100	1.35	0.28	0.1	0	7	3
3546211	1	30	1.17	0.35	0.12	1	6.45	2
3546211	2	10	1.25	0.32	0.12	0.22	6.45	2
3546211	3	10	1.25	0.32	0.12	0.22	6.45	2
3546211	4	50	1.25	0.34	0.12	0.22	6.45	2
3546211	5	10	1.35	0.3	0.1	0	6.45	2
3546211	6	90	1.5	0.21	0.05	0	6.45	2
3547211	1	30	1.3	0.38	0.14	0.87	6.45	2
3547211	2	20	1.35	0.36	0.1	0.54	7	2
3547211	3	30	1.4	0.34	0.14	0.54	6.45	2
3547211	4	10	1.35	0.25	0.09	0	7	2
3548211	1	25	1.21	0.38	0.14	2.24	6.45	3
3548211	2	5	1.35	0.33	0.11	0.44	7	3
3548211	3	20	1.25	0.27	0.15	0.44	7	3
3548211	4	10	1.25	0.27	0.15	0.44	7	3
3548211	5	40	1.35	0.28	0.21	0	7	3
3548211	6	100	1.35	0.28	0.21	0	7	3
3549212	1	30	1.21	0.3	0.2	2.2	7	1
3549212	2	20	1.3	0.29	0.2	0.69	7.55	1
3551211	1	25	1.21	0.48	0.3	2.4	6.45	2

Soil no.	Horizon no.	Depth (cm)	Density (kg/L)	Field capacity (m³/m³)	Wilting point (m³/m³)	C_{org} (%)	pH (-)	Hydrologic soil group
3551211	2	10	1.32	0.38	0.28	0.5	7	2
3551211	3	45	1.4	0.36	0.28	0.5	7	2
3551211	4	20	1.35	0.37	0.27	0	7.55	2
3551211	5	120	1.35	0.37	0.27	0	7.55	2
3553211	1	30	1.17	0.36	0.2	0.87	6.45	2
3553211	2	20	1.25	0.27	0.15	0.54	7	2
3553211	3	10	1.35	0.19	0.11	0.54	7	2
3555211	1	30	1.21	0.38	0.14	2.1	6.45	2
3555211	2	20	1.36	0.33	0.12	0.56	6.45	2
3555211	3	40	1.35	0.19	0.11	0	6.45	2
3556211	1	30	1.1	0.35	0.13	2.1	6.45	1
3556211	2	20	1.35	0.28	0.1	0.56	7	1
3556211	3	20	1.4	0.2	0.06	0.56	7	1
3557211	1	30	1.17	0.34	0.13	2.1	5.05	3
3557211	2	20	1.35	0.28	0.1	0.56	5.75	3
3557211	3	20	1.35	0.28	0.1	0.56	5.75	3
3557211	4	10	1.4	0.2	0.06	0	5.75	3
3559211	1	30	1.1	0.38	0.21	2.4	6.45	3
3559211	2	20	1.25	0.3	0.17	0.5	7	3
3559211	3	10	1.25	0.3	0.17	0.5	7	3
3559211	4	10	1.4	0.3	0.24	0	7	3
3561212	1	30	1.26	0.34	0.12	4.5	5.05	1
3561212	2	20	1.4	0.27	0.09	0.46	5.75	1
3561212	3	20	1.5	0.21	0.05	0.46	5.75	1
3563211	1	30	1.17	0.31	0.07	4.5	5.05	1
3563211	2	20	1.4	0.24	0.06	0.46	5.75	1
3563211	3	20	1.55	0.12	0.03	0.46	5.75	1
3564211	1	30	1.1	0.38	0.21	4.5	6.45	1
3564211	2	20	1.25	0.27	0.1	0.46	7	1
3565211	1	30	1.21	0.4	0.15	2.4	6.45	2

Soil no.	Horizon no.	Depth (cm)	Density (kg/L)	Field capacity (m^3/m^3)	Wilting point (m^3/m^3)	C_{org} (%)	pH (-)	Hydrologic soil group
3565211	2	20	1.4	0.36	0.16	0.5	6.45	2
3565211	3	20	1.4	0.36	0.16	0.5	6.45	2
3565211	4	30	1.45	0.32	0.21	0	7	2
3566211	1	30	1.26	0.33	0.19	2.2	6.45	2
3566211	2	20	1.35	0.3	0.1	0.69	6.45	2
3566211	3	10	1.35	0.28	0.16	0.69	6.45	2
3566211	4	40	1.4	0.3	0.2	0	7	2
3566211	5	30	1.35	0.28	0.21	0	7	2

4.2 Appendix 2: Soil – climate – combinations used for the step 2 analysis

Table 4-2: All soil – climate – combinations used for the step 2 analysis

No.	Soil	Station	No.	Soil	Station	No.	Soil	Station	No.	Soil	Station
1	3304211	4393	838	3542211	3126	1675	3563211	3668	2512	3555211	5779
2	3306211	4466	839	3540211	5300	1676	3531212	282	2513	3459211	953
3	3303211	4393	840	3546211	5825	1677	3543211	191	2514	3435211	4411
4	3317211	4466	841	3541211	2951	1678	3545211	5440	2515	3456211	2750
5	3304211	4466	842	3541211	5825	1679	3543211	5440	2516	3444211	4377
6	3319211	2303	843	3532211	4642	1680	3543211	314	2517	3559211	1411
7	3319211	4466	844	3322211	3023	1681	3515211	5750	2518	3459211	1279
8	3331211	4466	845	3466211	44	1682	3531212	3667	2519	3459211	4323
9	3325211	4466	846	3411211	5100	1683	3529211	2700	2520	3461212	3761
10	3319211	4896	847	3466211	3939	1684	3546211	1684	2521	3463211	5426
11	3523211	183	848	3408211	5100	1685	3459211	5717	2522	3463211	1645
12	3303211	4466	849	3442211	4651	1686	3452211	3034	2523	3454212	4323
13	3325211	4393	850	3465211	1964	1687	3461212	1645	2524	3454212	5279
14	3331211	4393	851	3338211	1297	1688	3451211	3660	2525	3459211	4411
15	3306211	4896	852	3338211	1691	1689	3449212	5158	2526	3463211	2750
16	3523211	298	853	3308211	1297	1690	3409211	896	2527	3411211	2750
17	3317211	4393	854	3536211	3126	1691	3545211	3289	2528	3444211	2750
18	3331211	2303	855	3541211	3126	1692	3545211	1001	2529	3444211	3034
19	3519211	298	856	3452211	3939	1693	3546211	896	2530	3460211	1639
20	3519211	4896	857	3466211	3540	1694	3531212	2532	2531	3461212	4411
21	3301211	4896	858	3428211	5100	1695	3544211	3667	2532	3461212	2712
22	3506211	298	859	3466211	5279	1696	3543211	4625	2533	3453211	4560
23	3304211	1266	860	3408211	2211	1697	3512211	314	2534	3463211	5017
24	3333211	4466	861	3408211	4371	1698	3508211	314	2535	3416211	4411
25	3303211	1266	862	3340211	294	1699	3545211	1684	2536	3440211	4349
26	3523211	4896	863	3540211	1297	1700	3508211	2700	2537	3453211	3761
27	3325211	1266	864	3540211	1691	1701	3460211	3167	2538	3451211	2597

No.	Soil	Sta-tion	No.	Soil	Station	No.	Soil	Station	No.	Soil	Station
28	3319211	4039	865	3509211	4709	1702	3460211	2947	2539	3463211	867
29	3307211	2303	866	3536211	5300	1703	3452211	1645	2540	3459211	2167
30	3301211	183	867	3452211	3791	1704	3442211	817	2541	3440211	3257
31	3320211	183	868	3442211	3540	1705	3449212	2601	2542	3459211	1964
32	3320211	596	869	3442211	2211	1706	3442211	1645	2543	3442211	867
33	3319211	596	870	3449212	4336	1707	3451211	5426	2544	3442211	320
34	3301211	596	871	3449212	4560	1708	3442211	3231	2545	3460211	3490
35	3303211	3032	872	3342211	1964	1709	3449212	896	2546	3453211	5017
36	3303211	2303	873	3308211	1639	1710	3545211	3668	2547	3453211	2618
37	3506211	4896	874	3306211	1691	1711	3508211	3668	2548	3463211	3875
38	3527211	298	875	3349212	1297	1712	3543211	1736	2549	3408211	2750
39	3331211	4039	876	3565211	1691	1713	3544211	320	2550	3453211	294
40	3331211	4896	877	3540211	4709	1714	3544211	3987	2551	3442211	2480
41	3523211	5097	878	3536211	1297	1715	3545211	5750	2552	3453211	4377
42	3527211	5097	879	3520211	5629	1716	3544211	2700	2553	3461212	320
43	3320211	298	880	3452211	3612	1717	3546211	2700	2554	3461212	867
44	3319211	298	881	3463211	4336	1718	3543211	2700	2555	3451211	3875
45	3517211	298	882	3463211	2947	1719	3442211	5717	2556	3464211	3348
46	3527211	4896	883	3449212	3348	1720	3460211	4692	2557	3408211	2480
47	3506211	5097	884	3449212	1300	1721	3460211	4508	2558	3408211	377
48	3319211	2306	885	3340211	963	1722	3460211	863	2559	3408211	3761
49	3526211	298	886	3338211	294	1723	3460211	390	2560	3461212	2597
50	3304211	2303	887	3528212	1297	1724	3460211	3034	2561	3442211	2597
51	3322211	596	888	3536211	4709	1725	3451211	2680	2562	3451211	2750
52	3523211	1803	889	3517211	2951	1726	3442211	2680	2563	3459211	2925
53	3519211	5097	890	3463211	3540	1727	3445211	198	2564	3460211	1107
54	3319211	2578	891	3408211	5279	1728	3545211	3231	2565	3408211	4169
55	3301211	4393	892	3422211	4371	1729	3511211	191	2566	3449212	867
56	3506211	3086	893	3342211	2039	1730	3508211	5705	2567	3463211	1107
57	3517211	5097	894	3349212	3591	1731	3557211	3668	2568	3563211	2261
58	3306211	2578	895	3565211	4978	1732	3531212	3668	2569	3464211	1300

No.	Soil	Station	No.	Soil	Station	No.	Soil	Station	No.	Soil	Station
59	3301211	2578	896	3528212	1691	1733	3544211	853	2570	3460211	5100
60	3306211	2306	897	3524211	2951	1734	3544211	3204	2571	3442211	4349
61	3529211	5097	898	3524211	5825	1735	3544211	314	2572	3408211	320
62	3529211	298	899	3519211	5825	1736	3515211	314	2573	3460211	4371
63	3523211	1757	900	3422211	5100	1737	3544211	5440	2574	3449212	2750
64	3319211	3086	901	3342211	460	1738	3543211	1684	2575	3463211	320
65	3322211	2578	902	3338211	2532	1739	3451211	817	2576	3459211	2171
66	3322211	2306	903	3449212	1691	1740	3542211	400	2577	3451211	3257
67	3523211	2578	904	3308211	1691	1741	3542211	314	2578	3451211	3761
68	3517211	1803	905	3542211	4978	1742	3531212	2928	2579	3449212	2597
69	3506211	1757	906	3537211	1297	1743	3543211	3086	2580	3461212	2750
70	3527211	1803	907	3506211	896	1744	3544211	5750	2581	3463211	1197
71	3523211	596	908	3506211	3126	1745	3511211	5750	2582	3453211	4349
72	3506211	596	909	3506211	5300	1746	3511211	1684	2583	3451211	2712
73	3506211	1803	910	3422211	294	1747	3544211	991	2584	3463211	4287
74	3506211	2578	911	3366211	294	1748	3544211	1684	2585	3460211	1691
75	3527211	596	912	3449212	2532	1749	3459211	4692	2586	3440211	377
76	3519211	1757	913	3542211	1107	1750	3408211	3167	2587	3440211	2480
77	3532211	1757	914	3542211	3204	1751	3509211	430	2588	3451211	4411
78	3532211	1803	915	3542211	896	1752	3541211	880	2589	3408211	4349
79	3519211	1803	916	3509211	896	1753	3555211	191	2590	3451211	320
80	3532211	5097	917	3537211	4709	1754	3555211	3811	2591	3459211	3939
81	3531212	5097	918	3541211	5300	1755	3542211	5440	2592	3435211	377
82	3531212	1803	919	3536211	896	1756	3546211	320	2593	3435211	2480
83	3527211	3086	920	3519211	3552	1757	3546211	1197	2594	3442211	755
84	3331211	1266	921	3506211	427	1758	3543211	320	2595	3557211	3034
85	3527211	2578	922	3517211	1001	1759	3447211	3527	2596	3460211	1580
86	3519211	3086	923	3452211	4336	1760	3538211	2680	2597	3442211	377
87	3331211	1451	924	3463211	2211	1761	3536211	1050	2598	3449212	3875
88	3331211	3028	925	3408211	294	1762	3541211	1050	2599	3451211	4349
89	3331211	5280	926	3366211	2039	1763	3541211	430	2600	3459211	1107

No.	Soil	Sta-tion	No.	Soil	Station	No.	Soil	Station	No.	Soil	Station
90	3322211	2303	927	3540211	2171	1764	3543211	4287	2601	3416211	377
91	3523211	3086	928	3540211	2532	1765	3540211	191	2602	3416211	3761
92	3526211	2578	929	3540211	4978	1766	3540211	3668	2603	3442211	3284
93	3526211	5097	930	3540211	3204	1767	3511211	1297	2604	3557211	2261
94	3527211	5009	931	3542211	4763	1768	3555211	314	2605	3416211	2480
95	3317211	2303	932	3509211	198	1769	3557211	1197	2606	3416211	5279
96	3317211	5280	933	3509211	4763	1770	3544211	1197	2607	3416211	4336
97	3526211	3086	934	3506211	1297	1771	3543211	3204	2608	3449212	3761
98	3506211	5009	935	3541211	4709	1772	3545211	2700	2609	3463211	191
99	3325211	3028	936	3546211	3987	1773	3408211	4508	2610	3440211	5100
100	3520211	2578	937	3546211	400	1774	3453211	91	2611	3463211	3204
101	3519211	2578	938	3317211	2211	1775	3447211	1107	2612	3463211	2680
102	3523211	5009	939	3408211	3939	1776	3538211	4763	2613	3460211	3761
103	3303211	1451	940	3408211	4336	1777	3540211	5426	2614	3455211	4560
104	3331211	3086	941	3546211	3196	1778	3451211	5300	2615	3455211	3761
105	3520211	596	942	3331211	1766	1779	3509211	1050	2616	3461212	5541
106	3529211	596	943	3311211	1766	1780	3511211	1639	2617	3411211	867
107	3306211	2303	944	3311211	78	1781	3555211	1297	2618	3557211	5017
108	3322211	4039	945	3566211	1297	1782	3540211	4287	2619	3411211	4287
109	3522211	2578	946	3538211	1297	1783	3540211	314	2620	3464211	953
110	3522211	298	947	3538211	1691	1784	3557211	320	2621	3464211	3287
111	3526211	1803	948	3522211	3552	1785	3546211	1736	2622	3464211	2925
112	3527211	1757	949	3546211	5629	1786	3543211	1197	2623	3464211	979
113	3306211	5280	950	3506211	1001	1787	3548211	3667	2624	3408211	3137
114	3325211	5280	951	3442211	78	1788	3545211	991	2625	3455211	4336
115	3529211	3086	952	3308211	3591	1789	3465211	4508	2626	3450212	3034
116	3512211	596	953	3442211	1691	1790	3460211	1300	2627	3449212	4411
117	3506211	4625	954	3566211	1691	1791	3460211	3348	2628	3459211	3257
118	3526211	1757	955	3509211	3126	1792	3447211	3034	2629	3408211	1420
119	3529211	4896	956	3317211	3	1793	3440211	191	2630	3416211	1420
120	3517211	596	957	3328211	3028	1794	3409211	4978	2631	3449212	755

No.	Soil	Station	No.	Soil	Station	No.	Soil	Station	No.	Soil	Station
121	3519211	4625	958	3442211	3028	1795	3409211	3204	2632	3435211	5541
122	3333211	5280	959	3442211	2947	1796	3451211	5158	2633	3449212	3257
123	3526211	5009	960	3452211	2211	1797	3555211	4625	2634	3463211	3667
124	3517211	5009	961	3452211	2947	1798	3542211	4287	2635	3440211	1420
125	3519211	5009	962	3349212	1964	1799	3506211	5440	2636	3455211	4651
126	3325211	2303	963	3449212	3591	1800	3548211	1736	2637	3451211	3667
127	3523211	2306	964	3442211	2532	1801	3548211	853	2638	3459211	4480
128	3529211	2578	965	3549212	1297	1802	3536211	5426	2639	3435211	1420
129	3322211	4466	966	3542211	2171	1803	3538211	5158	2640	3455211	5279
130	3532211	5009	967	3542211	4323	1804	3442211	198	2641	3411211	1297
131	3319211	5280	968	3349212	2039	1805	3551211	896	2642	3449212	191
132	3531212	3086	969	3442211	3591	1806	3551211	2680	2643	3463211	2597
133	3522211	4625	970	3461212	294	1807	3542211	5797	2644	3452211	5541
134	3517211	1757	971	3442211	2039	1808	3509211	5797	2645	3455211	3257
135	3529211	2306	972	3538211	4709	1809	3540211	5797	2646	3411211	191
136	3531212	596	973	3540211	4323	1810	3540211	5440	2647	3411211	2597
137	3522211	596	974	3506211	4709	1811	3545211	1197	2648	3411211	4323
138	3522211	3086	975	3541211	1297	1812	3544211	3875	2649	3463211	3287
139	3512211	1757	976	3317211	3031	1813	3545211	320	2650	3559211	5097
140	3523211	4625	977	3331211	3	1814	3511211	3667	2651	3459211	460
141	3512211	5097	978	3449212	2211	1815	3511211	5440	2652	3449212	4480
142	3528212	5009	979	3452211	3540	1816	3545211	5397	2653	3455211	3284
143	3304211	1451	980	3452211	4560	1817	3447211	3204	2654	3451211	191
144	3517211	2578	981	3461212	3098	1818	3447211	4978	2655	3559211	5280
145	3517211	3086	982	3349212	5279	1819	3440211	4287	2656	3553211	853
146	3319211	1736	983	3317211	3540	1820	3440211	1297	2657	3459211	3761
147	3317211	3086	984	3328211	4336	1821	3409211	91	2658	3461212	3667
148	3531212	2578	985	3449212	3028	1822	3538211	5300	2659	3442211	3667
149	3522211	5097	986	3446211	2947	1823	3536211	2932	2660	3465211	3155
150	3522211	1757	987	3452211	5279	1824	3543211	2171	2661	3449212	460
151	3519211	3509	988	3442211	1639	1825	3546211	5750	2662	3415211	1420

No.	Soil	Sta-tion	No.	Soil	Station	No.	Soil	Station	No.	Soil	Station
152	3531212	4625	989	3310211	3	1826	3506211	314	2663	3416211	5100
153	3531212	298	990	3322211	4371	1827	3546211	5440	2664	3451211	1297
154	3531212	1757	991	3316211	78	1828	3545211	2532	2665	3465211	4480
155	3319211	5014	992	3352211	3540	1829	3548211	1197	2666	3542211	853
156	3529211	4625	993	3352211	4371	1830	3548211	320	2667	3451211	4480
157	3307211	5280	994	3466211	2211	1831	3548211	3204	2668	3442211	4745
158	3333211	4393	995	3466211	2532	1832	3544211	5397	2669	3452211	460
159	3322211	3086	996	3537211	5300	1833	3508211	4592	2670	3460211	3939
160	3506211	3509	997	3310211	3031	1834	3543211	4592	2671	3461212	4480
161	3322211	5280	998	3310211	1303	1835	3547211	5397	2672	3449212	5280
162	3501211	5009	999	3316211	4371	1836	3447211	2171	2673	3461212	460
163	3333211	891	1000	3352211	4336	1837	3461212	191	2674	3459211	2480
164	3517211	3509	1001	3319211	4371	1838	3459211	3348	2675	3416211	4349
165	3331211	1736	1002	3452211	3098	1839	3538211	5426	2676	3449212	2167
166	3532211	3086	1003	3452211	3167	1840	3548211	314	2677	3555211	1411
167	3319211	4745	1004	3440211	294	1841	3511211	4625	2678	3451211	460
168	3333211	1451	1005	3449212	2039	1842	3529211	3811	2679	3449212	4301
169	3526211	3509	1006	3442211	953	1843	3529211	3668	2680	3450212	4377
170	3305211	1266	1007	3537211	3126	1844	3555211	3204	2681	3461212	5280
171	3331211	4745	1008	3317211	1303	1845	3555211	320	2682	3458211	1297
172	3317211	1736	1009	3322211	1303	1846	3547211	151	2683	3440211	4301
173	3527211	4625	1010	3319211	3791	1847	3543211	5546	2684	3449212	150
174	3331211	44	1011	3466211	3028	1848	3511211	5546	2685	3406211	1420
175	3532211	4625	1012	3442211	4560	1849	3465211	2618	2686	3458211	4323
176	3322211	44	1013	3440211	1964	1850	3551211	5426	2687	3411211	4301
177	3506211	3196	1014	3466211	2039	1851	3536211	880	2688	3416211	4301
178	3532211	3196	1015	3319211	3023	1852	3545211	3204	2689	3449212	1420
179	3527211	3509	1016	3451211	3098	1853	3555211	3667	2690	3416211	294
180	3519211	3196	1017	3451211	3939	1854	3555211	991	2691	3416211	4287
181	3322211	4745	1018	3451211	4560	1855	3543211	5397	2692	3458211	1639
182	3304211	44	1019	3566211	4709	1856	3555211	2700	2693	3451211	1197

No.	Soil	Station	No.	Soil	Station	No.	Soil	Station	No.	Soil	Station
183	3519211	591	1020	3541211	2794	1857	3459211	863	2694	3450212	3348
184	3317211	44	1021	3546211	4625	1858	3440211	2925	2695	3442211	5280
185	3517211	4625	1022	3529211	3987	1859	3440211	91	2696	3458211	2600
186	3303211	891	1023	3319211	3540	1860	3409211	4709	2697	3435211	4301
187	3305211	2303	1024	3451211	4371	1861	3551211	3231	2698	3416211	896
188	3322211	1736	1025	3461212	5100	1862	3551211	1645	2699	3449212	4745
189	3305211	1451	1026	3506211	1691	1863	3542211	4605	2700	3416211	150
190	3305211	44	1027	3519211	4642	1864	3545211	4978	2701	3440211	150
191	3333211	1266	1028	3526211	4625	1865	3545211	2925	2702	3449212	5692
192	3333211	44	1029	3319211	78	1866	3545211	91	2703	3439211	1420
193	3506211	1694	1030	3319211	3612	1867	3543211	867	2704	3463211	3527
194	3307211	1736	1031	3331211	5100	1868	3542211	3668	2705	3451211	3155
195	3531212	1736	1032	3466211	2947	1869	3508211	3126	2706	3459211	2600
196	3304211	891	1033	3451211	2947	1870	3534211	5705	2707	3459211	3442
197	3519211	1736	1034	3451211	5279	1871	3534211	3668	2708	3439211	4411
198	3331211	5014	1035	3451211	4336	1872	3555211	5397	2709	3408211	348
199	3519211	1694	1036	3461212	3939	1873	3544211	4592	2710	3449212	1279
200	3317211	5014	1037	3466211	1964	1874	3460211	817	2711	3459211	1580
201	3306211	1736	1038	3537211	896	1875	3447211	2925	2712	3411211	150
202	3526211	1694	1039	3536211	5825	1876	3459211	3287	2713	3416211	3257
203	3532211	3509	1040	3529211	3552	1877	3542211	1645	2714	3461212	3875
204	3322211	1975	1041	3319211	4336	1878	3538211	5797	2715	3542211	3034
205	3325211	44	1042	3319211	5100	1879	3509211	314	2716	3411211	1580
206	3519211	5546	1043	3352211	5100	1880	3548211	5750	2717	3435211	150
207	3506211	164	1044	3319211	294	1881	3542211	867	2718	3449212	2814
208	3517211	164	1045	3449212	1964	1882	3555211	5229	2719	3459211	5705
209	3517211	5142	1046	3442211	3348	1883	3555211	4300	2720	3458211	4411
210	3306211	44	1047	3449212	979	1884	3543211	991	2721	3439211	348
211	3328211	44	1048	3451211	2532	1885	3460211	4445	2722	3435211	3257
212	3322211	5014	1049	3536211	2794	1886	3460211	1645	2723	3416211	5705
213	3519211	5142	1050	3541211	896	1887	3459211	2532	2724	3407211	3875

No.	Soil	Station	No.	Soil	Station	No.	Soil	Station	No.	Soil	Station
214	3506211	5142	1051	3526211	591	1888	3509211	5300	2725	3407211	3739
215	3333211	2303	1052	3451211	3167	1889	3551211	91	2726	3458211	3442
216	3325211	4745	1053	3408211	1964	1890	3540211	3231	2727	3411211	3442
217	3306211	4625	1054	3465211	2532	1891	3540211	445	2728	3439211	1580
218	3527211	164	1055	3308211	2532	1892	3511211	867	2729	3455211	2039
219	3328211	1451	1056	3444211	1297	1893	3548211	5397	2730	3542211	3875
220	3325211	1736	1057	3466211	1297	1894	3342211	1590	2731	3461212	4336
221	3317211	4625	1058	3536211	3552	1895	3442211	2667	2732	3460211	460
222	3306211	1451	1059	3532211	427	1896	3460211	3527	2733	3442211	2600
223	3527211	5546	1060	3352211	3612	1897	3447211	91	2734	3442211	3442
224	3519211	164	1061	3310211	5100	1898	3451211	3287	2735	3411211	2600
225	3306211	3086	1062	3451211	2211	1899	3459211	1691	2736	3440211	3761
226	3531212	3196	1063	3452211	5100	1900	3513211	198	2737	3442211	1580
227	3527211	5142	1064	3408211	2039	1901	3513211	896	2738	3458211	1580
228	3329211	3086	1065	3449212	4651	1902	3543211	3811	2739	3416211	4169
229	3526211	3196	1066	3451211	2039	1903	3543211	5750	2740	3435211	4169
230	3529211	5546	1067	3537211	1691	1904	3542211	282	2741	3440211	4651
231	3526211	5546	1068	3536211	1691	1905	3542211	3667	2742	3431211	4287
232	3329211	4625	1069	3522211	3987	1906	3555211	5440	2743	3431211	191
233	3331211	1975	1070	3322211	4336	1907	3555211	3875	2744	3465211	5100
234	3326211	3086	1071	3444211	1691	1908	3545211	3875	2745	3442211	450
235	3506211	5546	1072	3529211	427	1909	3545211	5229	2746	3455211	2600
236	3328211	5014	1073	3331211	3031	1910	3545211	867	2747	3416211	5906
237	3307211	44	1074	3322211	3540	1911	3543211	4703	2748	3435211	3284
238	3317211	591	1075	3466211	3098	1912	3442211	1590	2749	3450212	2750
239	3517211	3196	1076	3466211	1691	1913	3447211	4709	2750	3411211	450
240	3328211	701	1077	3508211	1691	1914	3461212	2953	2751	3458211	4709
241	3305211	5014	1078	3466211	460	1915	3545211	2171	2752	3455211	1639
242	3526211	164	1079	3408211	460	1916	3511211	320	2753	3455211	4323
243	3520211	3509	1080	3442211	979	1917	3459211	1468	2754	3442211	150
244	3520211	164	1081	3508211	1297	1918	3461212	2814	2755	3406211	5906

No.	Soil	Station	No.	Soil	Station	No.	Soil	Station	No.	Soil	Station
245	3305211	1975	1082	3524211	5629	1919	3551211	4763	2756	3435211	3761
246	3308211	1975	1083	3519211	5629	1920	3511211	3204	2757	3442211	4169
247	3317211	3196	1084	3546211	3376	1921	3544211	5229	2758	3416211	1279
248	3532211	5546	1085	3465211	4651	1922	3544211	3739	2759	3465211	4336
249	3326211	4625	1086	3529211	1001	1923	3544211	5546	2760	3458211	953
250	3317211	5097	1087	3322211	3	1924	3453211	2925	2761	3453211	2600
251	3519211	1869	1088	3322211	78	1925	3540211	3289	2762	3453211	953
252	3527211	3196	1089	3449212	2947	1926	3546211	853	2763	3458211	433
253	3308211	963	1090	3449212	953	1927	3511211	3875	2764	3455211	662
254	3325211	3086	1091	3461212	953	1928	3511211	1612	2765	3455211	1279
255	3520211	5142	1092	3537211	2171	1929	3451211	2814	2766	3406211	2480
256	3520211	5546	1093	3537211	91	1930	3551211	5797	2767	3442211	5705
257	3319211	1975	1094	3536211	198	1931	3548211	5440	2768	3542211	5229
258	3311211	44	1095	3317211	4336	1932	3555211	5705	2769	3458211	1964
259	3328211	5280	1096	3461212	2039	1933	3548211	3875	2770	3455211	1580
260	3319211	44	1097	3522211	3196	1934	3544211	4300	2771	3411211	1420
261	3308211	691	1098	3522211	5629	1935	3453211	4709	2772	3415211	2480
262	3312211	4625	1099	3522211	400	1936	3545211	4592	2773	3416211	3126
263	3306211	3196	1100	3546211	5745	1937	3543211	3668	2774	3451211	5705
264	3333211	5014	1101	3452211	4651	1938	3543211	2532	2775	3451211	282
265	3333211	4745	1102	3517211	400	1939	3543211	853	2776	3542211	3739
266	3331211	3196	1103	3532211	3376	1940	3316211	2110	2777	3453211	1580
267	3306211	5014	1104	3452211	1300	1941	3536211	314	2778	3461212	1580
268	3328211	1975	1105	3408211	1691	1942	3308211	2110	2779	3408211	3284
269	3346211	4745	1106	3520211	3987	1943	3465211	4692	2780	3416211	445
270	3326211	5097	1107	3546211	1001	1944	3463211	4978	2781	3451211	3126
271	3346211	5280	1108	3529211	2794	1945	3463211	1691	2782	3450212	2814
272	3346211	1975	1109	3346211	3023	1946	3538211	2171	2783	3461212	1964
273	3520211	1869	1110	3458211	2532	1947	3509211	191	2784	3461212	2600
274	3306211	1975	1111	3408211	2532	1948	3543211	2932	2785	3435211	2600
275	3306211	591	1112	3444211	2532	1949	3548211	991	2786	3415211	5906

No.	Soil	Station	No.	Soil	Station	No.	Soil	Station	No.	Soil	Station
276	3312211	591	1113	3537211	2925	1950	3544211	222	2787	3431211	867
277	3331211	5097	1114	3520211	400	1951	3346211	2110	2788	3449212	2600
278	3512211	3509	1115	3532211	1001	1952	3460211	953	2789	3435211	1050
279	3519211	5643	1116	3342211	3023	1953	3463211	4709	2790	3449212	1050
280	3301211	891	1117	3346211	5100	1954	3538211	314	2791	3431211	3667
281	3331211	4625	1118	3346211	4371	1955	3555211	1279	2792	3431211	2532
282	3326211	3196	1119	3465211	4560	1956	3548211	2700	2793	3442211	1197
283	3531212	3509	1120	3458211	2039	1957	3555211	3739	2794	3463211	5229
284	3506211	5643	1121	3536211	2171	1958	3460211	2953	2795	3439211	150
285	3308211	3086	1122	3536211	5158	1959	3463211	2171	2796	3453211	3284
286	3326211	591	1123	3519211	400	1960	3409211	1691	2797	3416211	282
287	3328211	4625	1124	3532211	5629	1961	3543211	896	2798	3453211	1964
288	3328211	2303	1125	3452211	979	1962	3543211	1757	2799	3416211	2600
289	3306211	4745	1126	3416211	4651	1963	3561212	3667	2800	3455211	1214
290	3328211	4745	1127	3458211	4651	1964	3561212	5440	2801	3453211	2211
291	3328211	1736	1128	3458211	5279	1965	3544211	2261	2802	3458211	3348
292	3308211	1736	1129	3536211	1957	1966	3460211	1468	2803	3465211	460
293	3308211	4625	1130	3466211	4651	1967	3409211	2171	2804	3406211	5692
294	3334211	4625	1131	3509211	5825	1968	3540211	4605	2805	3458211	3287
295	3306211	5097	1132	3528212	3987	1969	3543211	1612	2806	3450212	3287
296	3526211	5142	1133	3528212	1001	1970	3548211	1684	2807	3449212	5705
297	3317211	691	1134	3461212	4560	1971	3555211	1684	2808	3458211	5541
298	3328211	591	1135	3466211	5541	1972	3546211	991	2809	3458211	5705
299	3328211	3086	1136	3458211	979	1973	3561212	991	2810	3458211	191
300	3312211	3196	1137	3537211	5158	1974	3342211	2110	2811	3415211	5692
301	3306211	3509	1138	3509211	1957	1975	3442211	4605	2812	3415211	4169
302	3333211	1736	1139	3508211	400	1976	3538211	4978	2813	3455211	2211
303	3319211	3509	1140	3531212	3083	1977	3538211	3289	2814	3458211	3155
304	3328211	691	1141	3512211	3083	1978	3543211	5797	2815	3458211	3257
305	3308211	591	1142	3528212	5546	1979	3540211	2932	2816	3450212	2532
306	3331211	3509	1143	3308211	1590	1980	3555211	2532	2817	3458211	1279

No.	Soil	Sta-tion	No.	Soil	Station	No.	Soil	Station	No.	Soil	Station
307	3326211	3509	1144	3466211	979	1981	3548211	222	2818	3411211	5692
308	3326211	5009	1145	3408211	4651	1982	3555211	222	2819	3455211	330
309	3307211	5014	1146	3444211	2171	1983	3546211	222	2820	3411211	3667
310	3333211	691	1147	3411211	1691	1984	3547211	3739	2821	3461212	1297
311	3312211	3509	1148	3308211	3023	1985	3442211	1297	2822	3458211	348
312	3319211	3196	1149	3322211	5100	1986	3453211	4605	2823	3450212	2597
313	3310211	4745	1150	3322211	3031	1987	3536211	1270	2824	3450212	2039
314	3310211	691	1151	3540211	896	1988	3543211	4605	2825	3450212	4287
315	3310211	2014	1152	3322211	1766	1989	3511211	2532	2826	3450212	3667
316	3333211	2014	1153	3461212	4651	1990	3508211	1048	2827	3411211	3257
317	3317211	2014	1154	3451211	979	1991	3545211	3739	2828	3458211	294
318	3319211	5097	1155	3411211	2171	1992	3543211	5097	2829	3411211	2532
319	3526211	2794	1156	3444211	4709	1993	3555211	1197	2830	3449212	3271
320	3520211	1694	1157	3508211	896	1994	3561212	2700	2831	3463211	5397
321	3334211	591	1158	3311211	5100	1995	3545211	2261	2832	3463211	3739
322	3520211	2794	1159	3451211	3348	1996	3544211	151	2833	3458211	817
323	3325211	5014	1160	3511211	5629	1997	3342211	78	2834	3435211	5692
324	3506211	5745	1161	3534211	5629	1998	3538211	91	2835	3415211	5275
325	3310211	1736	1162	3466211	4560	1999	3540211	1270	2836	3450212	4323
326	3303211	44	1163	3461212	979	2000	3548211	4605	2837	3450212	4978
327	3333211	4039	1164	3451211	4651	2001	3548211	2171	2838	3449212	1297
328	3310211	591	1165	3440211	5279	2002	3548211	1757	2839	3451211	1279
329	3333211	591	1166	3411211	4978	2003	3540211	1612	2840	3458211	2167
330	3303211	5014	1167	3444211	4978	2004	3544211	2750	2841	3431211	5397
331	3333211	4625	1168	3508211	4709	2005	3547211	4300	2842	3458211	3939
332	3506211	2794	1169	3508211	5300	2006	3449212	5229	2843	3458211	4978
333	3331211	691	1170	3445211	896	2007	3540211	91	2844	3450212	3271
334	3331211	591	1171	3509211	445	2008	3548211	5097	2845	3458211	3098
335	3317211	4745	1172	3512211	1001	2009	3543211	2680	2846	3408211	5906
336	3333211	3086	1173	3331211	1303	2010	3555211	2814	2847	3450212	191
337	3303211	701	1174	3319211	3	2011	3543211	3739	2848	3450212	3167

No.	Soil	Station	No.	Soil	Station	No.	Soil	Station	No.	Soil	Station
338	3325211	3791	1175	3411211	3204	2012	3545211	151	2849	3453211	3098
339	3328211	3196	1176	3444211	3204	2013	3511211	4592	2850	3450212	2171
340	3519211	5745	1177	3444211	91	2014	3540211	2925	2851	3431211	1197
341	3303211	2306	1178	3444211	5426	2015	3542211	1050	2852	3458211	330
342	3519211	2794	1179	3408211	4709	2016	3548211	2680	2853	3411211	5906
343	3512211	164	1180	3445211	4709	2017	3542211	1612	2854	3458211	4480
344	3317211	1975	1181	3445211	3126	2018	3511211	282	2855	3458211	460
345	3303211	691	1182	3536211	445	2019	3511211	1279	2856	3407211	5541
346	3307211	4745	1183	3541211	445	2020	3308211	2968	2857	3411211	4411
347	3527211	5745	1184	3319211	3031	2021	3451211	4287	2858	3407211	2039
348	3517211	3376	1185	3352211	3031	2022	3551211	2925	2859	3407211	953
349	3512211	3196	1186	3445211	5300	2023	3551211	4978	2860	3458211	755
350	3326211	1757	1187	3315211	3023	2024	3551211	3289	2861	3455211	1297
351	3333211	1975	1188	3331211	3540	2025	3551211	1270	2862	3408211	5275
352	3317211	3093	1189	3440211	979	2026	3551211	2171	2863	3459211	330
353	3317211	4642	1190	3461212	3348	2027	3551211	314	2864	3455211	191
354	3517211	2794	1191	3444211	817	2028	3542211	445	2865	3411211	2480
355	3328211	3093	1192	3442211	5426	2029	3561212	314	2866	3453211	2947
356	3311211	4745	1193	3532211	5825	2030	3548211	1612	2867	3453211	4508
357	3317211	3791	1194	3322211	3791	2031	3508211	5797	2868	3453211	330
358	3512211	2794	1195	3442211	91	2032	3542211	5750	2869	3435211	4349
359	3307211	3791	1196	3442211	4709	2033	3556211	991	2870	3453211	3167
360	3512211	3376	1197	3442211	4763	2034	3315211	2968	2871	3460211	5541
361	3308211	3093	1198	3445211	4763	2035	3538211	4605	2872	3453211	4480
362	3305211	3791	1199	3522211	5825	2036	3551211	4605	2873	3411211	5275
363	3346211	1736	1200	3449212	3167	2037	3561212	4605	2874	3451211	4377
364	3346211	3086	1201	3440211	3098	2038	3544211	4605	2875	3458211	4692
365	3311211	591	1202	3440211	2039	2039	3544211	2171	2876	3458211	3167
366	3308211	4642	1203	3537211	198	2040	3561212	2680	2877	3458211	5433
367	3508211	164	1204	3506211	198	2041	3540211	5750	2878	3458211	4508
368	3508211	3376	1205	3522211	1001	2042	3511211	991	2879	3408211	5692

No.	Soil	Sta-tion	No.	Soil	Station	No.	Soil	Station	No.	Soil	Station
369	3333211	3791	1206	3311211	3031	2043	3556211	5397	2880	3458211	5029
370	3328211	4642	1207	3463211	4508	2044	3556211	2700	2881	3453211	4692
371	3312211	4642	1208	3463211	4692	2045	3561212	320	2882	3453211	5029
372	3508211	2794	1209	3440211	4560	2046	3563211	991	2883	3458211	2947
373	3311211	3791	1210	3440211	2532	2047	3460211	5426	2884	3461212	4692
374	3307211	1975	1211	3444211	896	2048	3448211	4709	2885	3461212	5029
375	3348211	44	1212	3522211	427	2049	3416211	4709	2886	3453211	4336
376	3311211	4625	1213	3316211	1590	2050	3513211	5797	2887	3458211	4336
377	3331211	4642	1214	3316211	3023	2051	3549212	4605	2888	3439211	5692
378	3512211	5745	1215	3311211	4371	2052	3561212	2171	2889	3450212	755
379	3531212	5546	1216	3459211	3167	2053	3561212	5797	2890	3450212	3257
380	3519211	1001	1217	3406211	896	2054	3561212	3875	2891	3461212	282
381	3508211	427	1218	3537211	445	2055	3563211	320	2892	3450212	1279
382	3311211	1975	1219	3316211	3031	2056	3563211	3667	2893	3458211	3540
383	3311211	4642	1220	3452211	3348	2057	3448211	2171	2894	3463211	151
384	3532211	5745	1221	3442211	3167	2058	3536211	4605	2895	3461212	3540
385	3508211	1001	1222	3444211	5300	2059	3549212	2171	2896	3461212	3668
386	3346211	4625	1223	3406211	5158	2060	3561212	896	2897	3449212	5029
387	3308211	3196	1224	3315211	1590	2061	3548211	3086	2898	3461212	5440
388	3526211	4642	1225	3316211	5100	2062	3561212	5397	2899	3461212	3284
389	3531212	3552	1226	3452211	2532	2063	3544211	4703	2900	3431211	282
390	3532211	164	1227	3459211	1300	2064	3416211	91	2901	3449212	3284
391	3517211	4642	1228	3459211	4709	2065	3416211	2171	2902	3452211	5029
392	3526211	3552	1229	3442211	896	2066	3509211	3289	2903	3458211	4560
393	3519211	3987	1230	3442211	5158	2067	3549212	314	2904	3458211	5100
394	3306211	3791	1231	3408211	3126	2068	3561212	4703	2905	3442211	5692
395	3310211	3791	1232	3408211	5158	2069	3461212	4287	2906	3450212	3155
396	3306211	4642	1233	3509211	5158	2070	3543211	222	2907	3450212	4560
397	3512211	4642	1234	3310211	1590	2071	3556211	3204	2908	3449212	151
398	3506211	4642	1235	3342211	1303	2072	3556211	3875	2909	3406211	4336
399	3527211	4642	1236	3342211	3	2073	3561212	1684	2910	3411211	2080

No.	Soil	Station	No.	Soil	Station	No.	Soil	Station	No.	Soil	Station
400	3532211	3552	1237	3449212	3540	2074	3342211	2667	2911	3450212	4480
401	3531212	3987	1238	3459211	4560	2075	3442211	4287	2912	3450212	1107
402	3317211	963	1239	3459211	91	2076	3509211	5426	2913	3450212	460
403	3326211	4642	1240	3459211	5426	2077	3509211	2171	2914	3448211	1107
404	3506211	3552	1241	3408211	198	2078	3509211	1270	2915	3461212	2680
405	3527211	3987	1242	3540211	198	2079	3538211	1270	2916	3555211	151
406	3527211	3552	1243	3352211	3	2080	3549212	1050	2917	3406211	460
407	3531212	1001	1244	3463211	3167	2081	3543211	3289	2918	3450212	3284
408	3512211	3552	1245	3442211	3155	2082	3556211	5229	2919	3450212	4336
409	3532211	3987	1246	3466211	953	2083	3563211	2700	2920	3415211	2080
410	3527211	1001	1247	3459211	5300	2084	3308211	2667	2921	3461212	330
411	3333211	963	1248	3442211	5300	2085	3409211	4323	2922	3450212	5279
412	3319211	4625	1249	3508211	5158	2086	3409211	4287	2923	3449212	5397
413	3311211	3196	1250	3508211	433	2087	3548211	3289	2924	3449212	3739
414	3328211	3791	1251	3346211	1590	2088	3548211	5546	2925	3461212	2211
415	3311211	963	1252	3459211	3098	2089	3555211	853	2926	3450212	5229
416	3306211	3093	1253	3540211	5158	2090	3556211	4703	2927	3411211	5397
417	3526211	3987	1254	3546211	3811	2091	3549212	896	2928	3458211	2211
418	3328211	963	1255	3508211	430	2092	3561212	4978	2929	3442211	1420
419	3346211	591	1256	3331211	1590	2093	3511211	1736	2930	3458211	3284
420	3517211	3552	1257	3352211	44	2094	3416211	4978	2931	3411211	4592
421	3331211	963	1258	3461212	3155	2095	3453211	3527	2932	3442211	1214
422	3331211	3093	1259	3440211	953	2096	3561212	3289	2933	3463211	2925
423	3311211	3093	1260	3442211	4978	2097	3511211	222	2934	3452211	3155
424	3316211	963	1261	3442211	1300	2098	3555211	4703	2935	3435211	3545
425	3319211	591	1262	3408211	5300	2099	3448211	4978	2936	3435211	3137
426	3512211	3987	1263	3459211	3126	2100	3453211	3204	2937	3442211	5029
427	3310211	963	1264	3528212	400	2101	3453211	3034	2938	3450212	4651
428	3308211	44	1265	3317211	1590	2102	3561212	3668	2939	3463211	4592
429	3346211	3196	1266	3308211	3791	2103	3561212	5097	2940	3553211	3875
430	3334211	4642	1267	3452211	3028	2104	3555211	1736	2941	3452211	4480

No.	Soil	Sta-tion	No.	Soil	Station	No.	Soil	Station	No.	Soil	Station
431	3308211	3552	1268	3528212	4625	2105	3556211	3402	2942	3408211	2080
432	3506211	3987	1269	3308211	1766	2106	3460211	4978	2943	3435211	2080
433	3346211	5014	1270	3342211	44	2107	3451211	4605	2944	3435211	450
434	3346211	963	1271	3452211	44	2108	3538211	2925	2945	3450212	2211
435	3531212	4642	1272	3461212	3167	2109	3508211	1270	2946	3450212	3204
436	3301211	3791	1273	3459211	1297	2110	3551211	3204	2947	3557211	3739
437	3312211	3093	1274	3542211	5158	2111	3551211	3667	2948	3411211	3137
438	3312211	3552	1275	3541211	1957	2112	3561212	1612	2949	3416211	5275
439	3508211	3552	1276	3319211	1766	2113	3548211	5797	2950	3435211	5064
440	3508211	3987	1277	3408211	44	2114	3559211	3402	2951	3431211	4592
441	3508211	5825	1278	3461212	2947	2115	3559211	5229	2952	3557211	5229
442	3319211	4642	1279	3509211	400	2116	3563211	4703	2953	3435211	1602
443	3308211	1544	1280	3546211	430	2117	3549212	3289	2954	3442211	1602
444	3301211	5014	1281	3531212	591	2118	3556211	5797	2955	3450212	3761
445	3308211	1694	1282	3534211	3552	2119	3551211	1297	2956	3557211	3875
446	3332211	3093	1283	3526211	1001	2120	3559211	3875	2957	3435211	5275
447	3319211	3093	1284	3342211	3791	2121	3557211	3402	2958	3406211	5275
448	3508211	4642	1285	3442211	4692	2122	3348211	2110	2959	3450212	3875
449	3508211	5629	1286	3466211	1300	2123	3453211	5229	2960	3442211	3137
450	3329211	4642	1287	3466211	3348	2124	3561212	3287	2961	3451211	2480
451	3332211	3196	1288	3508211	4763	2125	3544211	2925	2962	3448211	4651
452	3508211	2856	1289	3542211	2680	2126	3544211	91	2963	3450212	5397
453	3329211	1694	1290	3537211	1957	2127	3508211	3289	2964	3451211	450
454	3312211	1694	1291	3540211	3811	2128	3551211	4300	2965	3411211	151
455	3508211	3158	1292	3541211	3811	2129	3509211	4605	2966	3448211	3155
456	3310211	5014	1293	3509211	5629	2130	3556211	4605	2967	3449212	3667
457	3322211	3093	1294	3509211	5705	2131	3564211	4605	2968	3411211	4336
458	3319211	1694	1295	3528212	591	2132	3564211	4978	2969	3463211	991
459	3526211	400	1296	3408211	5541	2133	3564211	3667	2970	3448211	3284
460	3310211	1975	1297	3456211	2680	2134	3511211	1197	2971	3431211	3875
461	3346211	691	1298	3541211	5629	2135	3461212	2167	2972	3448211	5731

No.	Soil	Station	No.	Soil	Station	No.	Soil	Station	No.	Soil	Station
462	3333211	1981	1299	3517211	433	2136	3453211	2171	2973	3448211	1197
463	3332211	4642	1300	3322211	1590	2137	3448211	2925	2974	3449212	3402
464	3346211	44	1301	3308211	3	2138	3448211	3204	2975	3557211	4592
465	3333211	3612	1302	3442211	5541	2139	3448211	3527	2976	3411211	377
466	3332211	591	1303	3440211	3348	2140	3408211	4287	2977	3451211	991
467	3319211	3552	1304	3408211	953	2141	3561212	1107	2978	3557211	5397
468	3512211	5629	1305	3456211	91	2142	3544211	5426	2979	3448211	3761
469	3328211	2306	1306	3316211	3	2143	3508211	198	2980	3431211	320
470	3346211	2306	1307	3308211	3031	2144	3556211	3289	2981	3431211	3204
471	3306211	963	1308	3461212	1300	2145	3564211	4300	2982	3431211	991
472	3311211	3552	1309	3410211	1691	2146	3508211	3667	2983	3450212	151
473	3527211	427	1310	3456211	5300	2147	3559211	853	2984	3450212	4592
474	3328211	78	1311	3508211	2680	2148	3556211	1197	2985	3451211	5731
475	3531212	427	1312	3316211	1303	2149	3557211	4703	2986	3449212	320
476	3306211	3552	1313	3440211	4323	2150	3559211	3166	2987	3450212	2700
477	3532211	400	1314	3449212	4709	2151	3559211	4703	2988	3451211	3284
478	3527211	3376	1315	3459211	3527	2152	3556211	3166	2989	3466211	3761
479	3307211	1766	1316	3459211	1645	2153	3315211	2667	2990	3451211	4300
480	3512211	400	1317	3456211	5426	2154	3561212	5229	2991	3431211	151
481	3317211	1766	1318	3456211	4709	2155	3509211	4978	2992	3450212	320
482	3310211	1766	1319	3532211	591	2156	3542211	4300	2993	3463211	2700
483	3301211	44	1320	3522211	591	2157	3542211	2925	2994	3406211	867
484	3310211	3086	1321	3449212	1107	2158	3564211	2925	2995	3450212	3402
485	3531212	2856	1322	3442211	2171	2159	3564211	5397	2996	3461212	4592
486	3531212	5629	1323	3408211	2680	2160	3556211	1612	2997	3451211	5397
487	3531212	3376	1324	3540211	5629	2161	3559211	222	2998	3451211	151
488	3346211	3791	1325	3342211	3031	2162	3559211	3667	2999	3442211	2700
489	3346211	3612	1326	3308211	4371	2163	3556211	853	3000	3463211	4300
490	3311211	3612	1327	3449212	2171	2164	3555211	3166	3001	3449212	991
491	3324211	3552	1328	3452211	953	2165	3348211	1766	3002	3450212	991
492	3327211	3552	1329	3455211	3527	2166	3452211	2167	3003	3442211	4592

No.	Soil	Sta-tion	No.	Soil	Station	No.	Soil	Station	No.	Soil	Station
493	3531212	3158	1330	3455211	1645	2167	3564211	314	3004	3442211	5397
494	3310211	3612	1331	3459211	2044	2168	3542211	5097	3005	3450212	4300
495	3329211	3196	1332	3536211	3811	2169	3511211	853	3006	3461212	3621
496	3301211	1766	1333	3306211	3	2170	3556211	222	3007	3466211	1197
497	3301211	963	1334	3342211	1766	2171	3555211	3402	3008	3442211	4300
498	3328211	3612	1335	3461212	2532	2172	3559211	1207	3009	3449212	2700
499	3306211	3612	1336	3410211	4709	2173	3549212	4978	3010	3461212	2700
500	3531212	400	1337	3449212	91	2174	3508211	4605	3011	3442211	3621
501	3334211	3552	1338	3452211	2039	2175	3549212	4300	3012	3466211	3284
502	3325211	1766	1339	3459211	3034	2176	3544211	3289	3013	3448211	3257
503	3322211	3552	1340	3455211	3204	2177	3545211	5097	3014	3442211	991
504	3331211	3612	1341	3542211	5426	2178	3545211	1612	3015	3442211	5155
505	3310211	3023	1342	3536211	5629	2179	3348211	1590	3016	3451211	3402
506	3317211	3023	1343	3540211	5825	2180	3444211	4287	3017	3449212	4349
507	3328211	3023	1344	3512211	4625	2181	3544211	4978	3018	3451211	5155
508	3307211	3612	1345	3315211	78	2182	3549212	2925	3019	3442211	5440
509	3307211	963	1346	3358211	4371	2183	3544211	5797	3020	3449212	4592
510	3329211	3093	1347	3449212	44	2184	3557211	5779	3021	3450212	3621
511	3319211	2794	1348	3449212	4978	2185	3549212	3204	3022	3410211	3621
512	3307211	3023	1349	3459211	3204	2186	3556211	1684	3023	3410211	3875
513	3301211	3023	1350	3542211	91	2187	3557211	2601	3024	3466211	3257
514	3329211	3552	1351	3342211	1975	2188	3460211	2167	3025	3410211	5155
515	3324211	2794	1352	3358211	1975	2189	3551211	3527	3026	3410211	2700
516	3317211	3612	1353	3358211	44	2190	3564211	2171	3027	3442211	3366
517	3329211	2794	1354	3431211	2039	2191	3559211	2601	3028	3461212	5155
518	3333211	1766	1355	3410211	4323	2192	3559211	5779	3029	3451211	5440
519	3311211	3023	1356	3459211	3231	2193	3460211	979	3030	3414211	3621
520	3322211	591	1357	3456211	3231	2194	3460211	1964	3031	3411211	3621
521	3512211	5825	1358	3408211	5426	2195	3442211	2167	3032	3450212	4703
522	3333211	3023	1359	3537211	4763	2196	3444211	2925	3033	3408211	3621
523	3317211	4063	1360	3532211	433	2197	3549212	1107	3034	3411211	5155

No.	Soil	Sta-tion	No.	Soil	Station	No.	Soil	Station	No.	Soil	Station
524	3328211	4063	1361	3358211	1766	2198	3544211	2680	3035	3442211	3875
525	3310211	4625	1362	3322211	4651	2199	3559211	2638	3036	3442211	2750
526	3319211	1544	1363	3431211	4560	2200	3549212	5229	3037	3411211	320
527	3329211	1544	1364	3461212	1691	2201	3508211	4978	3038	3451211	3621
528	3333211	4063	1365	3440211	1691	2202	3542211	3231	3039	3449212	4300
529	3310211	4063	1366	3456211	2044	2203	3559211	991	3040	3414211	5155
530	3312211	1544	1367	3555211	5300	2204	3559211	2700	3041	3452211	1197
531	3506211	400	1368	3536211	4763	2205	3342211	1327	3042	3416211	3621
532	3329211	591	1369	3358211	3031	2206	3460211	3155	3043	3418211	2700
533	3306211	1544	1370	3408211	3348	2207	3551211	4464	3044	3414211	73
534	3312211	2794	1371	3408211	4560	2208	3545211	853	3045	3411211	73
535	3526211	5825	1372	3456211	3660	2209	3557211	2638	3046	3442211	73
536	3307211	3086	1373	3555211	2680	2210	3508211	1107	3047	3452211	5229
537	3311211	1736	1374	3555211	4763	2211	3508211	3204	3048	3452211	3875
538	3312211	2951	1375	3555211	5158	2212	3509211	4300	3049	3418211	151
539	3308211	3612	1376	3542211	198	2213	3561212	2925	3050	3418211	320
540	3307211	4625	1377	3537211	1001	2214	3508211	3287	3051	3408211	73
541	3307211	591	1378	3537211	2680	2215	3508211	5229	3052	3451211	142
542	3322211	4625	1379	3542211	3552	2216	3551211	1107	3053	3416211	5155
543	3506211	5629	1380	3534211	3987	2217	3551211	3946	3054	3449212	1197
544	3307211	4063	1381	3306211	1303	2218	3509211	3231	3055	3418211	3875
545	3312211	5825	1382	3455211	5426	2219	3561212	4300	3056	3418211	5155
546	3306211	4063	1383	3537211	2794	2220	3555211	5797	3057	3408211	5155
547	3306211	691	1384	3537211	3552	2221	3555211	4605	3058	3411211	4169
548	3333211	5676	1385	3542211	4642	2222	3556211	5097	3059	3449212	5155
549	3322211	4642	1386	3536211	430	2223	3315211	2110	3060	3418211	3366
550	3332211	3552	1387	3546211	433	2224	3551211	5229	3061	3442211	3271
551	3331211	4063	1388	3449212	3031	2225	3544211	1107	3062	3450212	5155
552	3308211	4063	1389	3449212	4377	2226	3563211	4605	3063	3418211	4592
553	3322211	3196	1390	3449212	330	2227	3544211	3527	3064	3458211	3761
554	3527211	400	1391	3456211	1645	2228	3549212	3527	3065	3461212	142

No.	Soil	Station	No.	Soil	Station	No.	Soil	Station	No.	Soil	Station
555	3333211	78	1392	3455211	3231	2229	3453211	1107	3066	3449212	142
556	3310211	78	1393	3537211	3811	2230	3508211	3034	3067	3440211	5155
557	3310211	5676	1394	3542211	3811	2231	3508211	853	3068	3440211	3621
558	3317211	5676	1395	3512211	3811	2232	3408211	78	3069	3411211	3875
559	3328211	5676	1396	3449212	3155	2233	3461212	5229	3070	3442211	1735
560	3526211	5629	1397	3455211	4763	2234	3549212	3946	3071	3440211	4592
561	3319211	5825	1398	3537211	5825	2235	3563211	5397	3072	3418211	3621
562	3527211	5629	1399	3546211	880	2236	3555211	3289	3073	3435211	1214
563	3333211	3028	1400	3449212	4323	2237	3348211	3023	3074	3435211	4560
564	3331211	78	1401	3442211	4377	2238	3408211	2667	3075	3451211	4592
565	3307211	691	1402	3459211	4377	2239	3408211	3031	3076	3450212	1197
566	3306211	5676	1403	3449212	817	2240	3453211	1300	3077	3450212	142
567	3331211	3791	1404	3342211	4651	2241	3452211	1964	3078	3449212	3621
568	3307211	2014	1405	3342211	4560	2242	3508211	2925	3079	3442211	4354
569	3315211	4063	1406	3452211	4323	2243	3508211	91	3080	3435211	4651
570	3317211	78	1407	3461212	1197	2244	3549212	2261	3081	3449212	4928
571	3346211	78	1408	3461212	3287	2245	3563211	4300	3082	3411211	1684
572	3315211	963	1409	3529211	400	2246	3563211	2925	3083	3416211	2700
573	3346211	3028	1410	3508211	3811	2247	3348211	3031	3084	3458211	1214
574	3311211	5676	1411	3506211	3811	2248	3316211	2667	3085	3450212	4349
575	3328211	2014	1412	3417211	2532	2249	3454212	3348	3086	3452211	2814
576	3322211	4063	1413	3461212	1107	2250	3564211	3527	3087	3451211	2700
577	3322211	963	1414	3517211	3811	2251	3549212	1207	3088	3451211	1684
578	3317211	3028	1415	3417211	953	2252	3551211	1207	3089	3416211	1684
579	3308211	2014	1416	3461212	4978	2253	3549212	4464	3090	3452211	5731
580	3331211	2014	1417	3444211	3348	2254	3561212	3231	3091	3418211	5397
581	3331211	5676	1418	3444211	953	2255	3556211	4300	3092	3408211	142
582	3307211	78	1419	3444211	2167	2256	3348211	5100	3093	3408211	3271
583	3306211	78	1420	3459211	817	2257	3454212	953	3094	3450212	3366
584	3524211	3552	1421	3408211	817	2258	3454212	1964	3095	3418211	991
585	3306211	2014	1422	3449212	1645	2259	3561212	3034	3096	3440211	259

No.	Soil	Sta-tion	No.	Soil	Station	No.	Soil	Station	No.	Soil	Station
586	3333211	662	1423	3538211	3126	2260	3564211	3204	3097	3466211	5731
587	3331211	662	1424	3528212	5629	2261	3561212	1270	3098	3411211	142
588	3306211	662	1425	3342211	3098	2262	3556211	2925	3099	3449212	259
589	3325211	3023	1426	3449212	3204	2263	3453211	3155	3100	3449212	1602
590	3310211	662	1427	3461212	2171	2264	3460211	2039	3101	3450212	3231
591	3309211	591	1428	3461212	3204	2265	3454212	2039	3102	3442211	142
592	3517211	3987	1429	3443211	3348	2266	3460211	4323	3103	3411211	4094
593	3322211	2014	1430	3443211	1107	2267	3442211	3287	3104	3440211	1602
594	3310211	400	1431	3461212	817	2268	3563211	5797	3105	3414211	142
595	3310211	4642	1432	3459211	4978	2269	3459211	3023	3106	3414211	4094
596	3309211	4642	1433	3549212	3231	2270	3459211	3612	3107	3451211	1602
597	3526211	3376	1434	3549212	5426	2271	3442211	3031	3108	3411211	2700
598	3342211	963	1435	3549212	2680	2272	3454212	979	3109	3451211	259
599	3342211	2014	1436	3537211	5426	2273	3453211	3287	3110	3451211	1214
600	3311211	2014	1437	3522211	3811	2274	3449212	4287	3111	3440211	1197
601	3349212	5280	1438	3508211	5750	2275	3509211	1645	3112	3442211	4094
602	3349212	3612	1439	3508211	4625	2276	3544211	1270	3113	3442211	2814
603	3348211	963	1440	3342211	3939	2277	3549212	5397	3114	3440211	320
604	3351211	963	1441	3452211	2171	2278	3459211	294	3115	3440211	4928
605	3342211	4063	1442	3443211	4978	2279	3442211	1766	3116	3449212	3366
606	3311211	4063	1443	3449212	5426	2280	3406211	2532	3117	3451211	3271
607	3506211	5825	1444	3545211	4763	2281	3448211	3348	3118	3408211	1214
608	3526211	427	1445	3545211	5426	2282	3564211	1645	3119	3408211	4175
609	3306211	3023	1446	3545211	2680	2283	3509211	2925	3120	3414211	4706
610	3349212	44	1447	3342211	3540	2284	3551211	2261	3121	3411211	4706
611	3349212	963	1448	3442211	1107	2285	3549212	1645	3122	3442211	2542
612	3342211	3612	1449	3408211	979	2286	3556211	3231	3123	3466211	3287
613	3311211	691	1450	3408211	4978	2287	3448211	3287	3124	3442211	5229
614	3328211	662	1451	3461212	5426	2288	3549212	1270	3125	3411211	3271
615	3331211	400	1452	3456211	817	2289	3466211	2171	3126	3555211	3271
616	3325211	78	1453	3512211	5750	2290	3466211	4978	3127	3555211	4094

No.	Soil	Sta-tion	No.	Soil	Station	No.	Soil	Station	No.	Soil	Station
617	3349212	4745	1454	3465211	3540	2291	3561212	3527	3128	3555211	2542
618	3361212	3612	1455	3465211	3098	2292	3563211	3231	3129	3440211	3366
619	3351211	4063	1456	3451211	1300	2293	3549212	5797	3130	3555211	1735
620	3322211	5676	1457	3549212	4763	2294	3564211	3231	3131	3466211	1279
621	3351211	662	1458	3536211	2680	2295	3460211	294	3132	3466211	1214
622	3331211	3552	1459	3342211	2211	2296	3459211	4371	3133	3450212	1735
623	3351211	2014	1460	3465211	2211	2297	3408211	3287	3134	3440211	5397
624	3348211	4063	1461	3442211	4323	2298	3466211	3204	3135	3418211	142
625	3348211	2014	1462	3442211	3204	2299	3564211	3946	3136	3411211	3366
626	3328211	1297	1463	3461212	4709	2300	3564211	2261	3137	3411211	991
627	3351211	591	1464	3549212	5300	2301	3308211	1327	3138	3406211	5155
628	3316211	591	1465	3509211	2680	2302	3440211	1107	3139	3418211	73
629	3527211	5825	1466	3538211	896	2303	3466211	2925	3140	3442211	222
630	3331211	294	1467	3538211	198	2304	3544211	3231	3141	3452211	2074
631	3361212	963	1468	3546211	591	2305	3564211	3289	3142	3415211	1443
632	3328211	2532	1469	3463211	979	2306	3564211	4464	3143	3466211	259
633	3328211	1639	1470	3463211	953	2307	3564211	1207	3144	3418211	1332
634	3527211	2794	1471	3408211	4323	2308	3559211	2814	3145	3442211	1332
635	3517211	5629	1472	3465211	3348	2309	3453211	2039	3146	3452211	4931
636	3317211	4371	1473	3443211	817	2310	3466211	91	3147	3452211	3761
637	3361212	4063	1474	3443211	5426	2311	3453211	1645	3148	3452211	259
638	3322211	662	1475	3440211	4709	2312	3556211	3946	3149	3450212	4887
639	3322211	2532	1476	3542211	3289	2313	3460211	3591	3150	3406211	3366
640	3363211	191	1477	3538211	1957	2314	3466211	3591	3151	3452211	4349
641	3333211	4642	1478	3463211	2039	2315	3453211	3348	3152	3442211	4706
642	3531212	2794	1479	3461212	4323	2316	3564211	5229	3153	3452211	5440
643	3310211	4371	1480	3452211	817	2317	3544211	1645	3154	3461212	3366
644	3466211	78	1481	3465211	1300	2318	3561212	3204	3155	3461212	1332
645	3317211	3939	1482	3465211	2171	2319	3561212	1645	3156	3418211	4706
646	3322211	3612	1483	3440211	5300	2320	3448211	979	3157	3452211	3667
647	3308211	294	1484	3440211	4763	2321	3461212	2601	3158	3452211	222

No.	Soil	Sta-tion	No.	Soil	Station	No.	Soil	Station	No.	Soil	Station
648	3311211	294	1485	3440211	2680	2322	3556211	4464	3159	3406211	1332
649	3322211	1639	1486	3545211	817	2323	3564211	1270	3160	3451211	2074
650	3363211	1639	1487	3545211	5158	2324	3453211	979	3161	3442211	232
651	3363211	3552	1488	3545211	5300	2325	3451211	5229	3162	3463211	5155
652	3317211	294	1489	3531212	3811	2326	3544211	3034	3163	3418211	232
653	3346211	4063	1490	3408211	3540	2327	3556211	3527	3164	3418211	154
654	3348211	294	1491	3461212	91	2328	3559211	4300	3165	3442211	154
655	3349212	294	1492	3452211	91	2329	3308211	3490	3166	3463211	232
656	3310211	294	1493	3452211	1691	2330	3466211	4063	3167	3463211	3366
657	3351211	5676	1494	3465211	979	2331	3342211	3490	3168	3463211	142
658	3322211	191	1495	3461212	5300	2332	3556211	3034	3169	3416211	142
659	3322211	1297	1496	3440211	5426	2333	3556211	2601	3170	3416211	3366
660	3322211	1691	1497	3440211	5158	2334	3555211	1270	3171	3411211	232
661	3361212	4642	1498	3408211	4763	2335	3408211	1639	3172	3461212	232
662	3363211	3126	1499	3540211	4763	2336	3559211	5397	3173	3416211	232
663	3363211	4642	1500	3541211	198	2337	3452211	4063	3174	3466211	5440
664	3466211	4371	1501	3511211	3987	2338	3459211	4336	3175	3466211	2074
665	3428211	4371	1502	3465211	953	2339	3460211	3287	3176	3466211	222
666	3342211	294	1503	3452211	4709	2340	3561212	2601	3177	3450212	1300
667	3328211	294	1504	3451211	4978	2341	3556211	1207	3178	3451211	4931
668	3351211	1639	1505	3444211	4763	2342	3556211	3739	3179	3466211	4931
669	3351211	2532	1506	3541211	2932	2343	3452211	294	3180	3411211	1332
670	3328211	191	1507	3311211	1590	2344	3460211	2532	3181	3451211	222
671	3351211	191	1508	3442211	1303	2345	3559211	3527	3182	3406211	2700
672	3361212	3552	1509	3465211	1107	2346	3556211	2261	3183	3450212	2953
673	3363211	1297	1510	3461212	2925	2347	3559211	4605	3184	3406211	3667
674	3363211	5300	1511	3449212	2925	2348	3452211	2014	3185	3442211	2074
675	3512211	2951	1512	3408211	2171	2349	3453211	2532	3186	3461212	154
676	3431211	4371	1513	3451211	953	2350	3561212	5017	3187	3442211	5731
677	3428211	4336	1514	3449212	3034	2351	3559211	5017	3188	3442211	4703
678	3331211	4371	1515	3451211	3034	2352	3559211	3034	3189	3461212	991

No.	Soil	Station	No.	Soil	Station	No.	Soil	Station	No.	Soil	Station
679	3306211	294	1516	3461212	5158	2353	3555211	1207	3190	3418211	1103
680	3322211	294	1517	3461212	4763	2354	3555211	4464	3191	3461212	1103
681	3340211	2014	1518	3461212	3126	2355	3459211	2039	3192	3413211	1332
682	3311211	1639	1519	3541211	427	2356	3459211	4651	3193	3411211	154
683	3349212	1639	1520	3511211	400	2357	3408211	1279	3194	3410211	1197
684	3351211	1691	1521	3534211	3811	2358	3442211	191	3195	3410211	2074
685	3351211	4709	1522	3452211	4978	2359	3453211	3231	3196	3406211	232
686	3322211	4709	1523	3453211	4978	2360	3449212	3231	3197	3410211	222
687	3319211	1297	1524	3410211	4978	2361	3544211	4464	3198	3413211	142
688	3466211	3791	1525	3442211	2925	2362	3451211	2601	3199	3449212	4703
689	3306211	4371	1526	3451211	3204	2363	3555211	2261	3200	3408211	1332
690	3351211	294	1527	3443211	4709	2364	3555211	3946	3201	3413211	3366
691	3351211	691	1528	3443211	5300	2365	3559211	3739	3202	3406211	142
692	3331211	1639	1529	3461212	896	2366	3555211	2638	3203	3414211	1332
693	3331211	1691	1530	3511211	3811	2367	3447211	817	3204	3450212	4508
694	3361212	1297	1531	3515211	3811	2368	3453211	1411	3205	3418211	2542
695	3361212	3126	1532	3529211	5750	2369	3564211	3034	3206	3430211	142
696	3312211	1297	1533	3308211	1303	2370	3544211	1207	3207	3408211	4706
697	3326211	3552	1534	3459211	3540	2371	3544211	3946	3208	3461212	4300
698	3531212	5825	1535	3459211	1303	2372	3557211	4300	3209	3430211	5155
699	3517211	5825	1536	3451211	2171	2373	3442211	3257	3210	3430211	154
700	3411211	3791	1537	3451211	1691	2374	3555211	3034	3211	3451211	2953
701	3411211	4371	1538	3410211	2925	2375	3564211	3739	3212	3449212	222
702	3428211	3939	1539	3461212	3034	2376	3442211	1279	3213	3406211	154
703	3442211	4371	1540	3451211	3527	2377	3447211	4323	3214	3461212	222
704	3442211	3939	1541	3445211	5158	2378	3449212	5017	3215	3461212	4703
705	3442211	5100	1542	3534211	400	2379	3555211	3527	3216	3410211	142
706	3317211	5100	1543	3557211	4625	2380	3564211	3166	3217	3414211	3366
707	3346211	294	1544	3512211	1612	2381	3459211	3155	3218	3415211	1224
708	3342211	691	1545	3465211	3527	2382	3453211	817	3219	3413211	4706
709	3348211	2532	1546	3452211	2925	2383	3461212	3231	3220	3430211	3366

No.	Soil	Sta-tion	No.	Soil	Station	No.	Soil	Station	No.	Soil	Station
710	3342211	662	1547	3461212	3527	2384	3461212	2261	3221	3430211	1103
711	3311211	662	1548	3449212	3527	2385	3564211	1411	3222	3430211	3244
712	3331211	1297	1549	3445211	5426	2386	3464211	4377	3223	3435211	1224
713	3351211	1297	1550	3443211	4763	2387	3564211	5017	3224	3450212	222
714	3328211	1691	1551	3443211	5158	2388	3564211	2601	3225	3430211	232
715	3366211	1691	1552	3536211	5797	2389	3453211	191	3226	3418211	3244
716	3366211	4709	1553	3508211	2932	2390	3467211	2532	3227	3410211	4706
717	3319211	4709	1554	3563211	3987	2391	3442211	3034	3228	3413211	154
718	3463211	3791	1555	3465211	3167	2392	3464211	3034	3229	3449212	154
719	3463211	4371	1556	3465211	2925	2393	3416211	1639	3230	3450212	2638
720	3449212	4371	1557	3443211	2925	2394	3416211	1297	3231	3422211	3244
721	3442211	294	1558	3443211	3204	2395	3453211	1297	3232	3422211	154
722	3442211	3612	1559	3443211	3527	2396	3467211	191	3233	3449212	4706
723	3349212	1691	1560	3443211	2680	2397	3461212	4377	3234	3442211	3244
724	3310211	1639	1561	3445211	2680	2398	3409211	1645	3235	3442211	1103
725	3342211	1639	1562	3449212	2680	2399	3409211	817	3236	3442211	1224
726	3342211	2532	1563	3459211	5158	2400	3409211	1107	3237	3449212	232
727	3342211	5676	1564	3536211	3289	2401	3559211	3231	3238	3413211	3244
728	3306211	1297	1565	3546211	3668	2402	3559211	2261	3239	3406211	4706
729	3366211	1297	1566	3531212	1612	2403	3559211	4464	3240	3422211	1103
730	3361212	4709	1567	3563211	1612	2404	3557211	5371	3241	3414211	154
731	3361212	191	1568	3443211	91	2405	3442211	2601	3242	3411211	1224
732	3319211	1691	1569	3459211	4763	2406	3464211	1107	3243	3411211	222
733	3363211	4709	1570	3459211	896	2407	3555211	5017	3244	3413211	1103
734	3463211	3939	1571	3557211	191	2408	3448211	3167	3245	3449212	3244
735	3342211	5279	1572	3531212	5750	2409	3416211	191	3246	3414211	1103
736	3342211	4371	1573	3459211	2211	2410	3416211	4323	3247	3422211	2542
737	3333211	1639	1574	3408211	2947	2411	3555211	4377	3248	3450212	3166
738	3361212	1691	1575	3451211	4323	2412	3555211	3231	3249	3450212	3927
739	3309211	1297	1576	3451211	1107	2413	3559211	3946	3250	3411211	259
740	3428211	2211	1577	3410211	1107	2414	3555211	2601	3251	3466211	5229

No.	Soil	Station	No.	Soil	Station	No.	Soil	Station	No.	Soil	Station
741	3465211	4371	1578	3449212	3287	2415	3557211	2814	3252	3442211	2812
742	3465211	3939	1579	3440211	3287	2416	3459211	3490	3253	3414211	3244
743	3461212	4371	1580	3451211	2925	2417	3459211	5279	3254	3465211	4703
744	3342211	1981	1581	3408211	91	2418	3448211	3098	3255	3450212	232
745	3310211	1691	1582	3449212	4763	2419	3448211	4560	3256	3430211	991
746	3348211	1691	1583	3545211	5797	2420	3416211	2532	3257	3410211	1224
747	3348211	1639	1584	3545211	896	2421	3453211	4323	3258	3465211	3402
748	3342211	1691	1585	3546211	2928	2422	3440211	1639	3259	3413211	2812
749	3332211	1544	1586	3548211	191	2423	3453211	1279	3260	3413211	1224
750	3511211	5825	1587	3511211	3668	2424	3448211	3939	3261	3430211	3927
751	3511211	3552	1588	3546211	314	2425	3448211	460	3262	3411211	3244
752	3528212	3552	1589	3531212	191	2426	3453211	5279	3263	3421211	1103
753	3446211	3939	1590	3512211	191	2427	3461212	1639	3264	3414211	5111
754	3306211	3939	1591	3529211	1612	2428	3467211	1639	3265	3408211	1224
755	3446211	4371	1592	3529211	5440	2429	3453211	1639	3266	3430211	4703
756	3465211	5279	1593	3508211	1612	2430	3467211	1279	3267	3406211	3927
757	3442211	5279	1594	3508211	5440	2431	3460211	4480	3268	3421211	154
758	3461212	5279	1595	3459211	2947	2432	3453211	460	3269	3430211	5111
759	3348211	662	1596	3451211	4709	2433	3464211	4978	3270	3421211	3244
760	3348211	1297	1597	3442211	3527	2434	3460211	5279	3271	3442211	5111
761	3365211	1691	1598	3440211	4978	2435	3440211	1279	3272	3413211	5111
762	3346211	1981	1599	3408211	3204	2436	3544211	3166	3273	3414211	217
763	3342211	5100	1600	3451211	1645	2437	3459211	5100	3274	3430211	2542
764	3342211	3591	1601	3540211	2680	2438	3442211	4480	3275	3410211	4169
765	3340211	1691	1602	3508211	880	2439	3448211	5100	3276	3413211	217
766	3342211	1297	1603	3563211	314	2440	3409211	3527	3277	3422211	5111
767	3365211	191	1604	3563211	4625	2441	3556211	5017	3278	3410211	1443
768	3365211	1297	1605	3557211	3667	2442	3556211	2638	3279	3411211	3927
769	3324211	1544	1606	3546211	3667	2443	3459211	1639	3280	3430211	2559
770	3508211	2951	1607	3546211	191	2444	3459211	348	3281	3442211	1443
771	3517211	427	1608	3529211	191	2445	3453211	3939	3282	3414211	2542

No.	Soil	Sta-tion	No.	Soil	Station	No.	Soil	Station	No.	Soil	Station
772	3446211	2211	1609	3465211	1645	2446	3440211	460	3283	3435211	259
773	3428211	3540	1610	3451211	91	2447	3435211	1639	3284	3435211	2812
774	3428211	294	1611	3451211	3231	2448	3454212	1297	3285	3452211	3402
775	3449212	294	1612	3537211	5797	2449	3454212	1691	3286	3442211	217
776	3308211	1981	1613	3546211	2932	2450	3411211	2039	3287	3414211	232
777	3363211	1691	1614	3548211	3987	2451	3454212	348	3288	3414211	2559
778	3363211	2532	1615	3563211	191	2452	3454212	3490	3289	3414211	3927
779	3546211	4709	1616	3556211	191	2453	3440211	5541	3290	3421211	2542
780	3326211	1544	1617	3529211	314	2454	3453211	5541	3291	3415211	2812
781	3324211	5825	1618	3515211	3987	2455	3461212	3257	3292	3408211	2812
782	3324211	2951	1619	3557211	5440	2456	3435211	1297	3293	3411211	2812
783	3352211	3023	1620	3465211	2947	2457	3453211	4651	3294	3416211	2812
784	3352211	3791	1621	3440211	2171	2458	3408211	4377	3295	3415211	259
785	3428211	5279	1622	3449212	5300	2459	3454212	2532	3296	3421211	217
786	3442211	1964	1623	3548211	400	2460	3411211	348	3297	3421211	2559
787	3449212	3098	1624	3542211	3987	2461	3448211	5279	3298	3415211	1602
788	3449212	3939	1625	3542211	4625	2462	3467211	4411	3299	3411211	4703
789	3449212	5279	1626	3511211	314	2463	3453211	3257	3300	3421211	142
790	3340211	1639	1627	3563211	5440	2464	3408211	3034	3301	3415211	4349
791	3542211	1691	1628	3557211	3086	2465	3449212	1357	3302	3411211	5229
792	3542211	1297	1629	3556211	3667	2466	3559211	390	3303	3450212	2542
793	3306211	191	1630	3545211	3667	2467	3553211	1207	3304	3421211	3927
794	3332211	5825	1631	3545211	191	2468	3454212	294	3305	3416211	1224
795	3466211	4336	1632	3545211	314	2469	3459211	5541	3306	3435211	4175
796	3449212	5100	1633	3531212	853	2470	3460211	3257	3307	3430211	3402
797	3340211	662	1634	3557211	2700	2471	3460211	4651	3308	3449212	2542
798	3340211	2532	1635	3529211	1684	2472	3440211	4411	3309	3465211	3927
799	3542211	191	1636	3465211	390	2473	3553211	2261	3310	3430211	4300
800	3310211	191	1637	3465211	3034	2474	3454212	3287	3311	3465211	2542
801	3309211	4709	1638	3410211	2171	2475	3454212	1300	3312	3449212	3927
802	3542211	4709	1639	3410211	2532	2476	3435211	5705	3313	3465211	142

No.	Soil	Station	No.	Soil	Station	No.	Soil	Station	No.	Soil	Station
803	3326211	3126	1640	3408211	1297	2477	3408211	4411	3314	3430211	3875
804	3546211	3126	1641	3408211	1107	2478	3448211	2532	3315	3465211	5155
805	3546211	3552	1642	3451211	2044	2479	3448211	1279	3316	3421211	222
806	3512211	427	1643	3409211	2680	2480	3453211	4411	3317	3421211	232
807	3352211	78	1644	3548211	3811	2481	3409211	3348	3318	3421211	5155
808	3331211	3023	1645	3548211	4625	2482	3555211	5371	3319	3421211	1332
809	3452211	4371	1646	3545211	3126	2483	3454212	1639	3320	3421211	2074
810	3466211	5100	1647	3545211	3811	2484	3459211	979	3321	3421211	4094
811	3466211	294	1648	3545211	3987	2485	3409211	3034	3322	3421211	73
812	3442211	3098	1649	3511211	896	2486	3463211	4377	3323	3430211	222
813	3465211	963	1650	3531212	314	2487	3460211	348	3324	3421211	1197
814	3308211	662	1651	3557211	314	2488	3449212	1639	3325	3421211	3271
815	3340211	1297	1652	3557211	1736	2489	3449212	5541	3326	3449212	5731
816	3338211	1639	1653	3543211	3667	2490	3442211	390	3327	3449212	4508
817	3549212	1691	1654	3545211	4625	2491	3463211	3034	3328	3421211	5111
818	3549212	2532	1655	3529211	853	2492	3449212	2953	3329	3421211	2712
819	3565211	191	1656	3531212	5440	2493	3449212	390	3330	3442211	4175
820	3542211	2532	1657	3557211	1684	2494	3553211	3034	3331	3442211	757
821	3310211	1297	1658	3508211	1684	2495	3553211	3739	3332	3449212	4354
822	3542211	5300	1659	3563211	1684	2496	3442211	330	3333	3413211	4169
823	3546211	5300	1660	3452211	3527	2497	3456211	5017	3334	3448211	1214
824	3546211	1297	1661	3410211	91	2498	3453211	1691	3335	3448211	4169
825	3540211	3126	1662	3408211	1300	2499	3442211	3761	3336	3448211	4094
826	3332211	3126	1663	3409211	5300	2500	3440211	3490	3337	3449212	4169
827	3332211	2951	1664	3409211	4763	2501	3456211	4377	3338	3430211	330
828	3411211	294	1665	3409211	5426	2502	3453211	3490	3339	3449212	863
829	3428211	3098	1666	3545211	4605	2503	3440211	348	3340	3430211	5731
830	3442211	4336	1667	3509211	2932	2504	3442211	3490	3341	3414211	5731
831	3342211	4336	1668	3546211	4287	2505	3442211	4411	3342	3449212	4692
832	3308211	5100	1669	3546211	2171	2506	3461212	755	3343	3414211	1214
833	3442211	460	1670	3545211	1297	2507	3553211	1411	3344	3411211	1214

No.	Soil	Sta-tion	No.	Soil	Station	No.	Soil	Station	No.	Soil	Station
834	3465211	3591	1671	3511211	3126	2508	3451211	867	3345	3411211	757
835	3465211	2039	1672	3515211	3126	2509	3456211	3348	3346	3449212	1214
836	3565211	2532	1673	3563211	3811	2510	3411211	4377	3347	3430211	1214
837	3509211	1297	1674	3563211	896	2511	3559211	4377	3348	3414211	2947

4.3 Appendix 3: Working with GISPELMO

The following figure shows the initial screen of the extended PELMO.

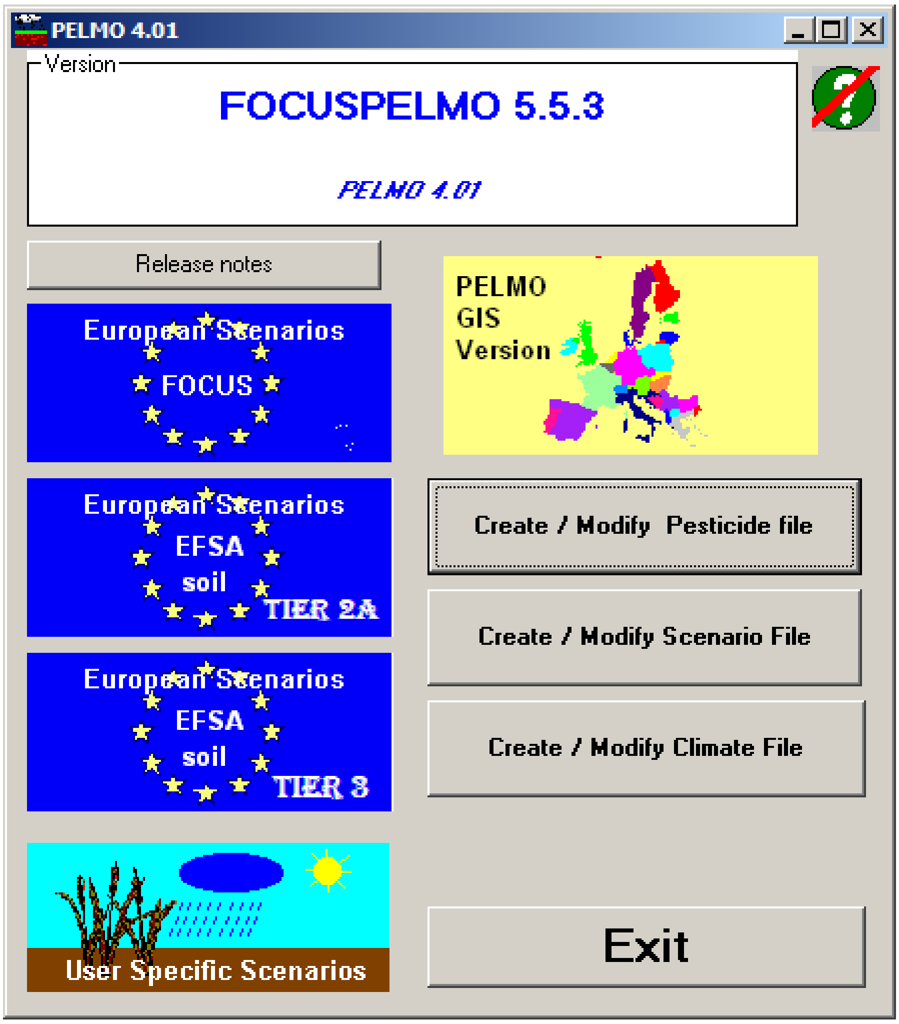

Figure 4-1: Initial screen of the extended computer model PELMO

The next figure shows the form for the execution of a GISPELMO simulation.

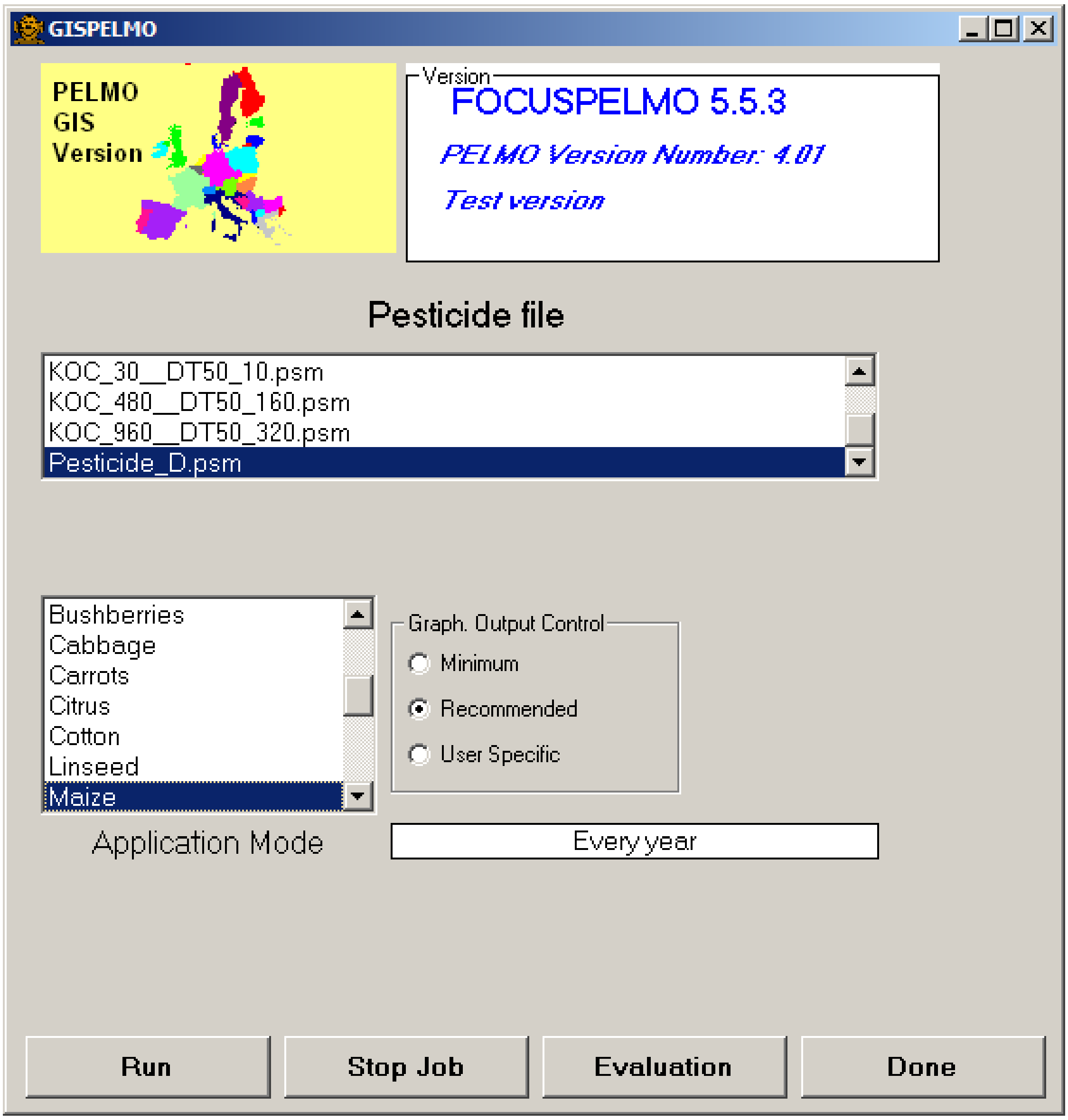

Figure 4-2: Starting screen of the extended program package

4.4 Appendix 4: GISPELMO: Distribution of the 80th temporal percentiles of annual concentrations

Winter cereals

- Kf_{oc} 15 L/kg- $DegT_{50}$ 5 d

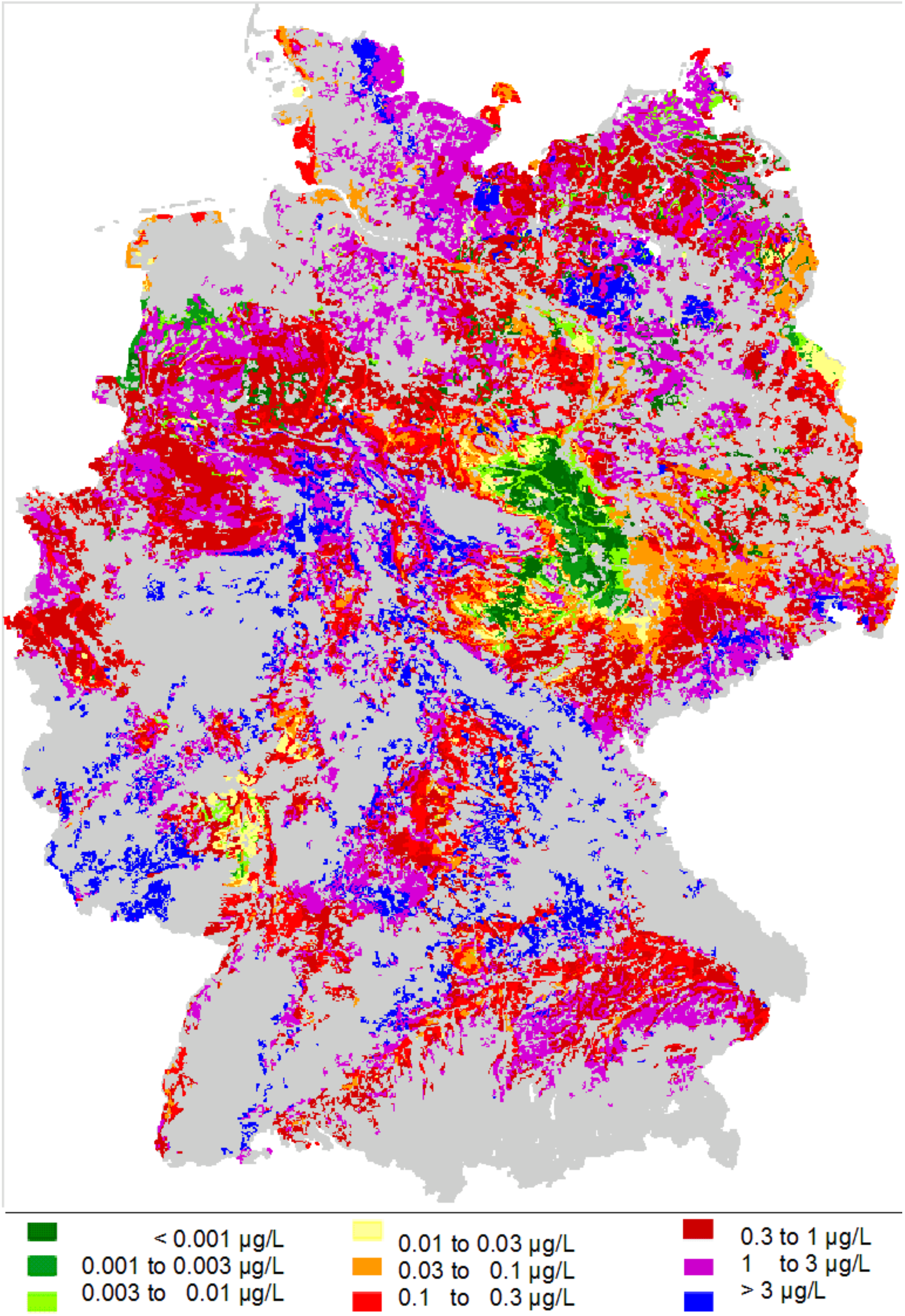

Figure 4-3: GISPELMO: Distribution of the 80th temporal percentiles of annual concentrations (Winter cereals, Kfoc 15 L/kg- DegT50 5 d)

- **Kf_{oc} 15 L/kg- $DegT_{50}$ 20 d**

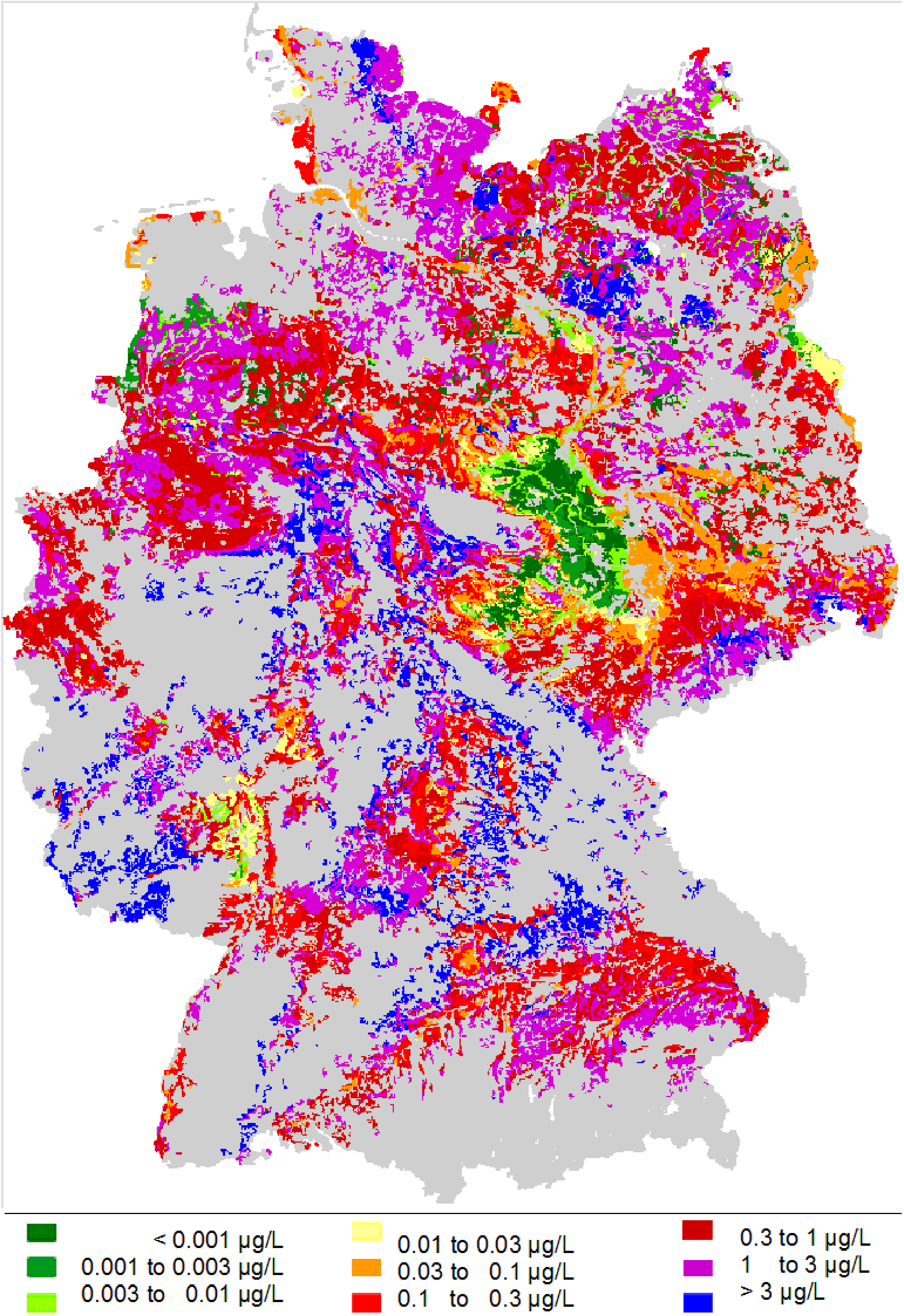

Figure 4-4: GISPELMO: Distribution of the 80th temporal percentiles of annual concentrations (Winter cereals, Kf_{oc} 15 L/kg- $DegT_{50}$ 20 d)

- **Kf_{oc} 15 L/kg- $DegT_{50}$ 80 d**

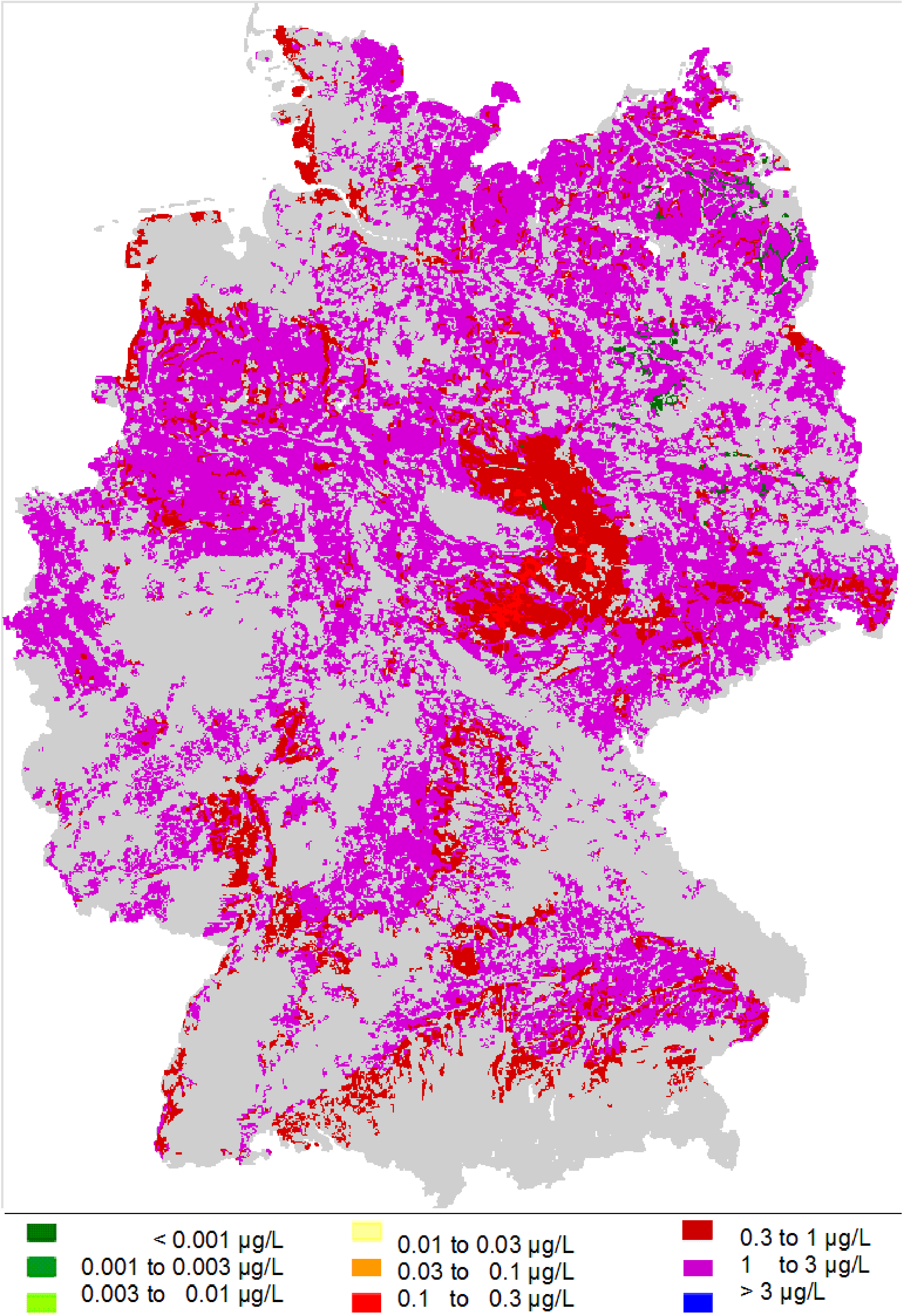

Figure 4-5: GISPELMO: Distribution of the 80th temporal percentiles of annual concentrations (Winter cereals, Kf_{oc} 15 L/kg- $DegT_{50}$ 80 d)

- **Kf_{oc} 30 L/kg- $DegT_{50}$ 10 d**

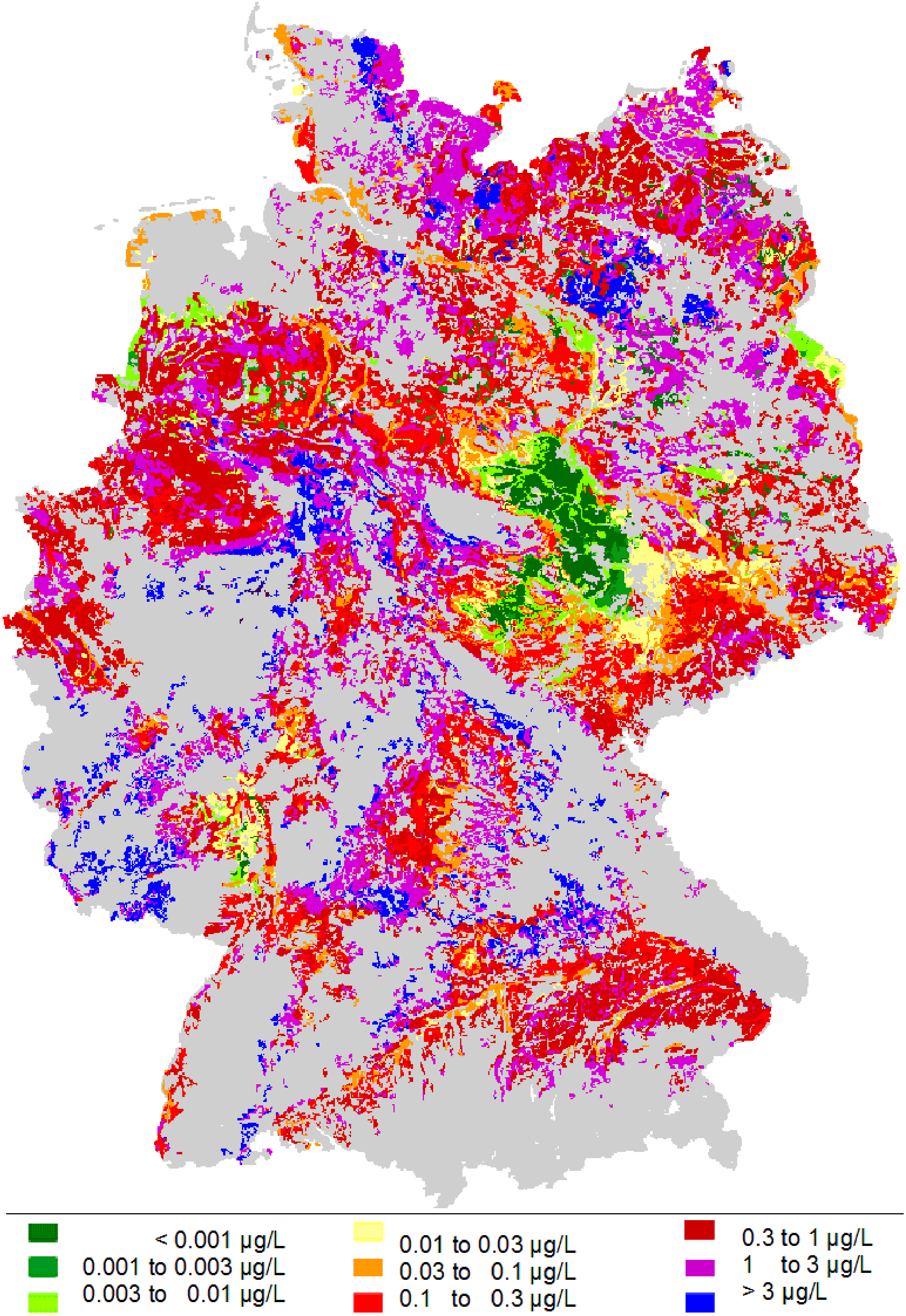

Figure 4-6: GISPELMO: Distribution of the 80th temporal percentiles of annual concentrations (Winter cereals, Kf_{oc} 30 L/kg- $DegT_{50}$ 10 d)

- **Kf_{oc} 60 L/kg- $DegT_{50}$ 20 d**

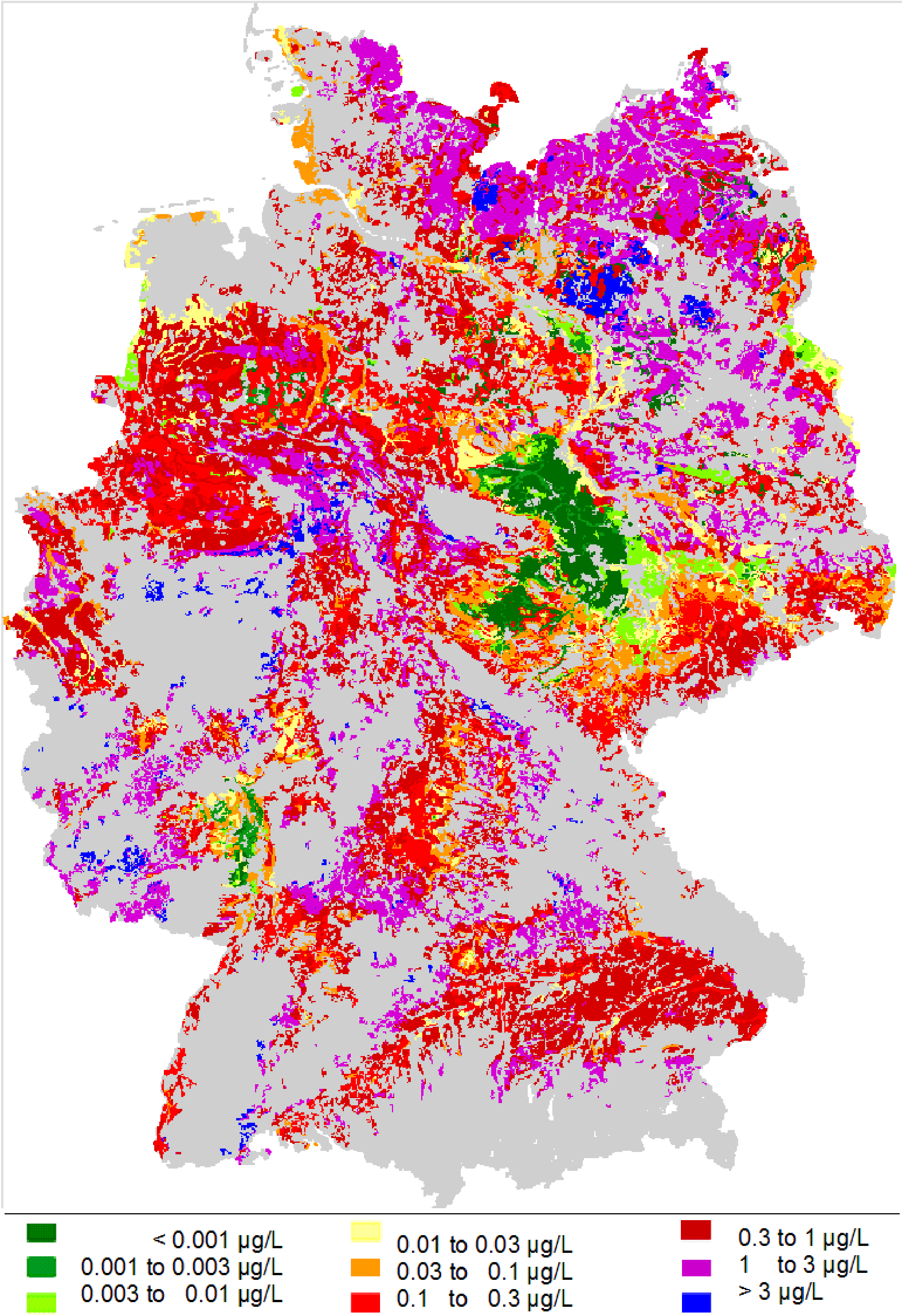

Figure 4-7: GISPELMO: Distribution of the 80th temporal percentiles of annual concentrations (Winter cereals, Kf_{oc} 60 L/kg- $DegT_{50}$ 20 d)

- **Kf_{oc} 60 L/kg- $DegT_{50}$ 80 d**

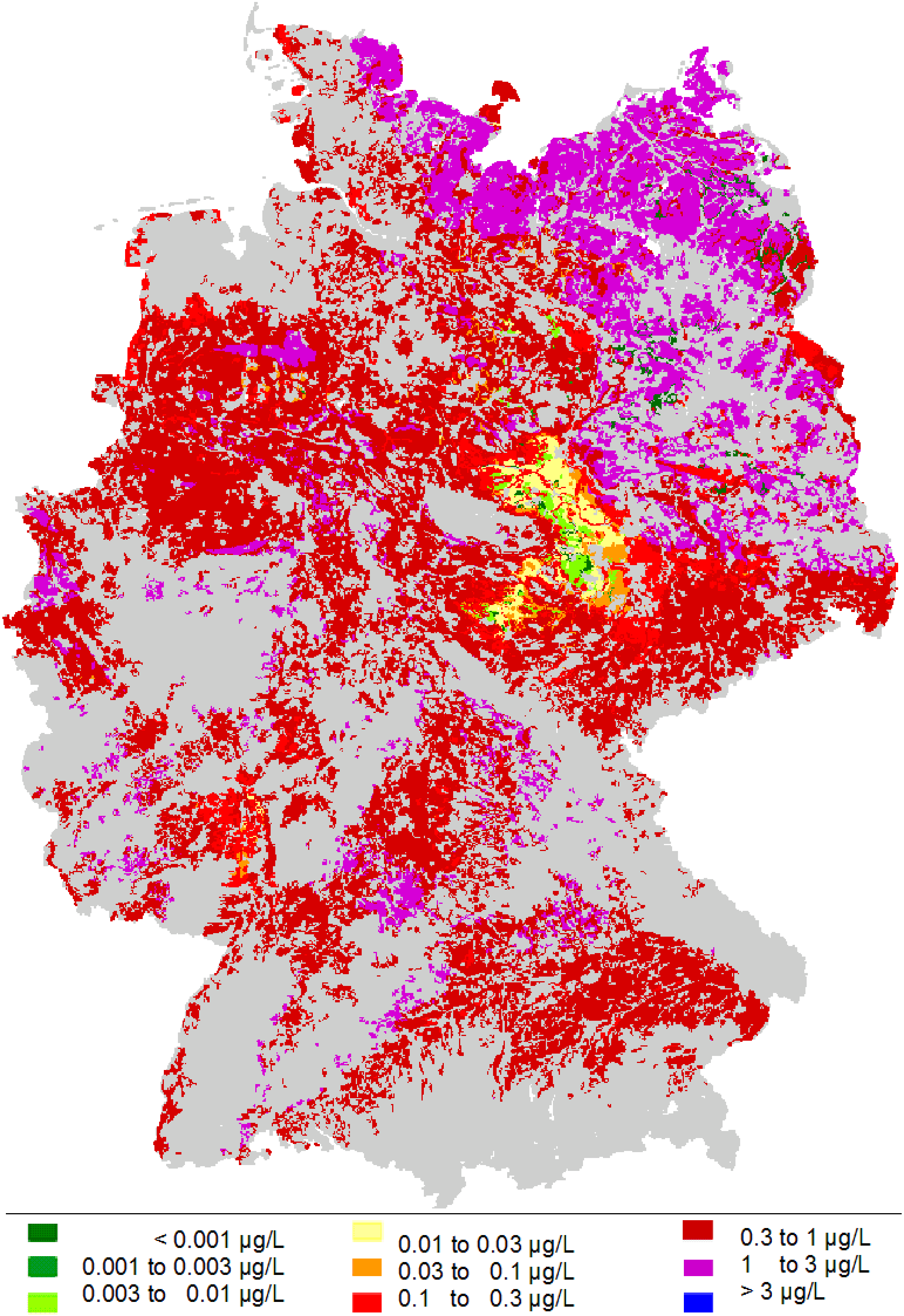

Figure 4-8: GISPELMO: Distribution of the 80th temporal percentiles of annual concentrations (Winter cereals, Kf_{oc} 60 L/kg- $DegT_{50}$ 80 d)

- **Kf_{oc} 120 L/kg- $DegT_{50}$ 40 d**

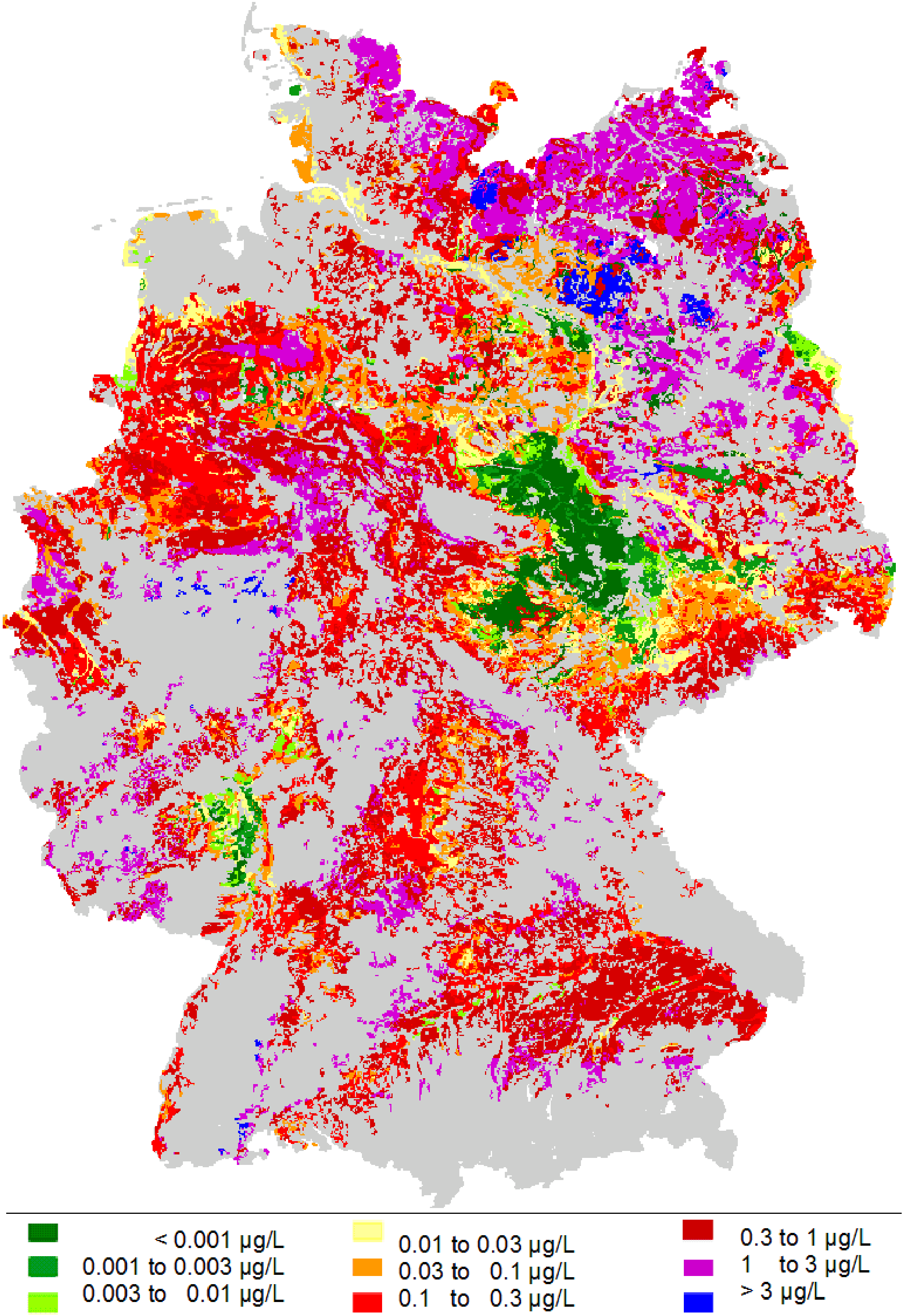

Figure 4-9: GISPELMO: Distribution of the 80th temporal percentiles of annual concentrations (Winter cereals, Kf_{oc} 120 L/kg- $DegT_{50}$ 40 d)

- **Kf_{oc} 240 L/kg- $DegT_{50}$ 80 d**

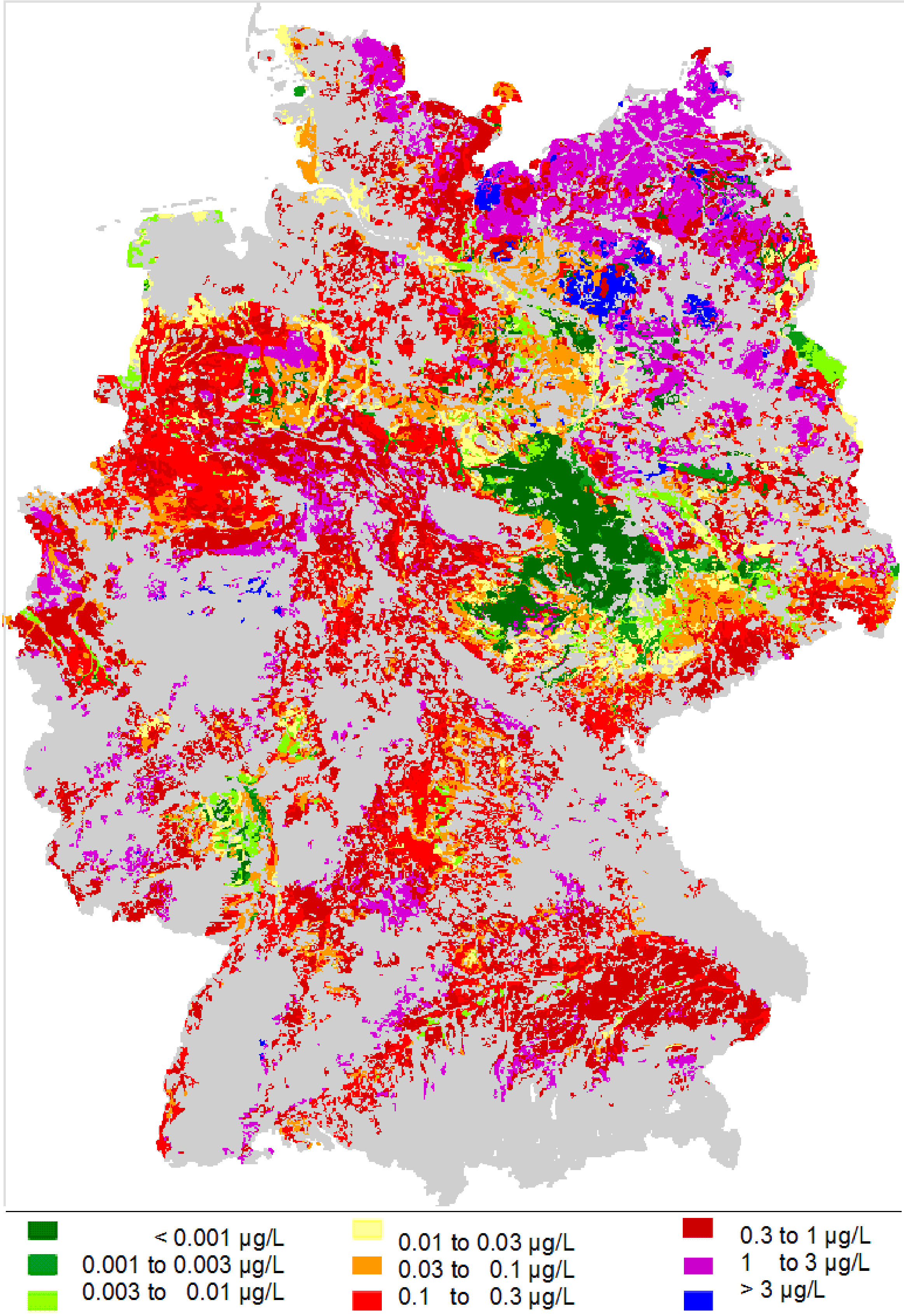

Figure 4-10: GISPELMO: Distribution of the 80th temporal percentiles of annual concentrations (Winter cereals, Kf_{oc} 240 L/kg- $DegT_{50}$ 80 d)

- **Kf_{oc} 480 L/kg- $DegT_{50}$ 160 d**

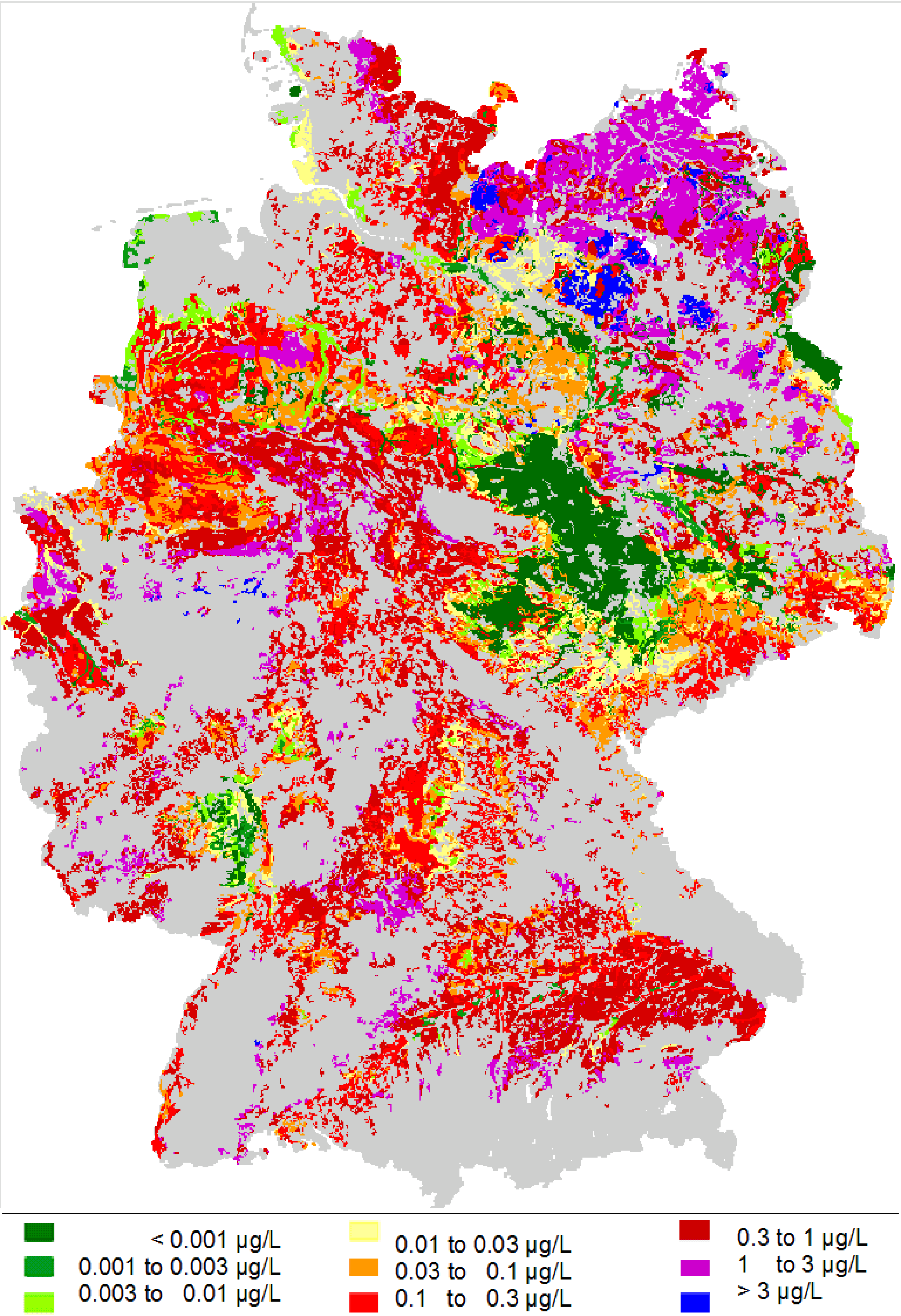

Figure 4-11: GISPELMO: Distribution of the 80th temporal percentiles of annual concentrations (Winter cereals, Kf_{oc} 480 L/kg- $DegT_{50}$ 160 d)

Maize

- Kf_{oc} 15 L/kg- $DegT_{50}$ 5 d

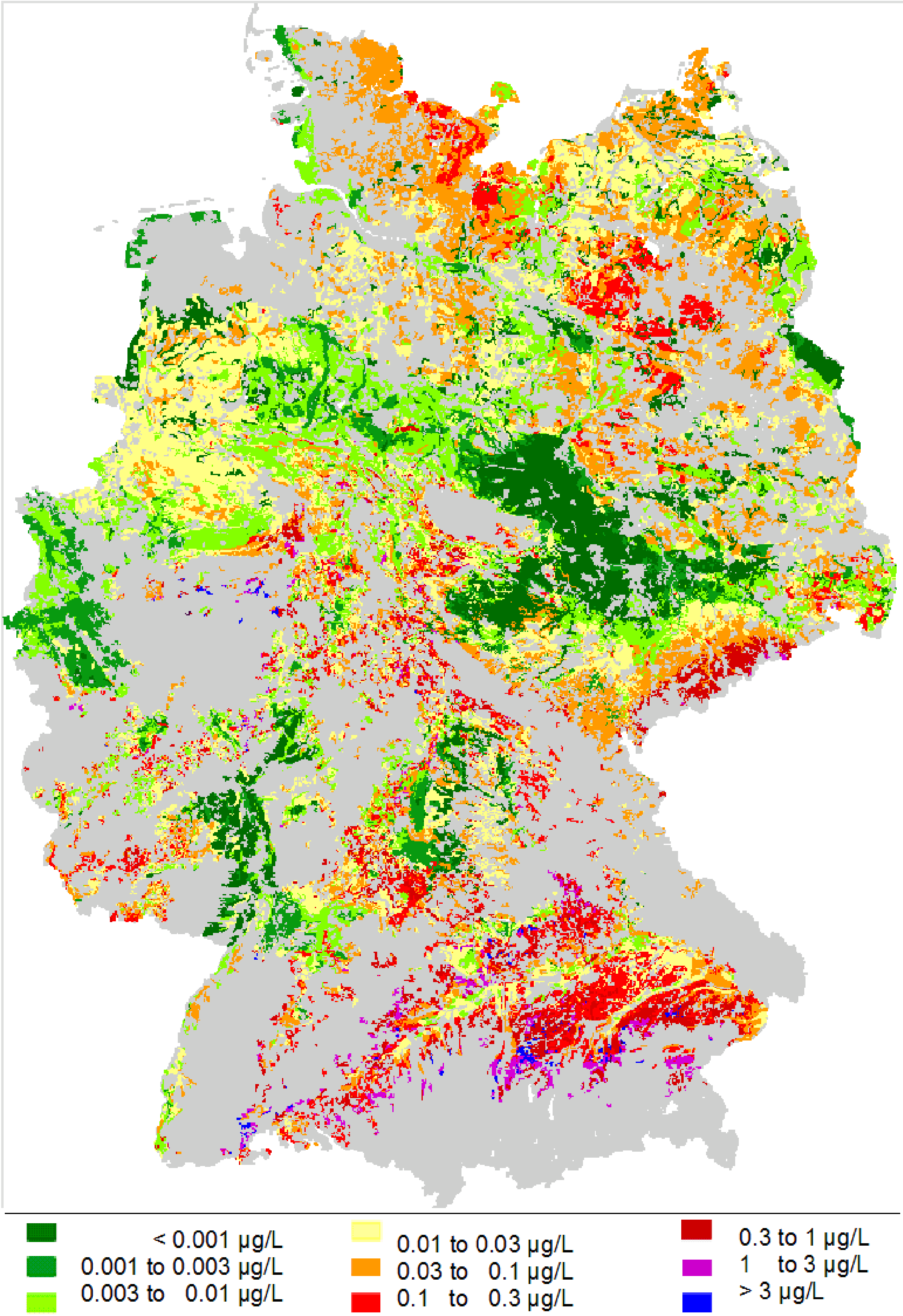

Figure 4-12: GISPELMO: Distribution of the 80th temporal percentiles of annual concentrations (Maize, Kf_{oc} 15 L/kg- $DegT_{50}$ 5 d)

- **Kf_{oc} 15 L/kg- $DegT_{50}$ 20 d**

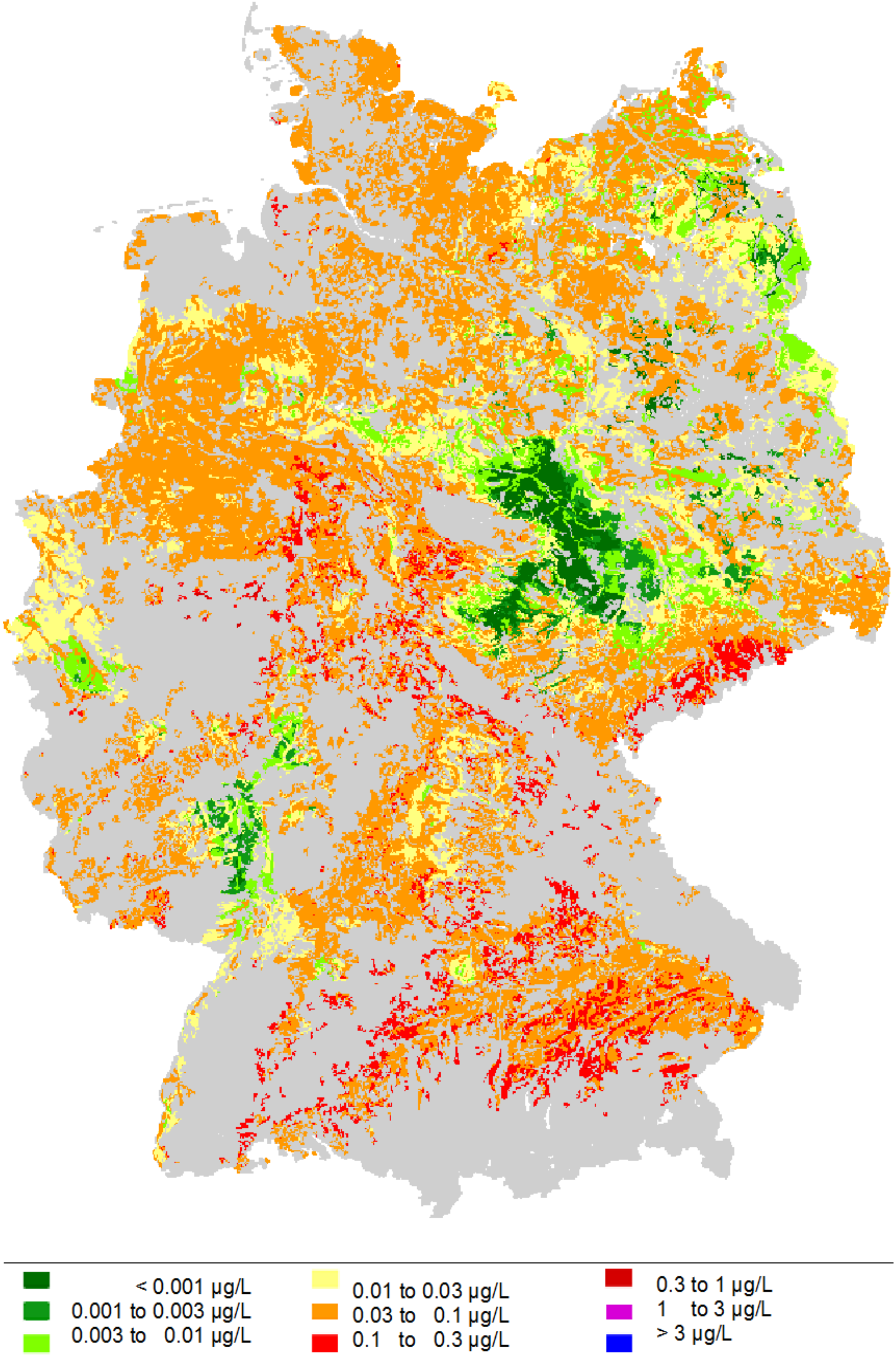

Figure 4-13: GISPELMO: Distribution of the 80th temporal percentiles of annual concentrations (Maize, Kf_{oc} 15 L/kg- $DegT_{50}$ 20 d)

- **Kf_{oc} 15 L/kg- $DegT_{50}$ 80 d**

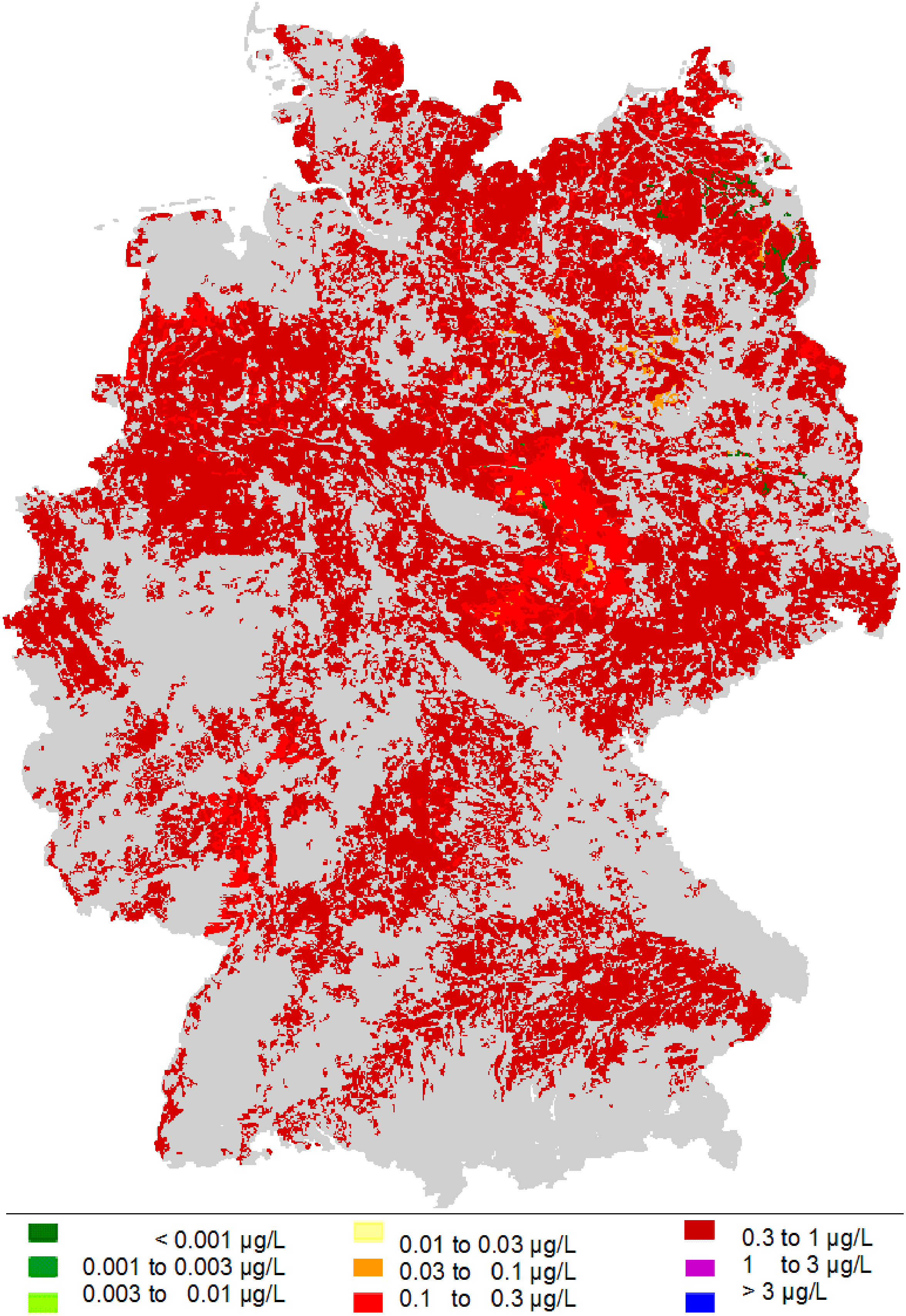

Figure 4-14: GISPELMO: Distribution of the 80th temporal percentiles of annual concentrations (Maize, Kf_{oc} 15 L/kg- $DegT_{50}$ 80 d)

- **Kf_{oc} 30 L/kg- $DegT_{50}$ 10 d**

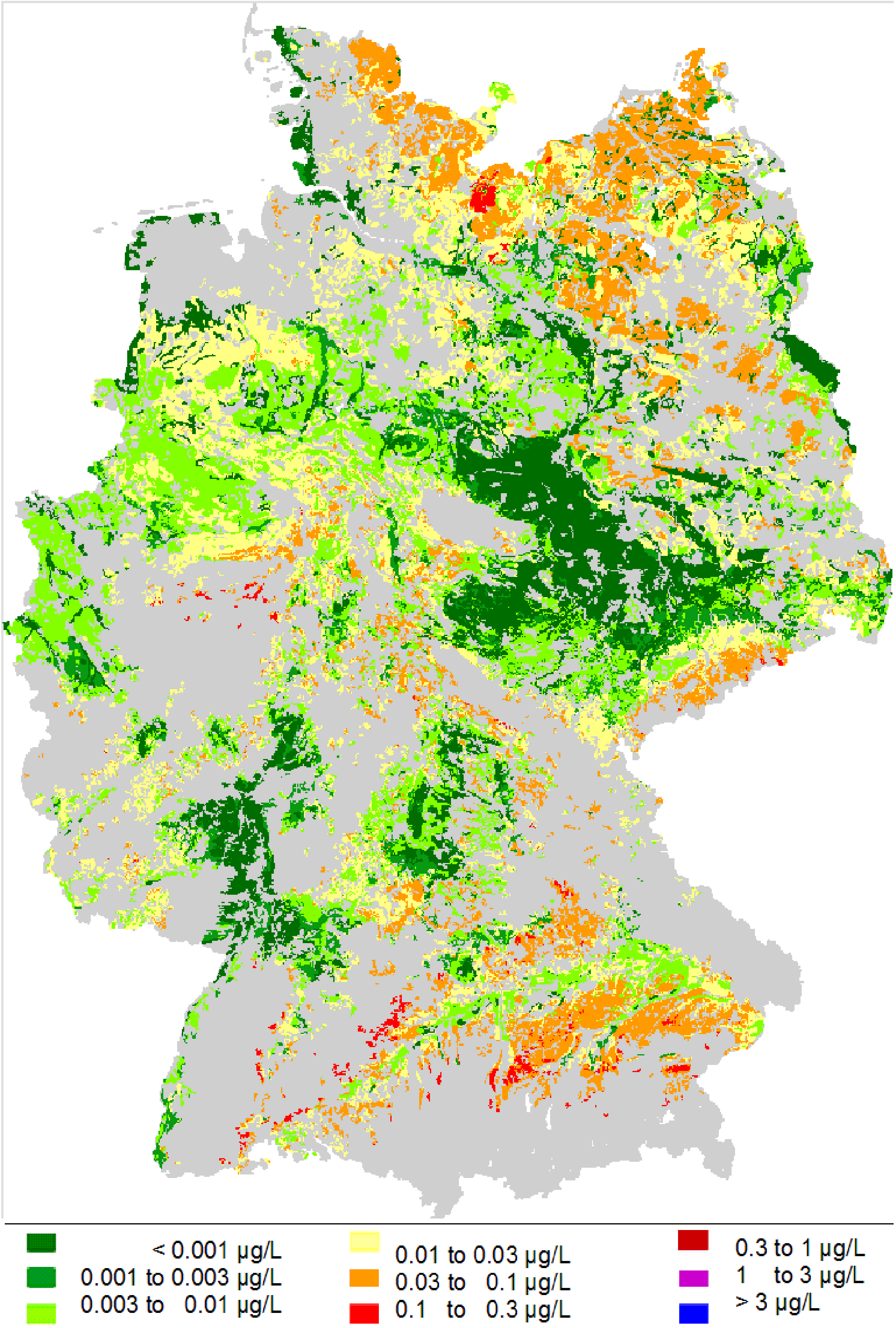

Figure 4-15: GISPELMO: Distribution of the 80th temporal percentiles of annual concentrations (Maize, Kf_{oc} 30 L/kg- $DegT_{50}$ 10 d)

- **Kf_{oc} 60 L/kg- $DegT_{50}$ 20 d**

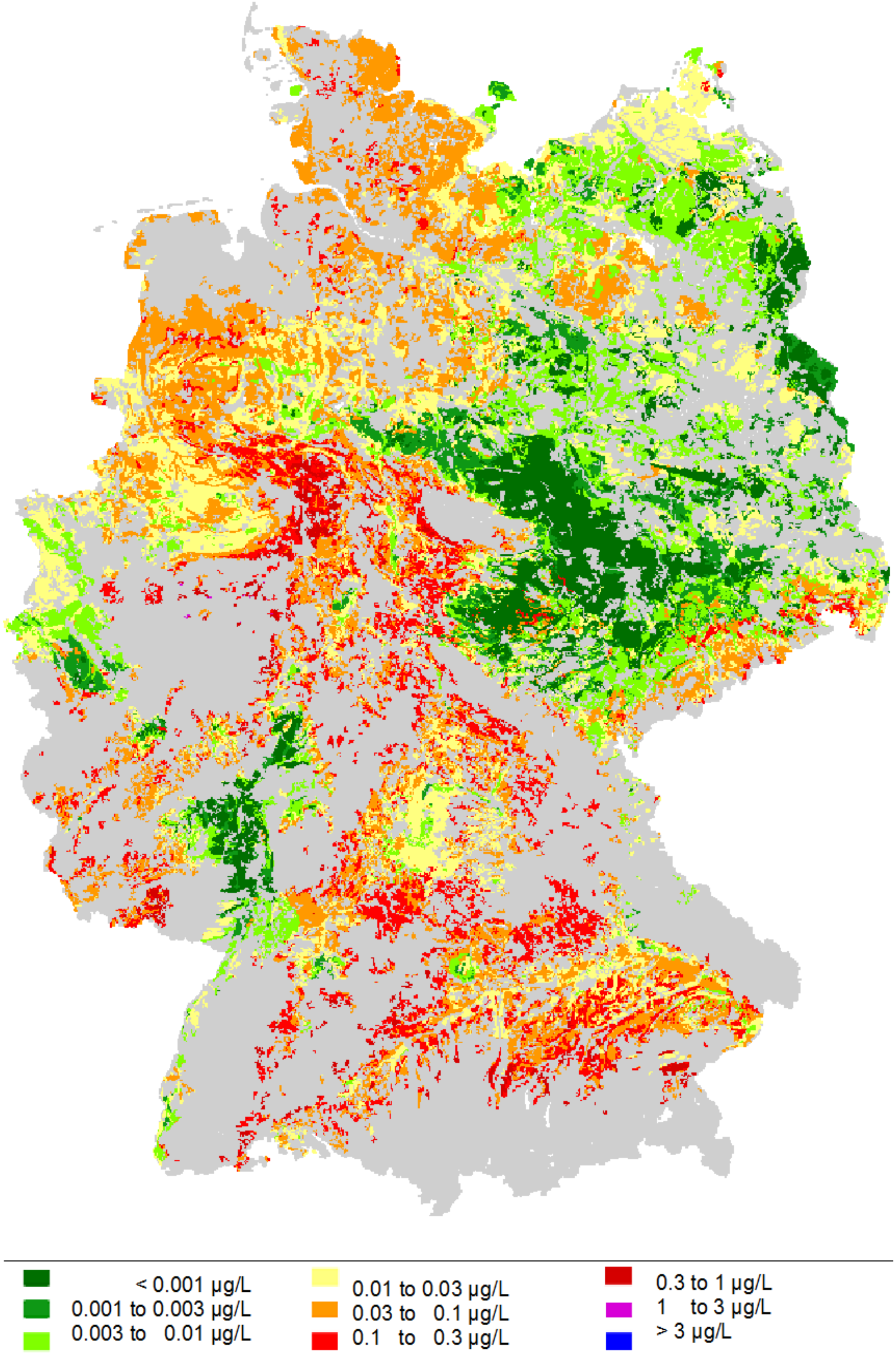

Figure 4-16: GISPELMO: Distribution of the 80th temporal percentiles of annual concentrations (Maize, Kf_{oc} 60 L/kg- $DegT_{50}$ 20 d)

- **Kf_{oc} 60 L/kg- $DegT_{50}$ 80 d**

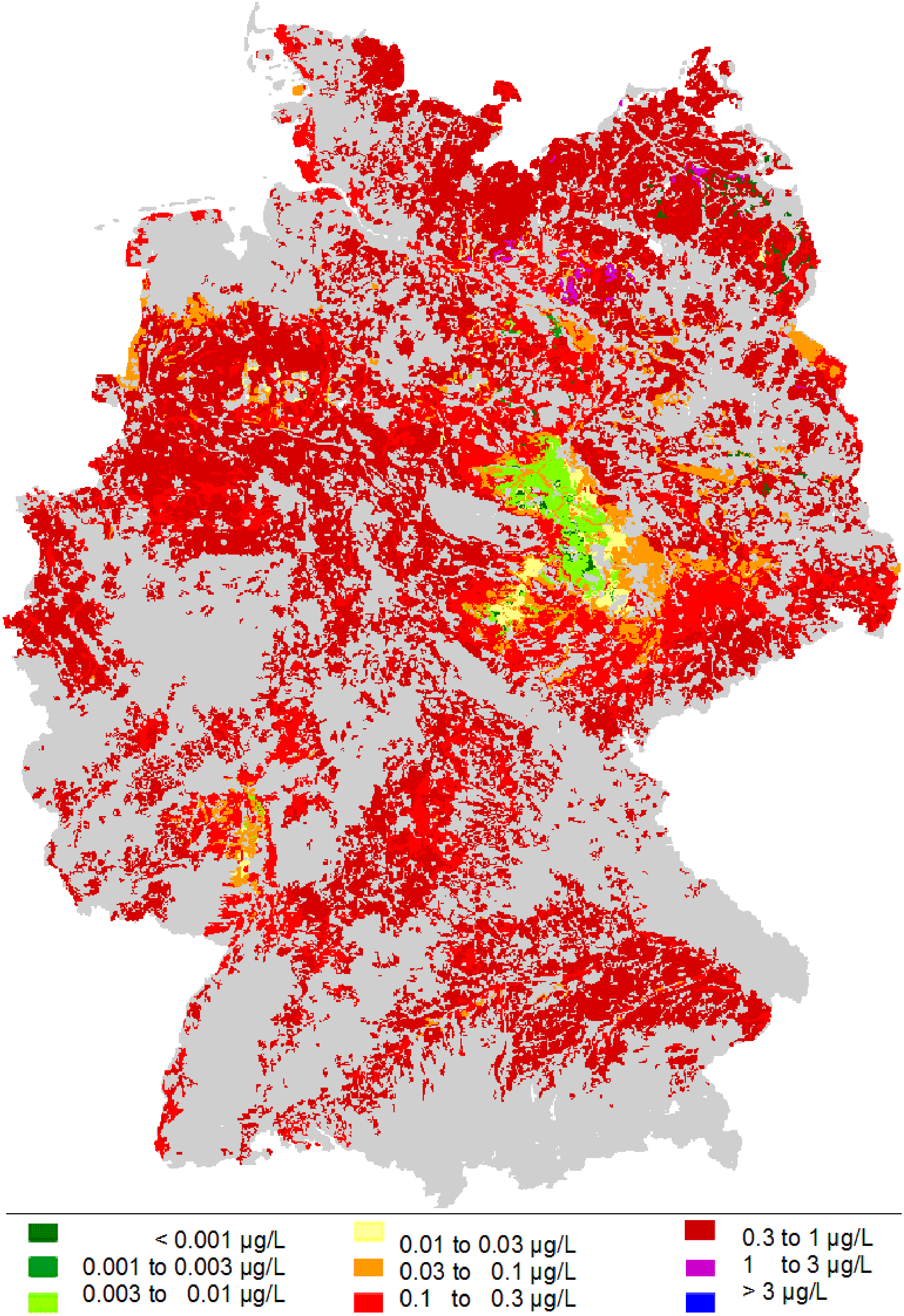

Figure 4-17: GISPELMO: Distribution of the 80th temporal percentiles of annual concentrations (Maize, Kf_{oc} 60 L/kg- $DegT_{50}$ 80 d)

- **Kf_{oc} 120 L/kg- $DegT_{50}$ 40 d**

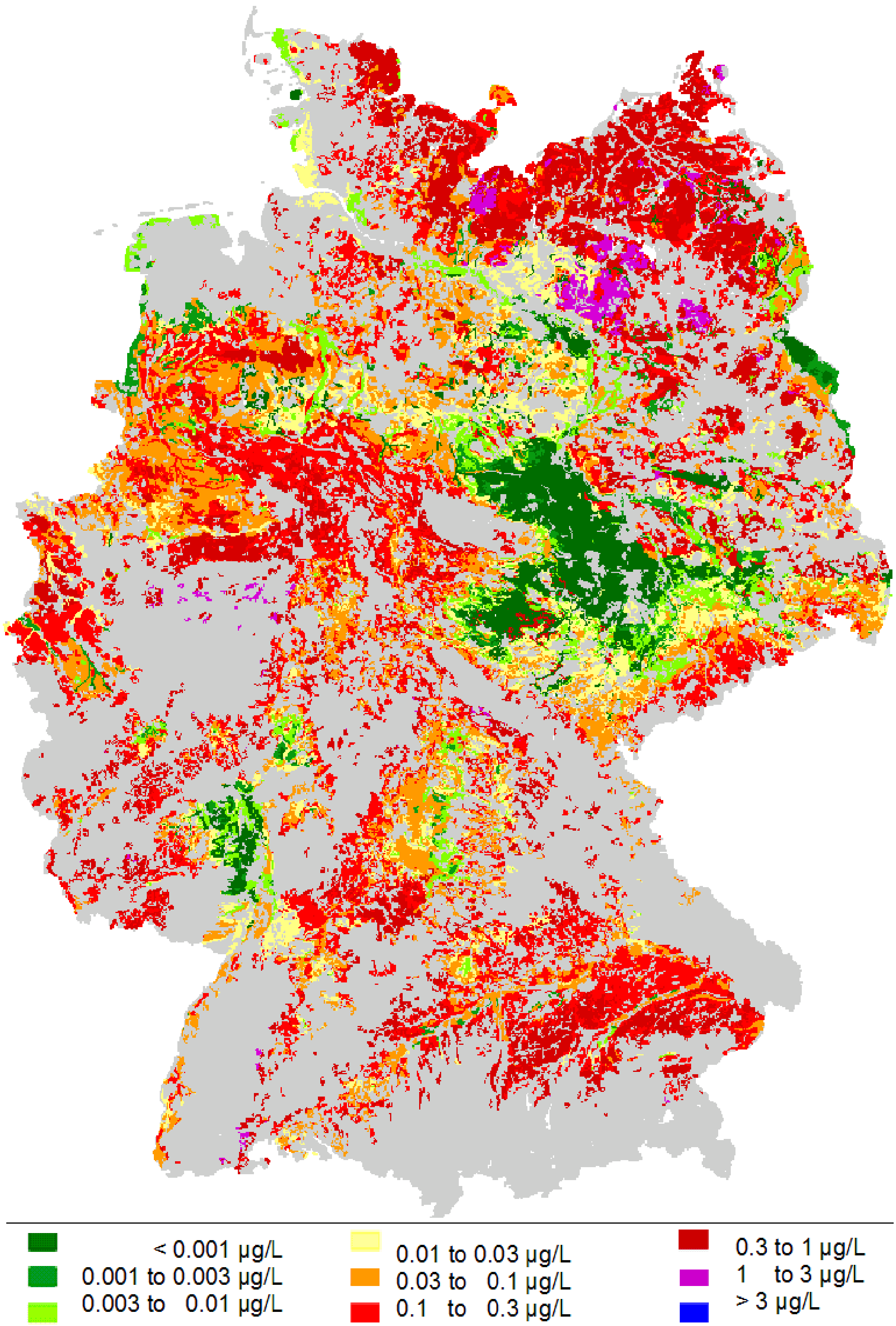

Figure 4-18: GISPELMO: Distribution of the 80th temporal percentiles of annual concentrations (Maize, Kf_{oc} 120 L/kg- $DegT_{50}$ 40 d)

- **Kf_{oc} 240 L/kg- $DegT_{50}$ 80 d**

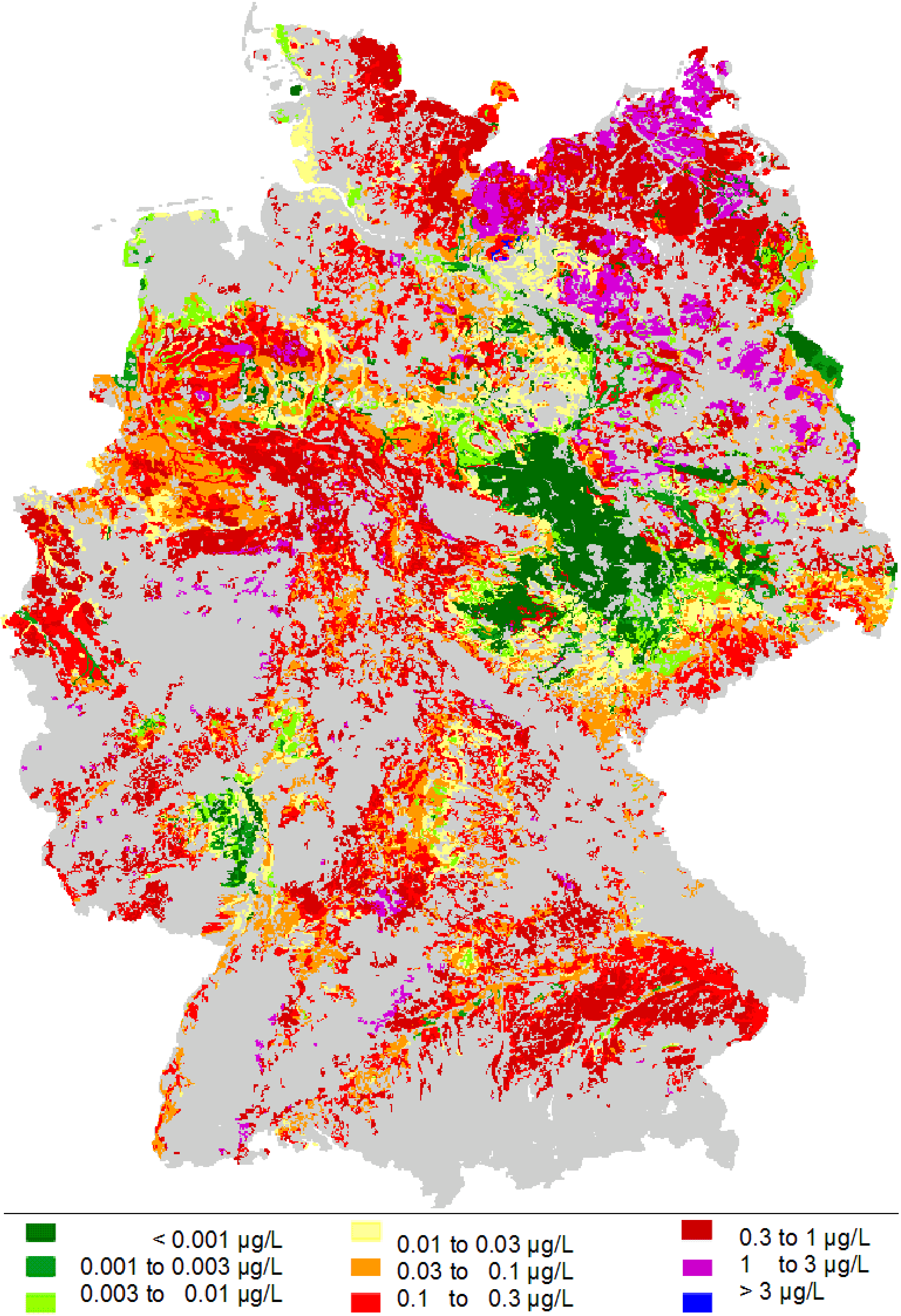

Figure 4-19: GISPELMO: Distribution of the 80th temporal percentiles of annual concentrations (Maize, Kf_{oc} 240 L/kg- $DegT_{50}$ 80 d)

- **Kf_{oc} 480 L/kg- $DegT_{50}$ 160 d**

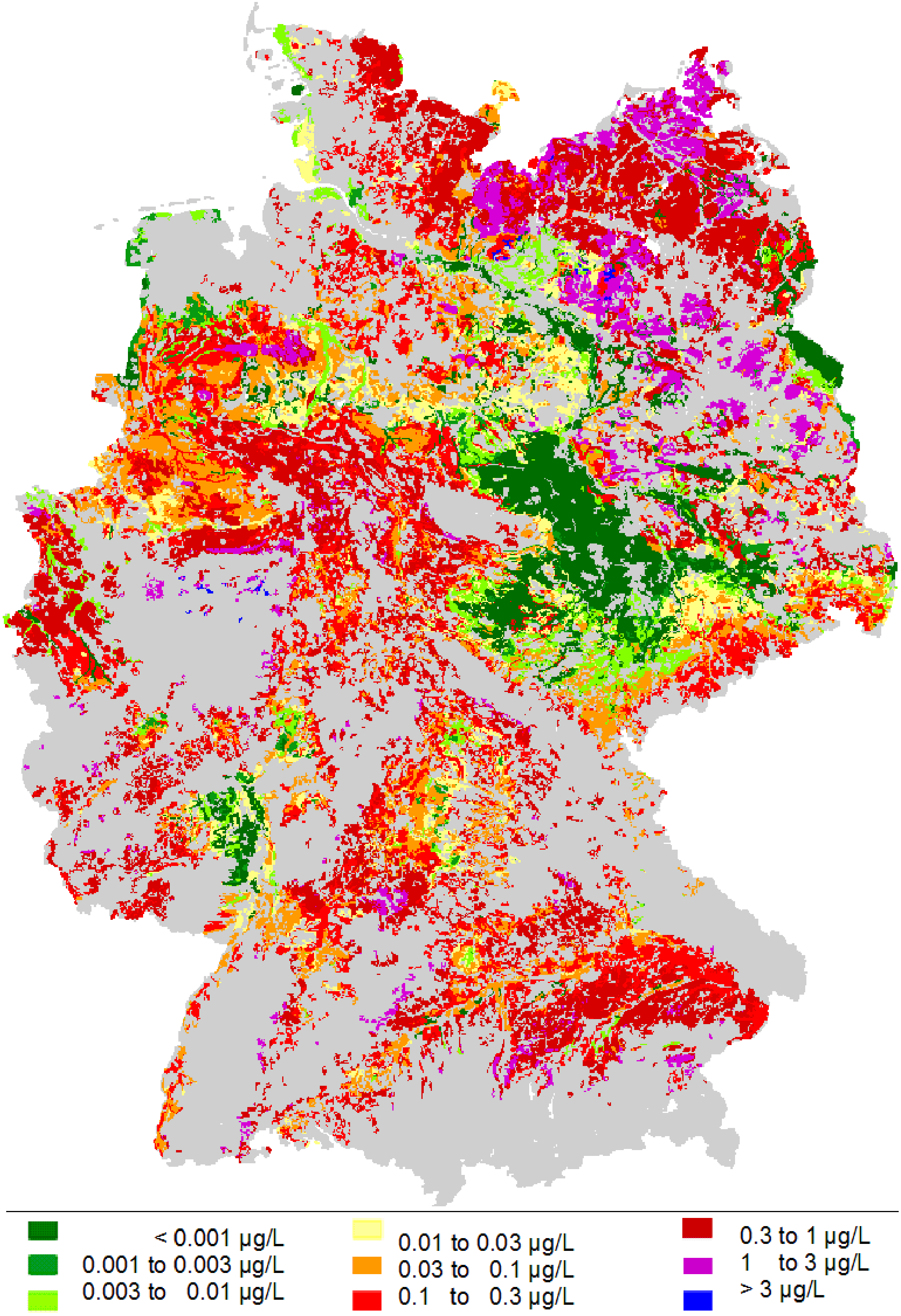

Figure 4-20: GISPELMO: Distribution of the 80th temporal percentiles of annual concentrations (Maize, Kf_{oc} 480 L/kg- $DegT_{50}$ 160 d)

4.5 Appendix 5: GISPELMO: Distribution of the 80 ± 5th spatial percentile of the 80th temporal percentiles of annual concentrations

Winter cereals

- **Kf_{oc} 15 L/kg- $DegT_{50}$ 5 d**

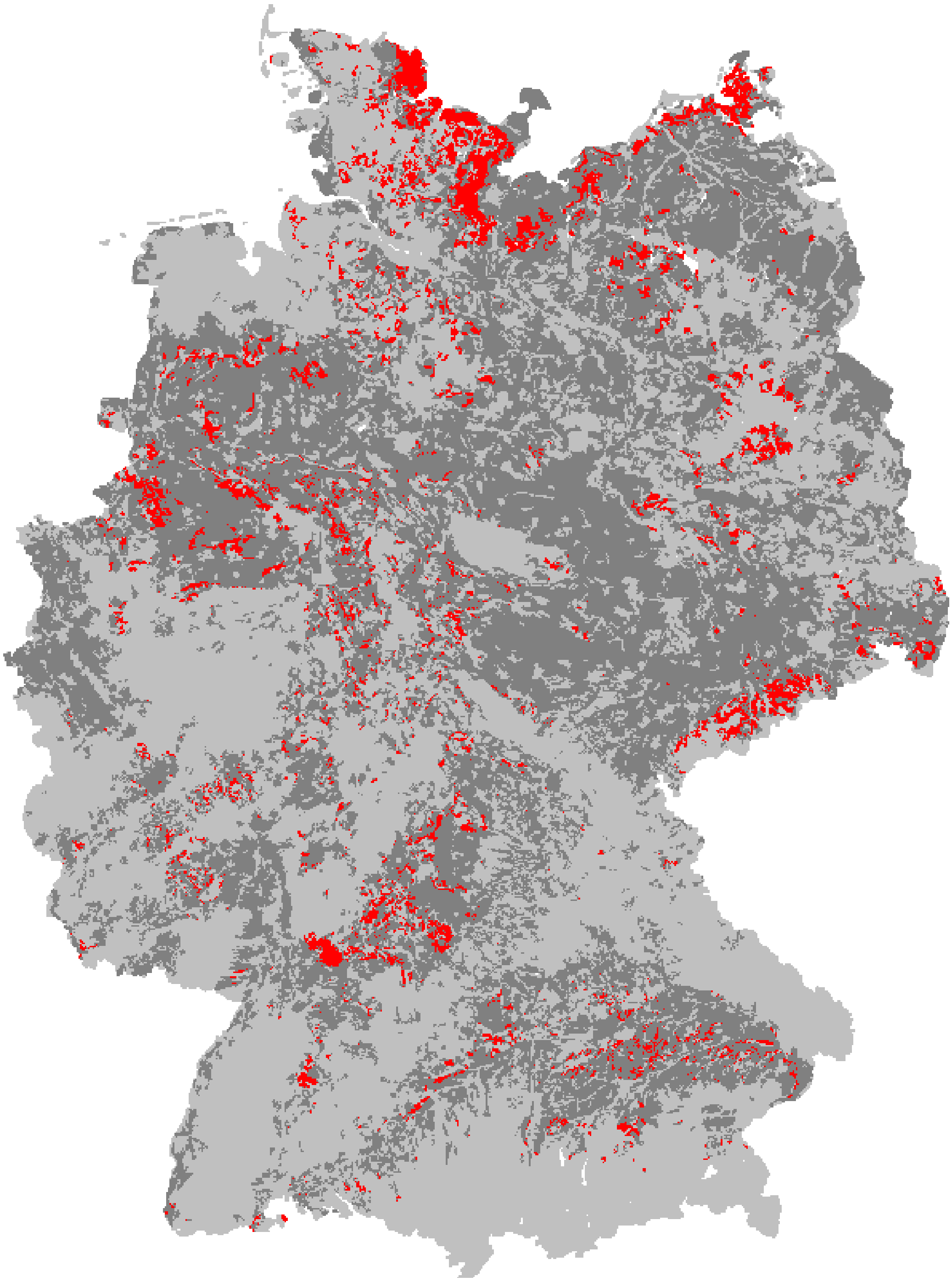

Figure 4-21: Distribution of the 80 ± 5th spatial percentile of the 80th temporal percentiles of annual concentrations (Winter cereals, Kf_{oc} 15 L/kg- $DegT_{50}$ 5 d)

- **Kf_{oc} 15 L/kg- $DegT_{50}$ 20 d**

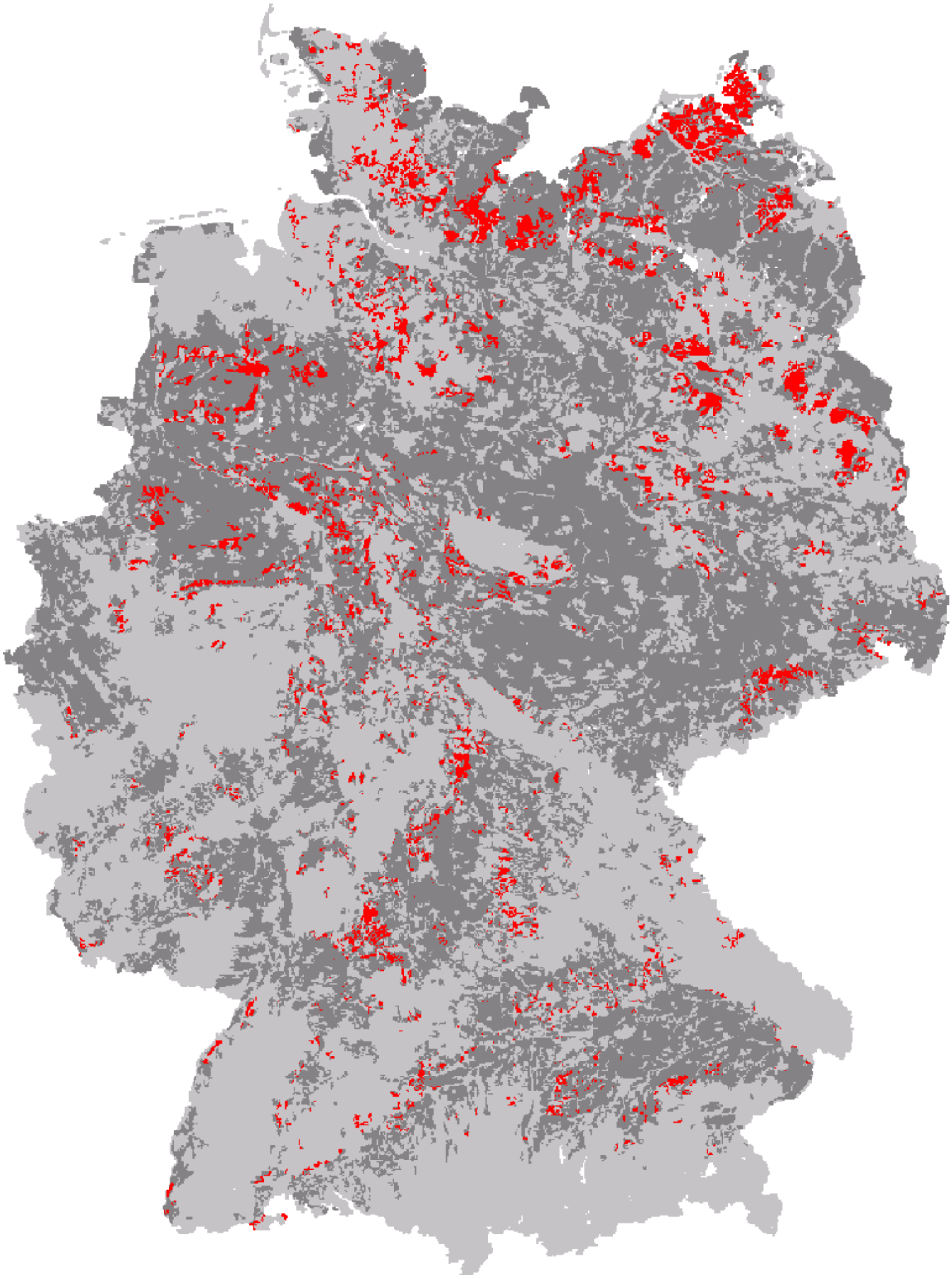

Figure 4-22: Distribution of the 80 ± 5th spatial percentile of the 80th temporal percentiles of annual concentrations (Winter cereals, Kf_{oc} 15 L/kg- $DegT_{50}$ 20 d)

- **Kf_{oc} 15 L/kg- $DegT_{50}$ 80 d**

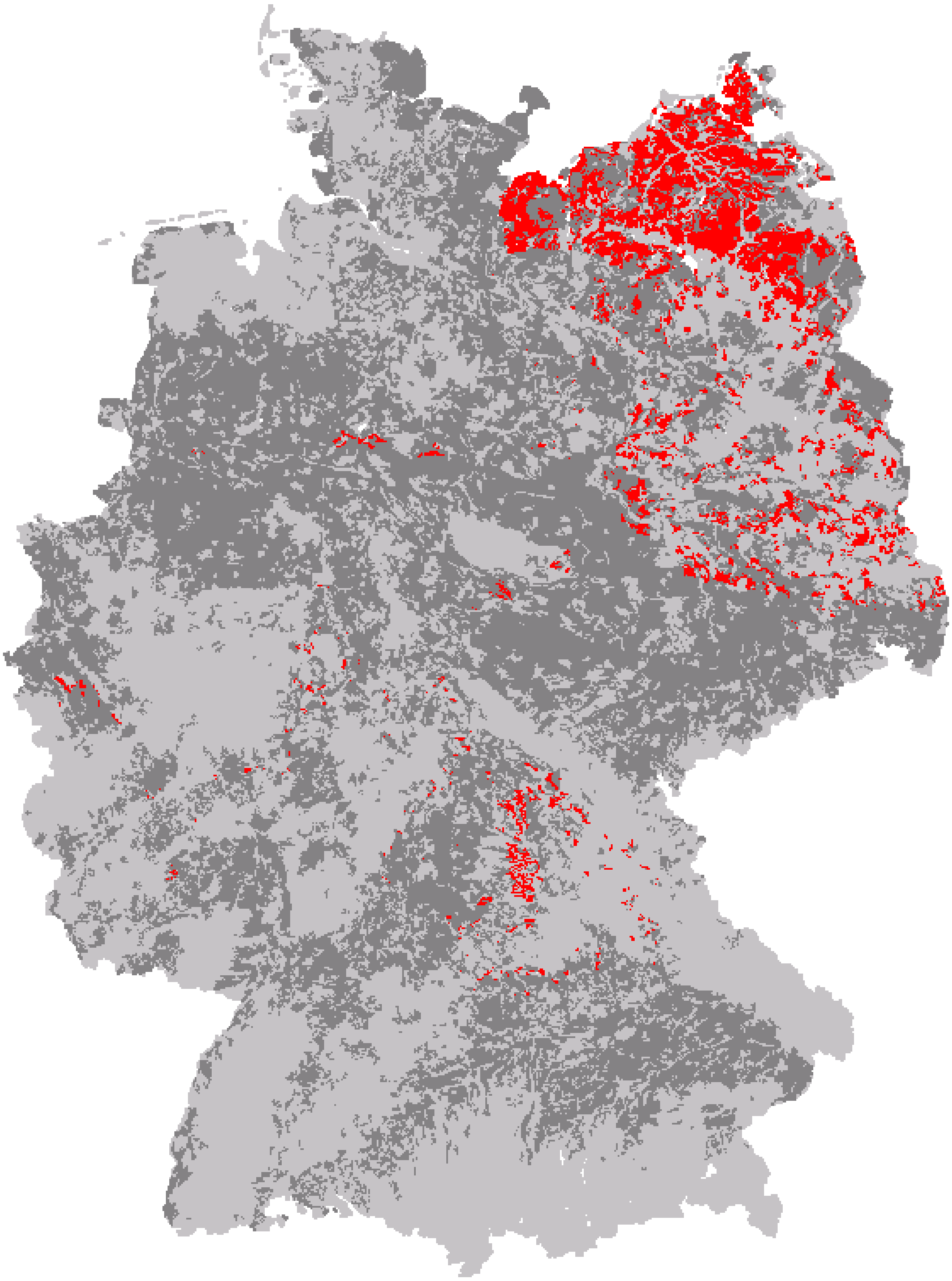

Figure 4-23: Distribution of the 80 ± 5th spatial percentile of the 80th temporal percentiles of annual concentrations (Winter cereals, Kf_{oc} 15 L/kg- $DegT_{50}$ 80 d)

- **Kf_{oc} 30 L/kg- $DegT_{50}$ 10 d**

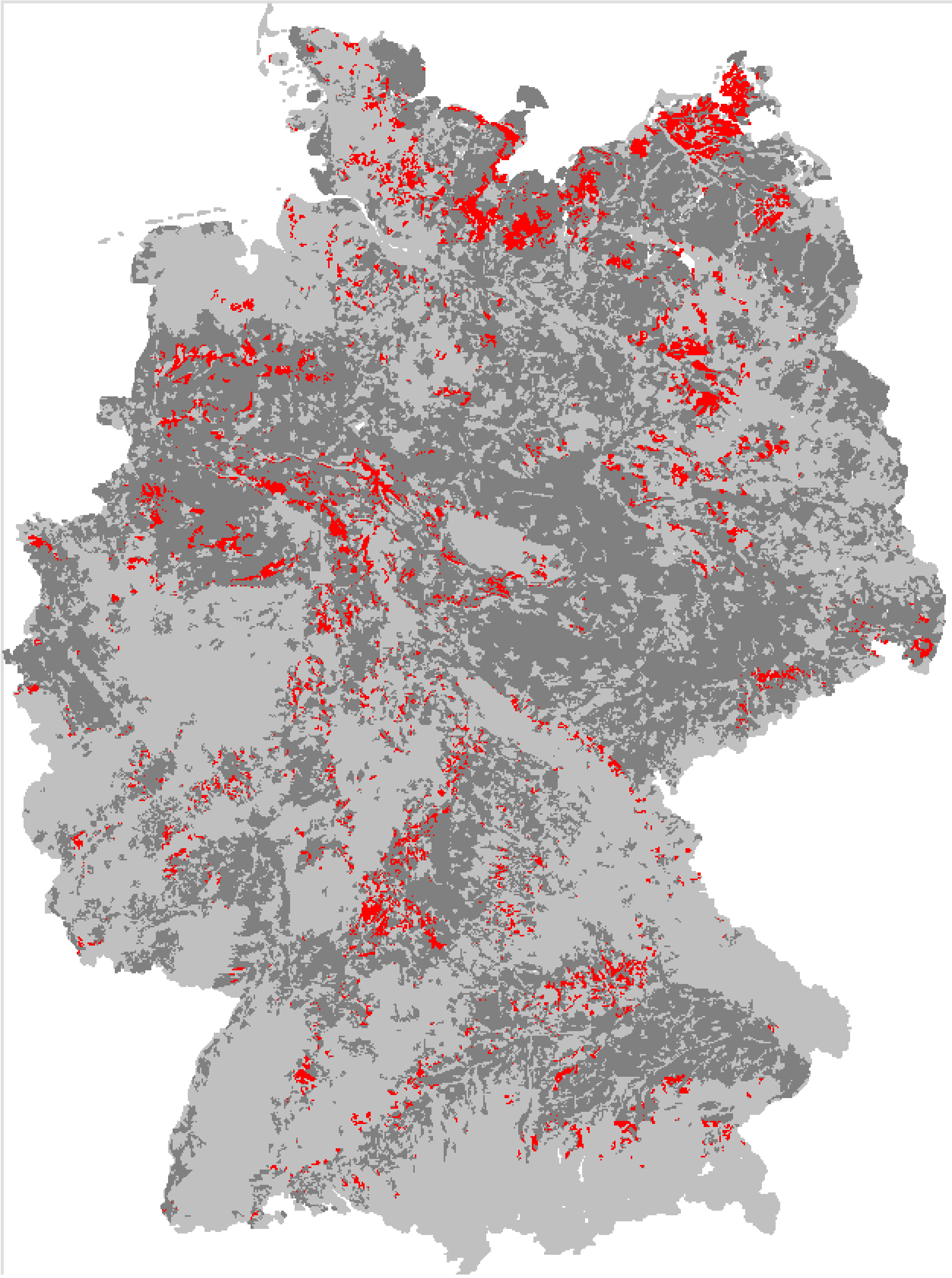

Figure 4-24: Distribution of the 80 ± 5th spatial percentile of the 80th temporal percentiles of annual concentrations (Winter cereals, Kf_{oc} 30 L/kg- $DegT_{50}$ 10 d)

- **Kf_{oc} 60 L/kg- $DegT_{50}$ 20 d**

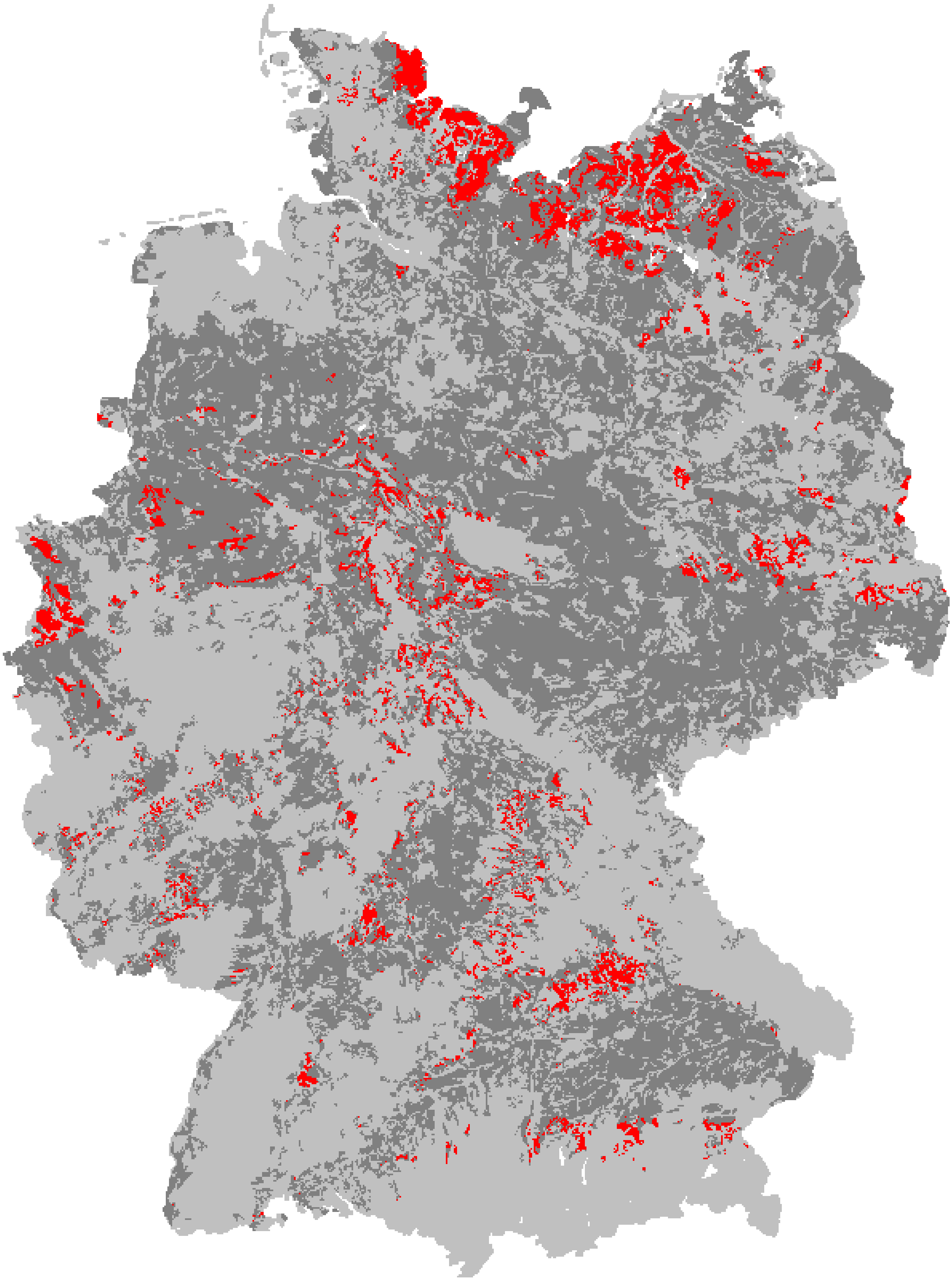

Figure 4-25: Distribution of the 80 ± 5th spatial percentile of the 80th temporal percentiles of annual concentrations (Winter cereals, Kf_{oc} 60 L/kg- $DegT_{50}$ 20 d)

- **Kf_{oc} 60 L/kg- $DegT_{50}$ 80 d**

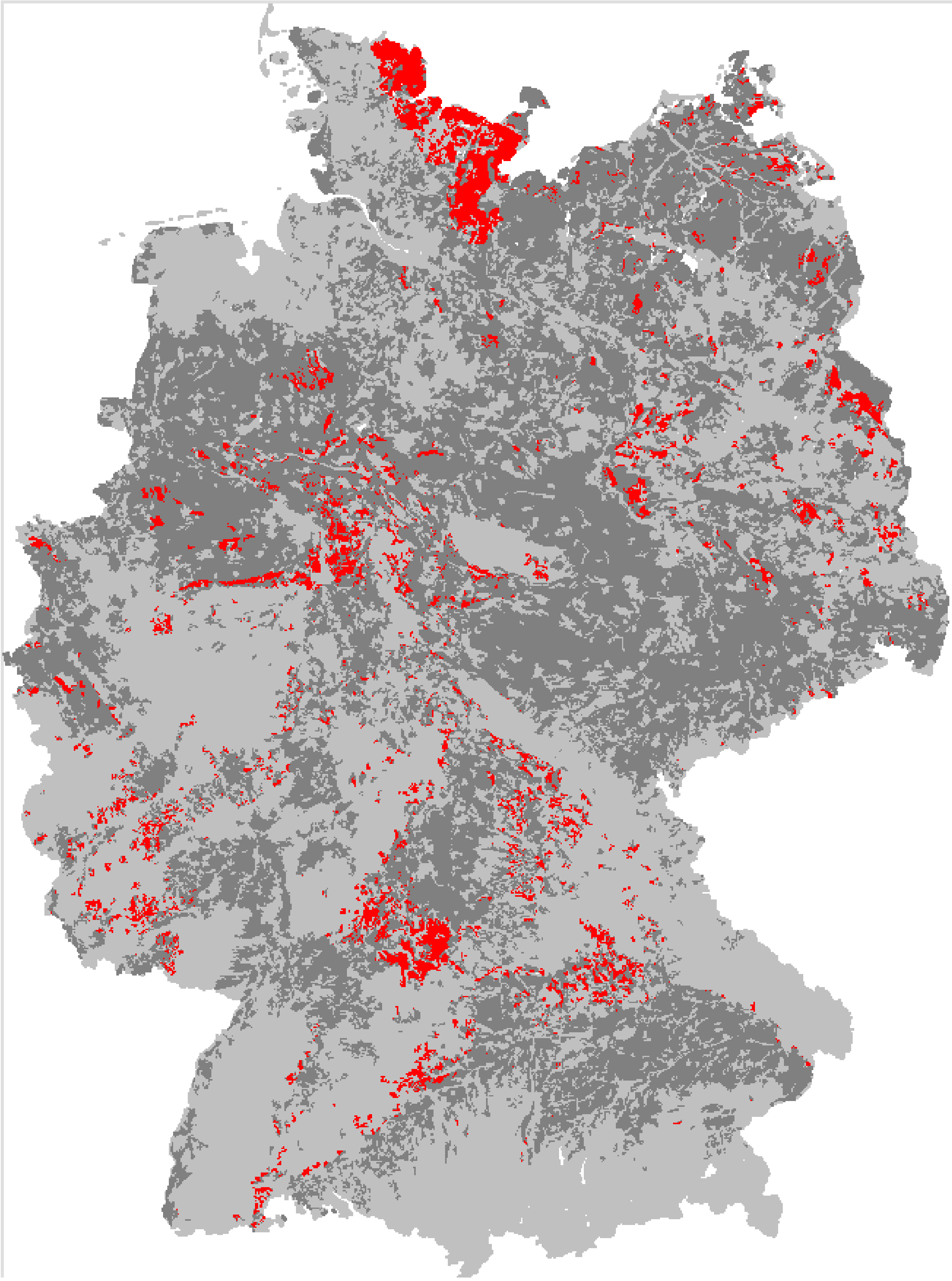

Figure 4-26: Distribution of the 80 ± 5th spatial percentile of the 80th temporal percentiles of annual concentrations (Winter cereals, Kf_{oc} 60 L/kg- $DegT_{50}$ 20 d)

- **Kf_{oc} 120 L/kg- $DegT_{50}$ 40 d**

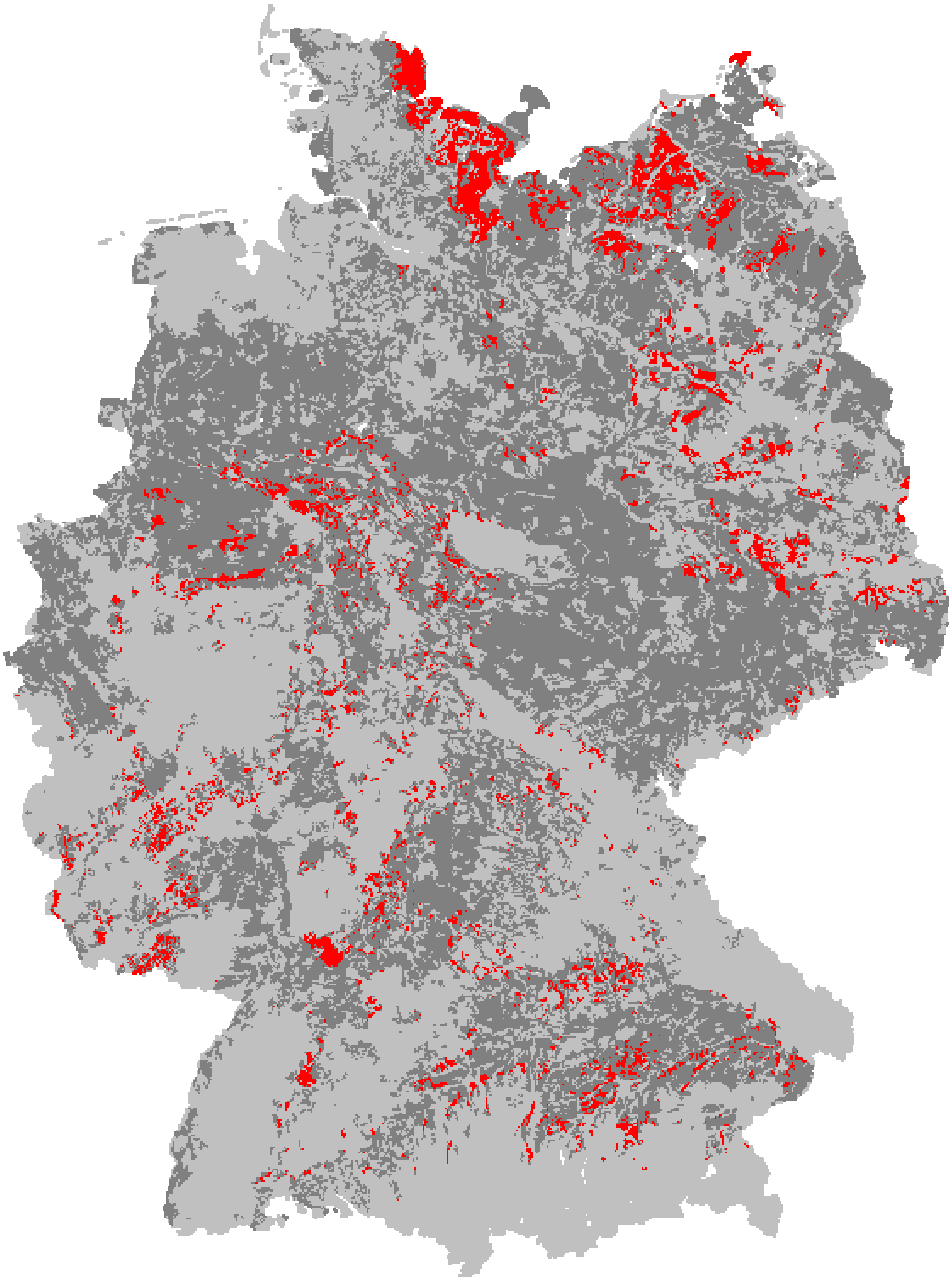

Figure 4-27: Distribution of the 80 ± 5th spatial percentile of the 80th temporal percentiles of annual concentrations (Winter cereals, Kf_{oc} 120 L/kg- $DegT_{50}$ 40 d)

- **Kf_{oc} 240 L/kg- $DegT_{50}$ 80 d**

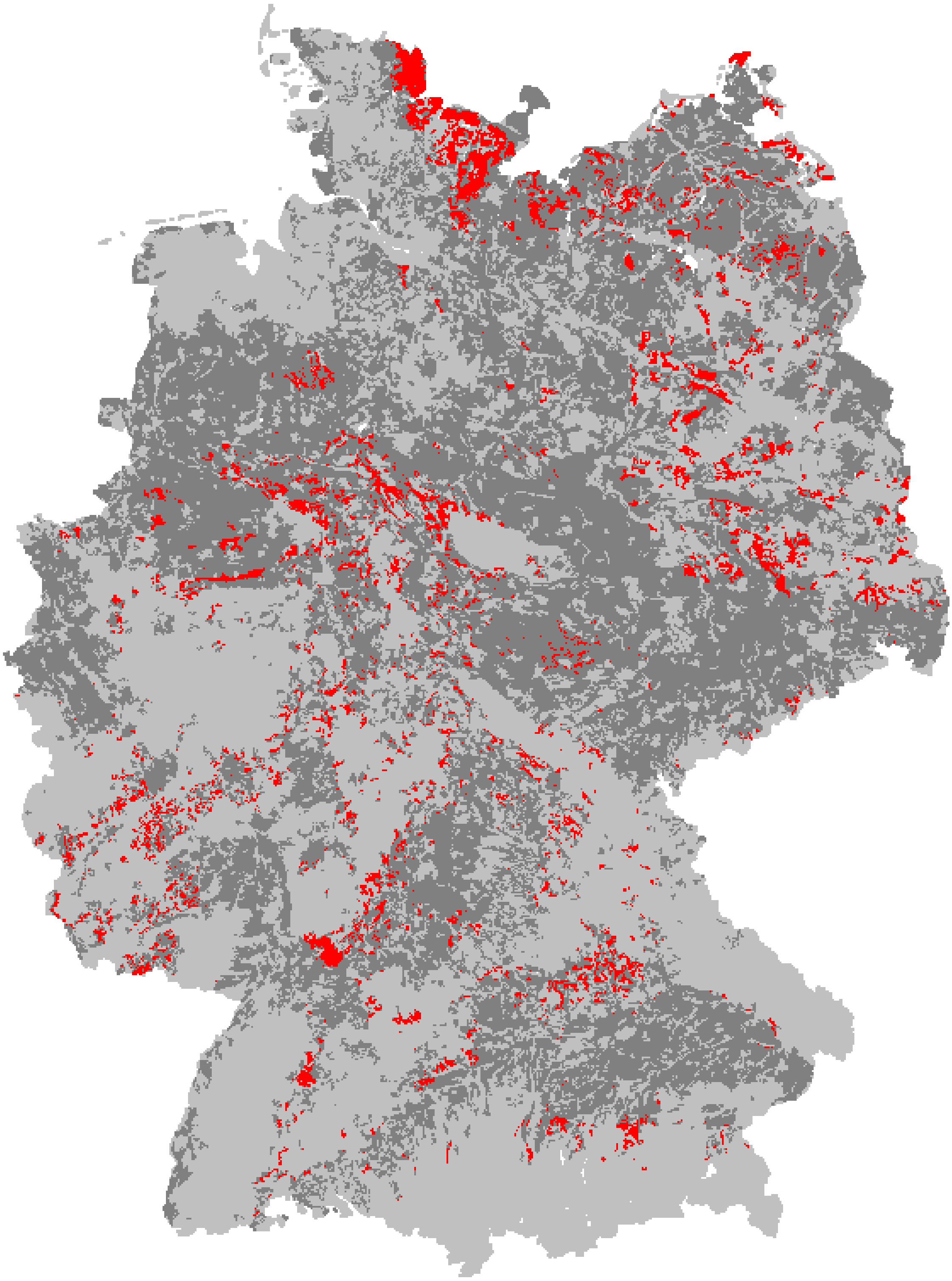

Figure 4-28: Distribution of the 80 ± 5th spatial percentile of the 80th temporal percentiles of annual concentrations (Winter cereals, Kf_{oc} 240 L/kg- $DegT_{50}$ 80 d)

- **Kf_{oc} 480 L/kg- $DegT_{50}$ 160 d**

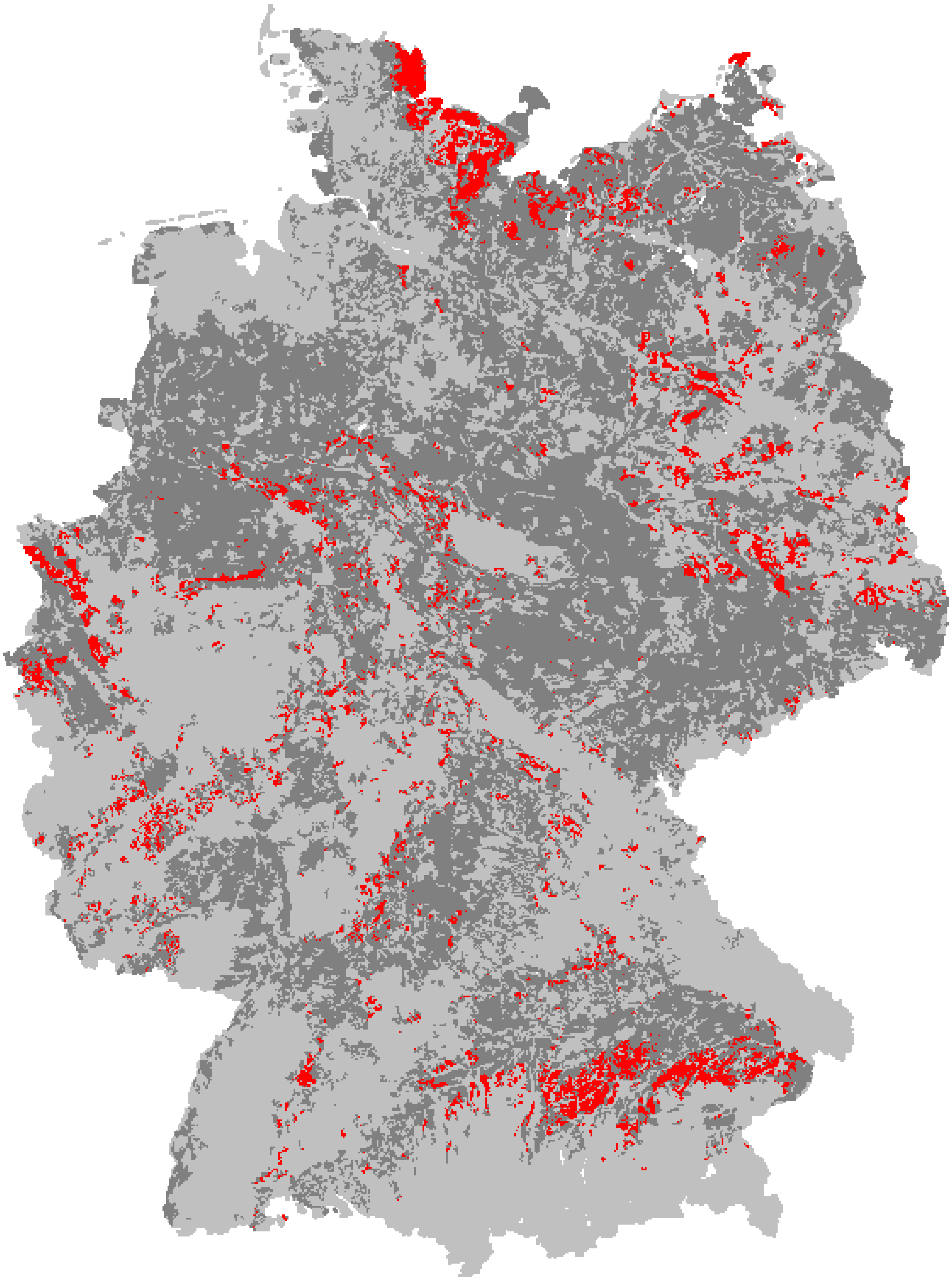

Figure 4-29: Distribution of the 80 ± 5th spatial percentile of the 80th temporal percentiles of annual concentrations (Winter cereals, Kf_{oc} 480 L/kg- $DegT_{50}$ 160 d)

Maize

- **Kf_{oc} 15 L/kg- $DegT_{50}$ 5 d**

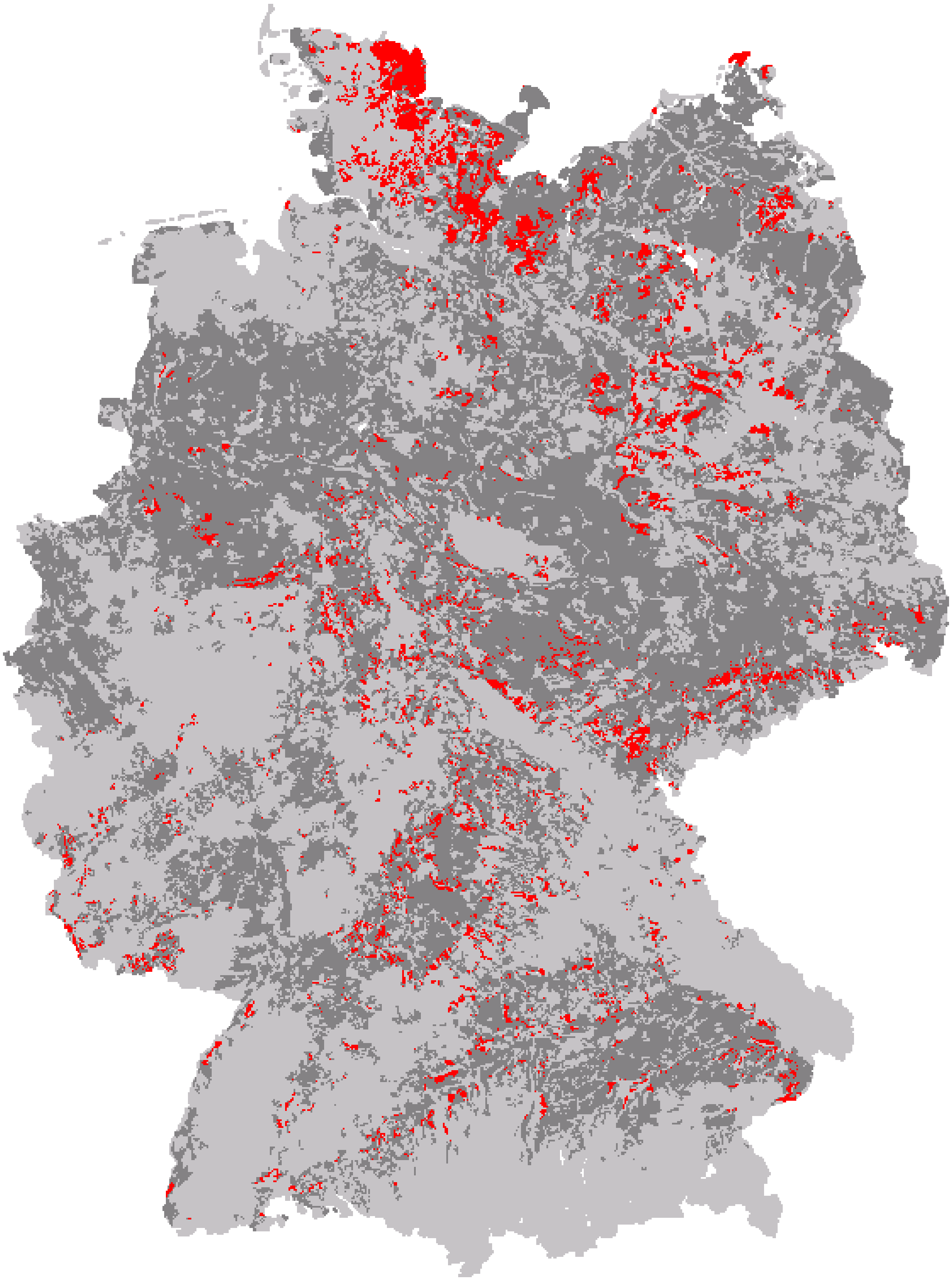

Figure 4-30: Distribution of the 80 ± 5th spatial percentile of the 80th temporal percentiles of annual concentrations (Maize, Kf_{oc} 15 L/kg- $DegT_{50}$ 5 d)

- **Kf_{oc} 15 L/kg- $DegT_{50}$ 20 d**

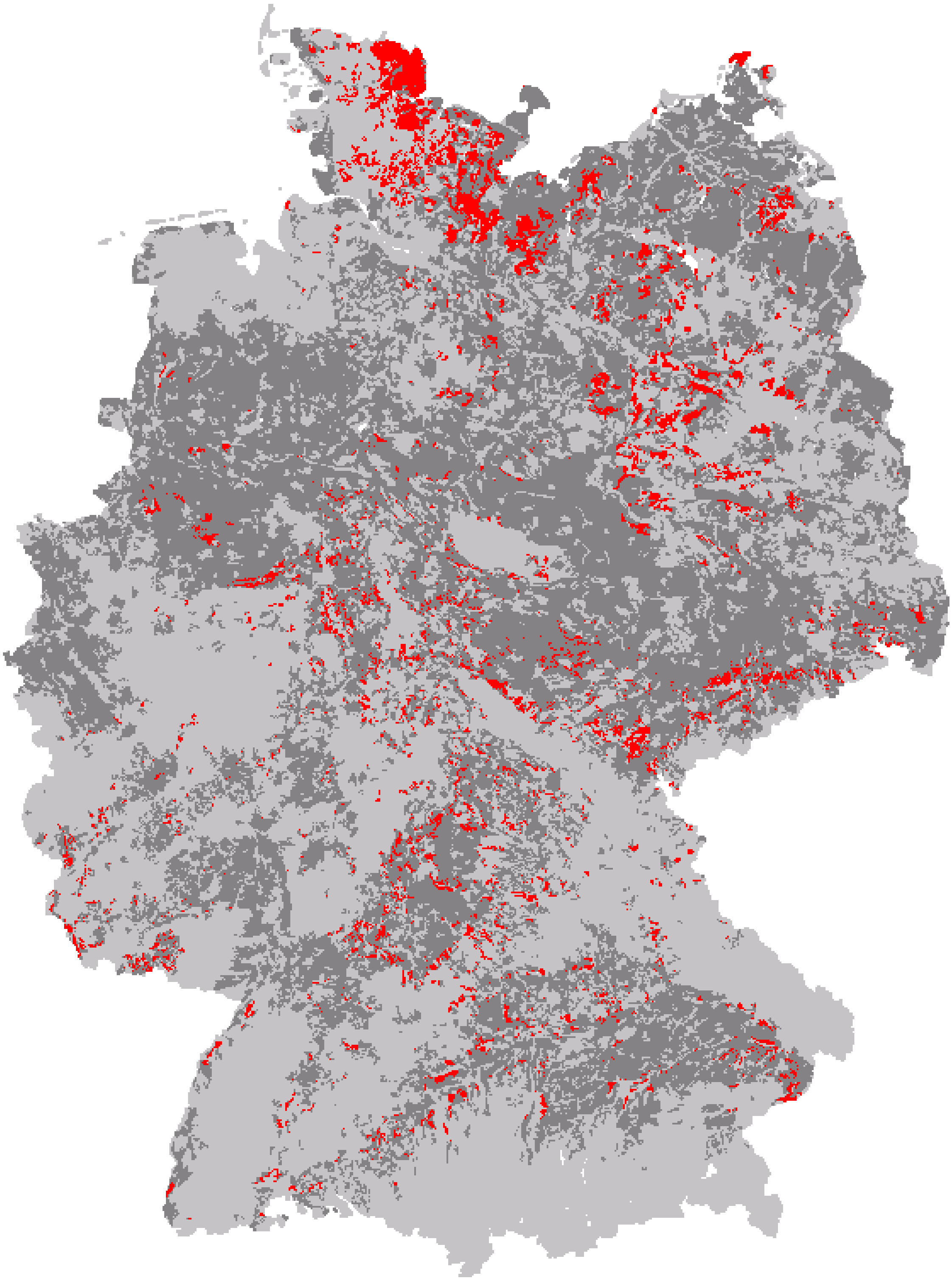

Figure 4-31: Distribution of the 80 ± 5th spatial percentile of the 80th temporal percentiles of annual concentrations (Maize, Kf_{oc} 15 L/kg- $DegT_{50}$ 20 d)

- **Kf_{oc} 15 L/kg- $DegT_{50}$ 80 d**

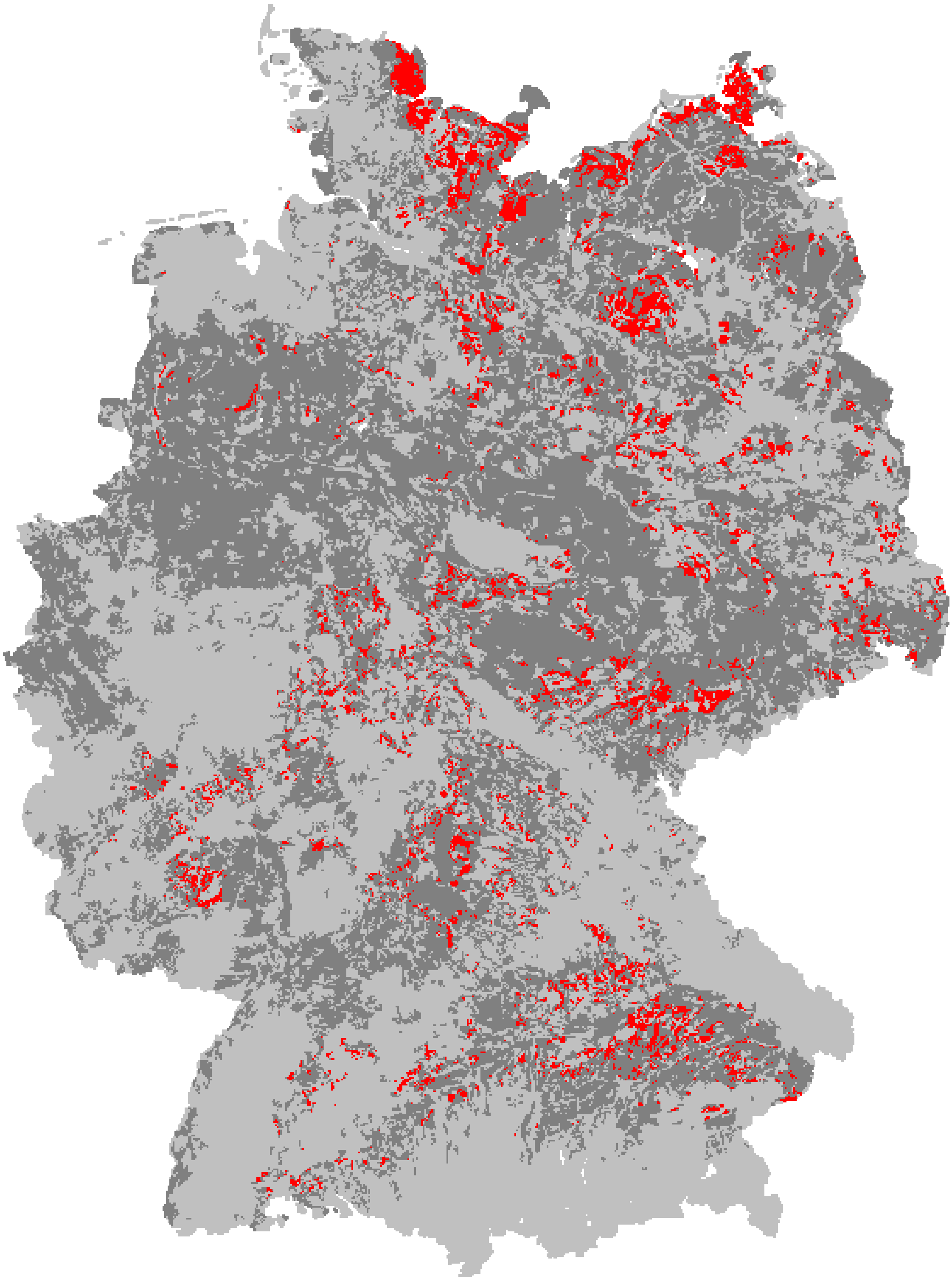

Figure 4-32: Distribution of the 80 ± 5th spatial percentile of the 80th temporal percentiles of annual concentrations (Maize, Kf_{oc} 15 L/kg- $DegT_{50}$ 80 d)

- **Kf_{oc} 30 L/kg- $DegT_{50}$ 10 d**

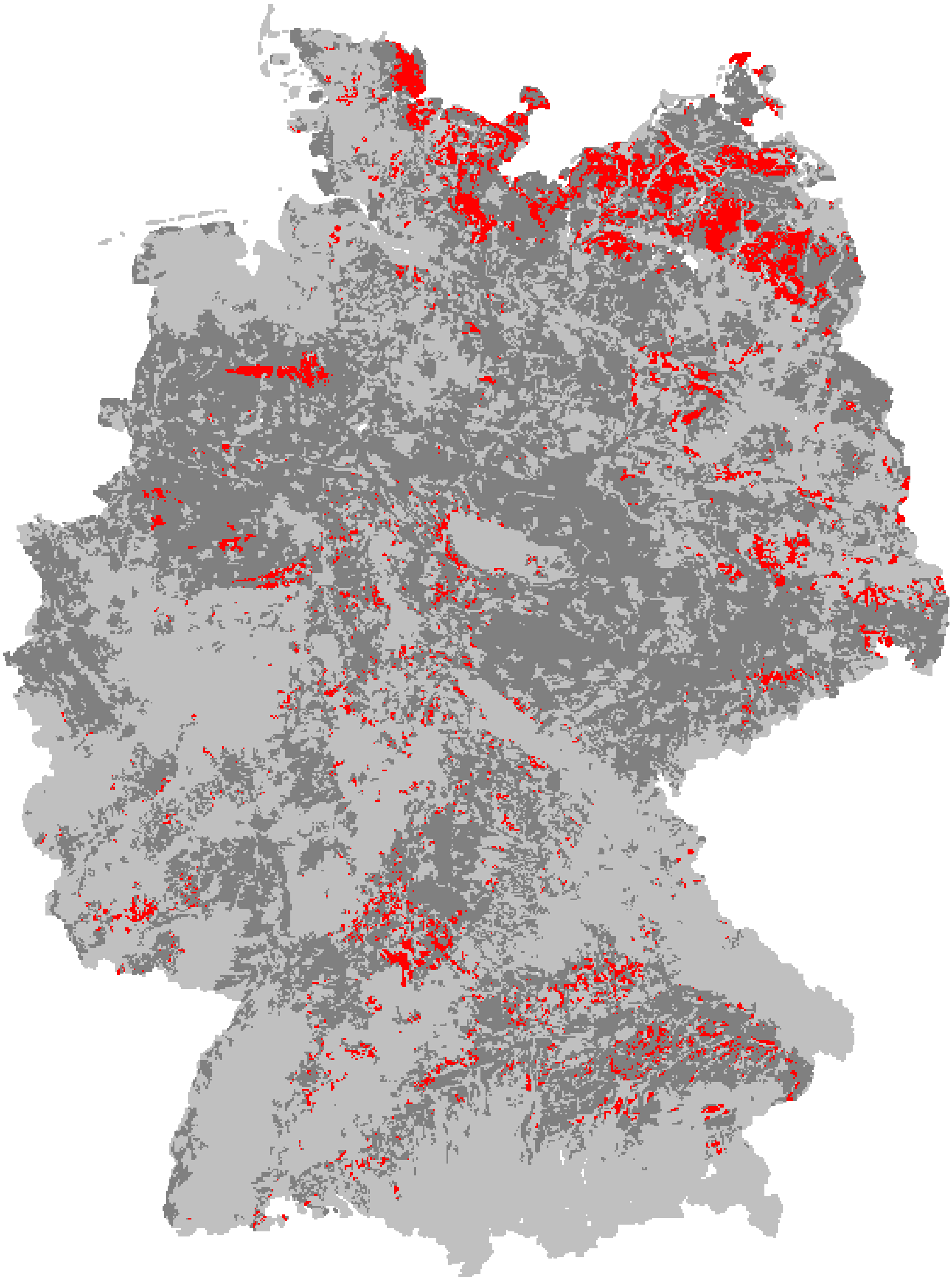

Figure 4-33: Distribution of the 80 ± 5th spatial percentile of the 80th temporal percentiles of annual concentrations (Maize, Kf_{oc} 30 L/kg- $DegT_{50}$ 10 d)

- **Kf_{oc} 60 L/kg- $DegT_{50}$ 20 d**

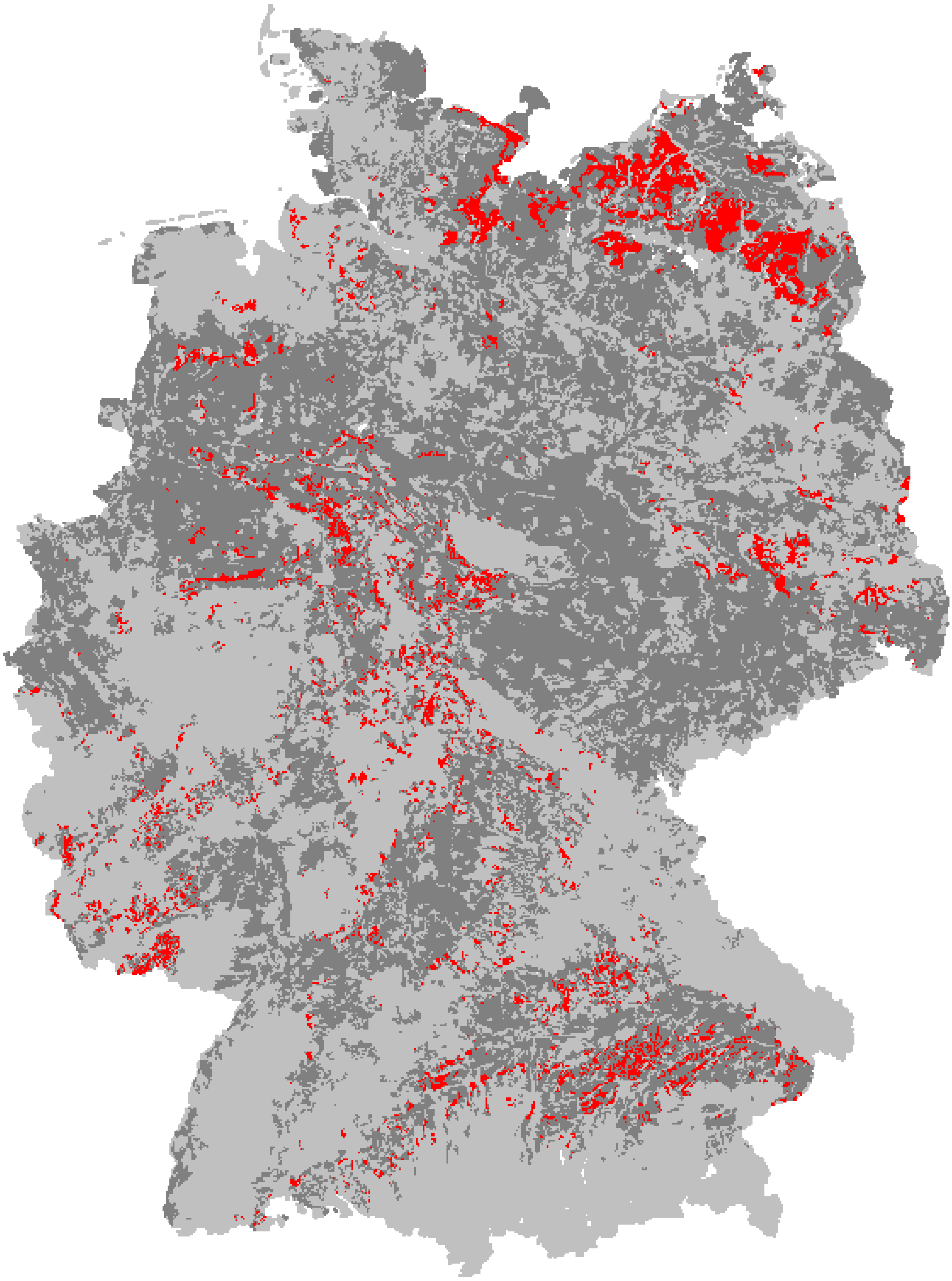

Figure 4-34: Distribution of the 80 ± 5^{th} spatial percentile of the 80^{th} temporal percentiles of annual concentrations (Maize, Kf_{oc} 60 L/kg- $DegT_{50}$ 20 d)

- **Kf_{oc} 60 L/kg- $DegT_{50}$ 80 d**

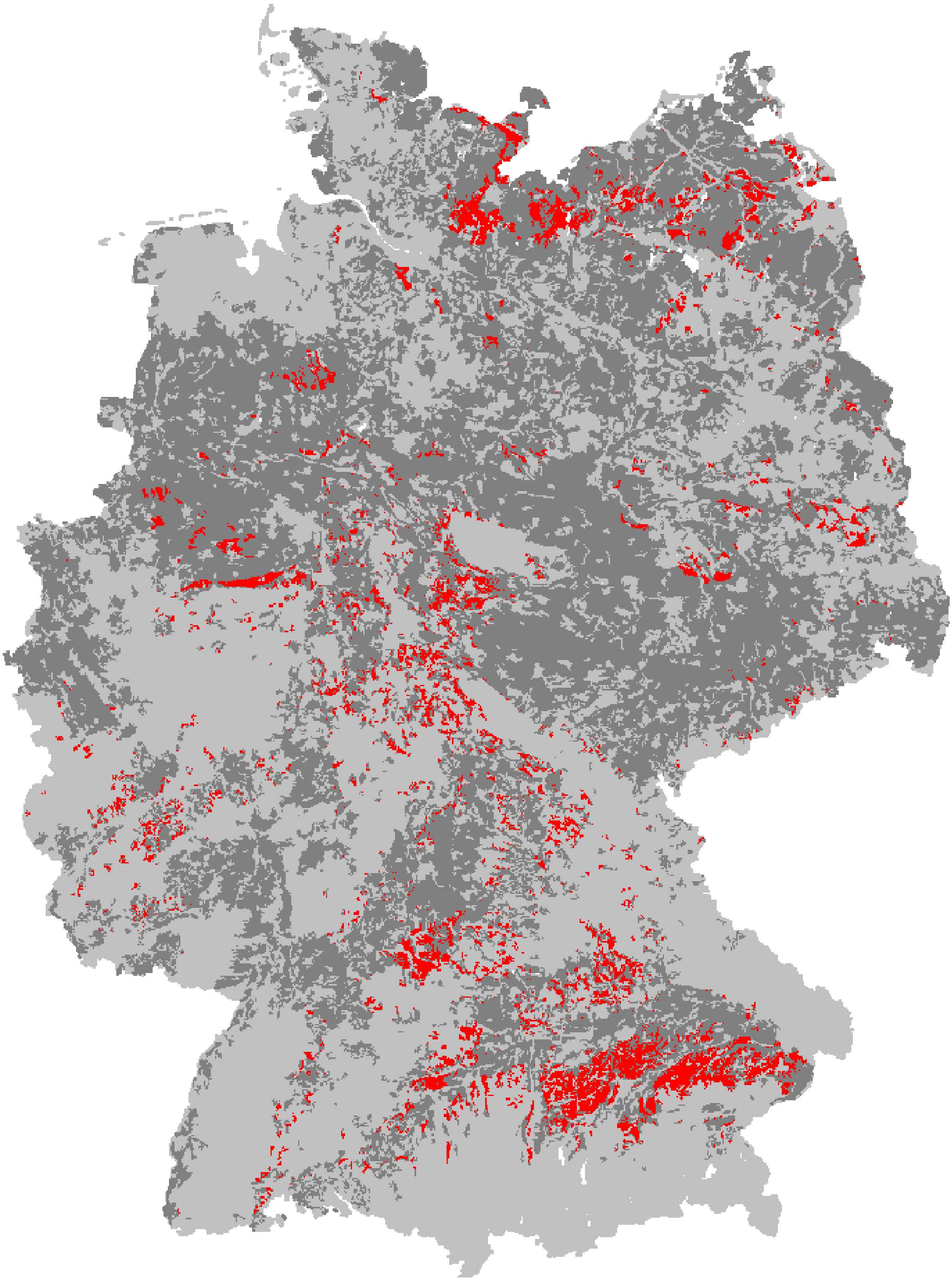

Figure 4-35: Distribution of the 80 ± 5th spatial percentile of the 80th temporal percentiles of annual concentrations (Maize, Kf_{oc} 60 L/kg- $DegT_{50}$ 80 d)

- **Kf_{oc} 120 L/kg- $DegT_{50}$ 40 d**

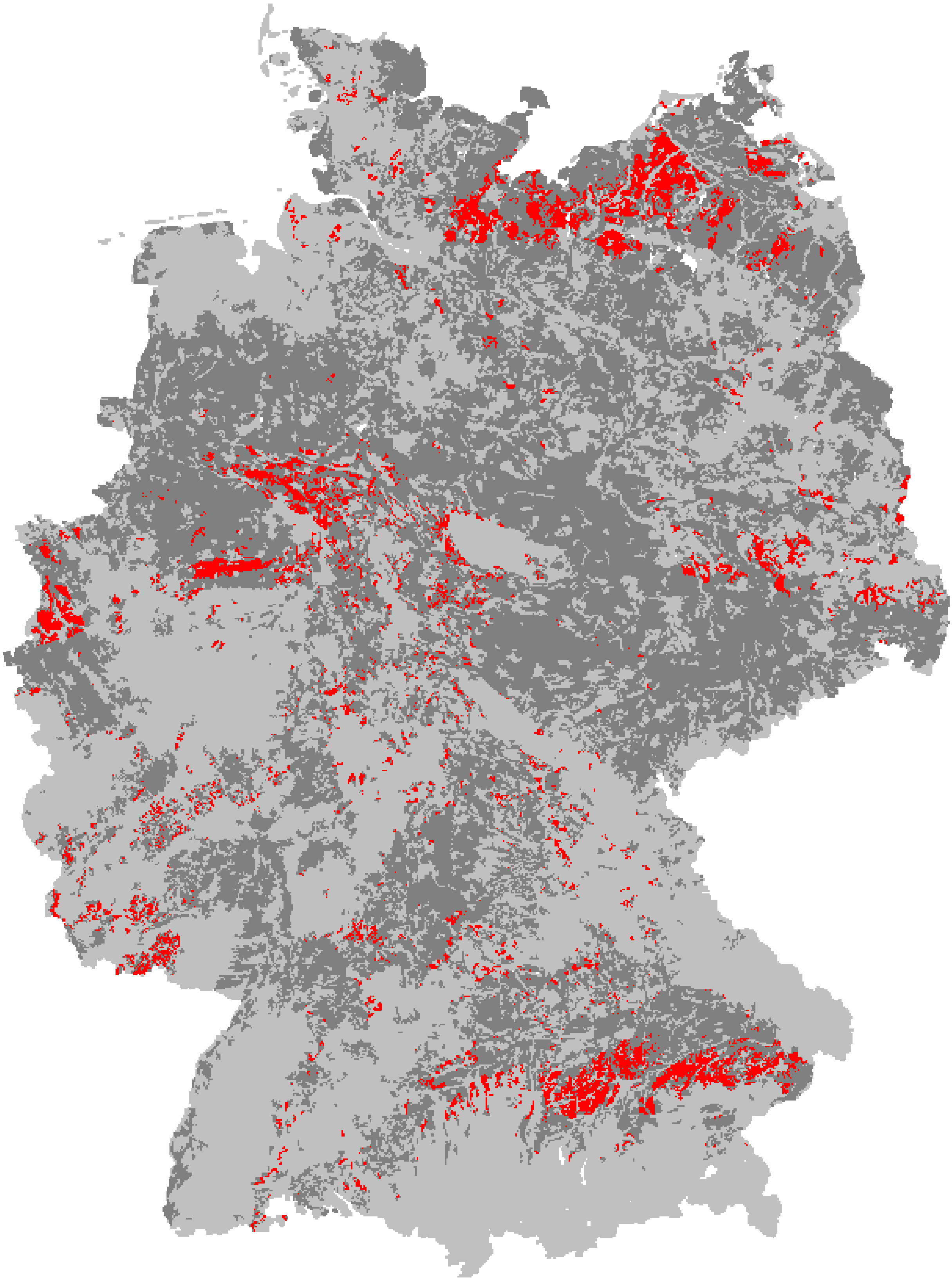

Figure 4-36: Distribution of the 80 ± 5^{th} spatial percentile of the 80^{th} temporal percentiles of annual concentrations (Maize, Kf_{oc} 120 L/kg- $DegT_{50}$ 40 d)

- **Kf_{oc} 240 L/kg- $DegT_{50}$ 80 d**

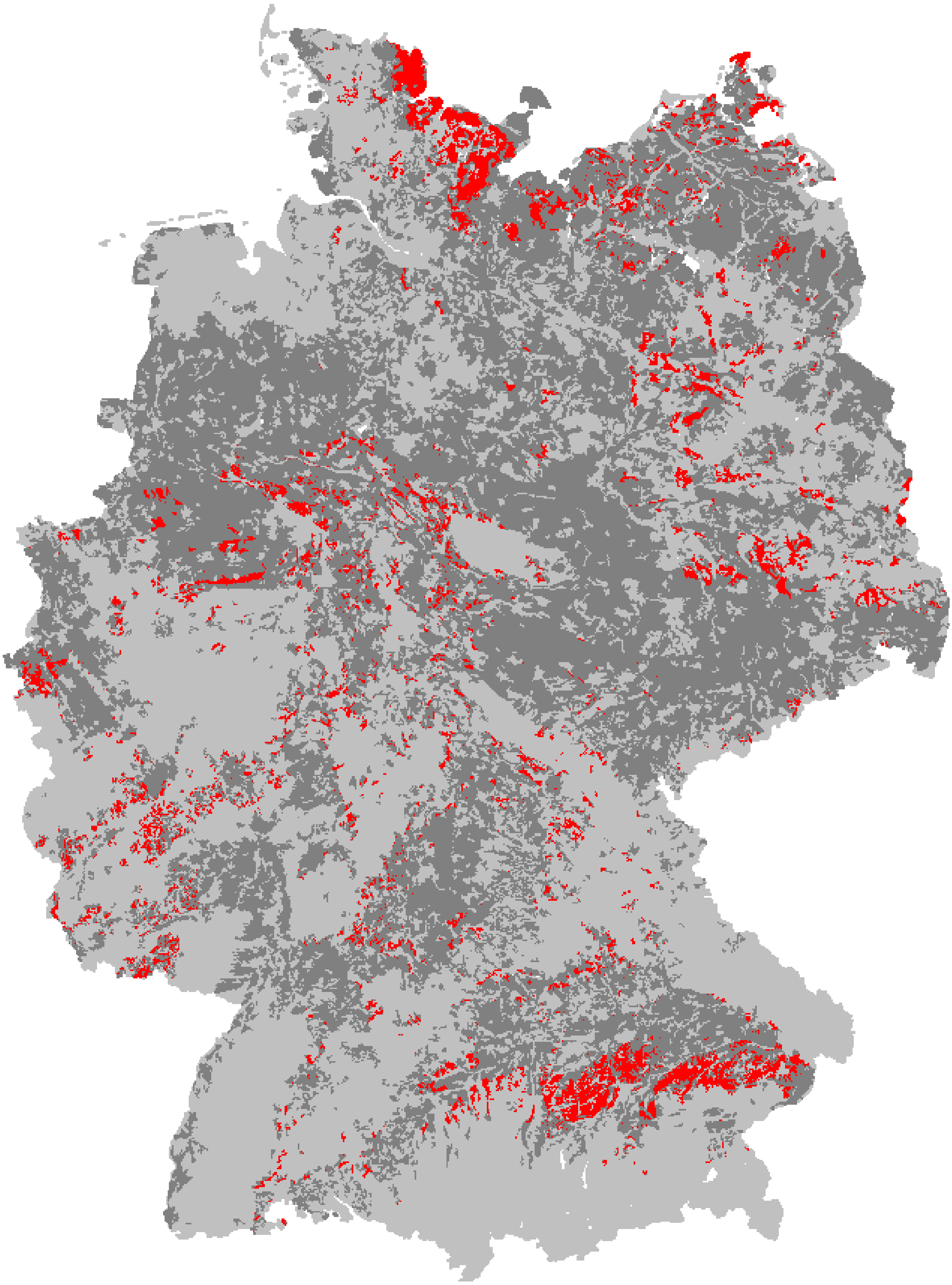

Figure 4-37: Distribution of the 80 ± 5th spatial percentile of the 80th temporal percentiles of annual concentrations (Maize, Kf_{oc} 240 L/kg- $DegT_{50}$ 80 d)

- **Kf_{oc} 480 L/kg- $DegT_{50}$ 160 d**

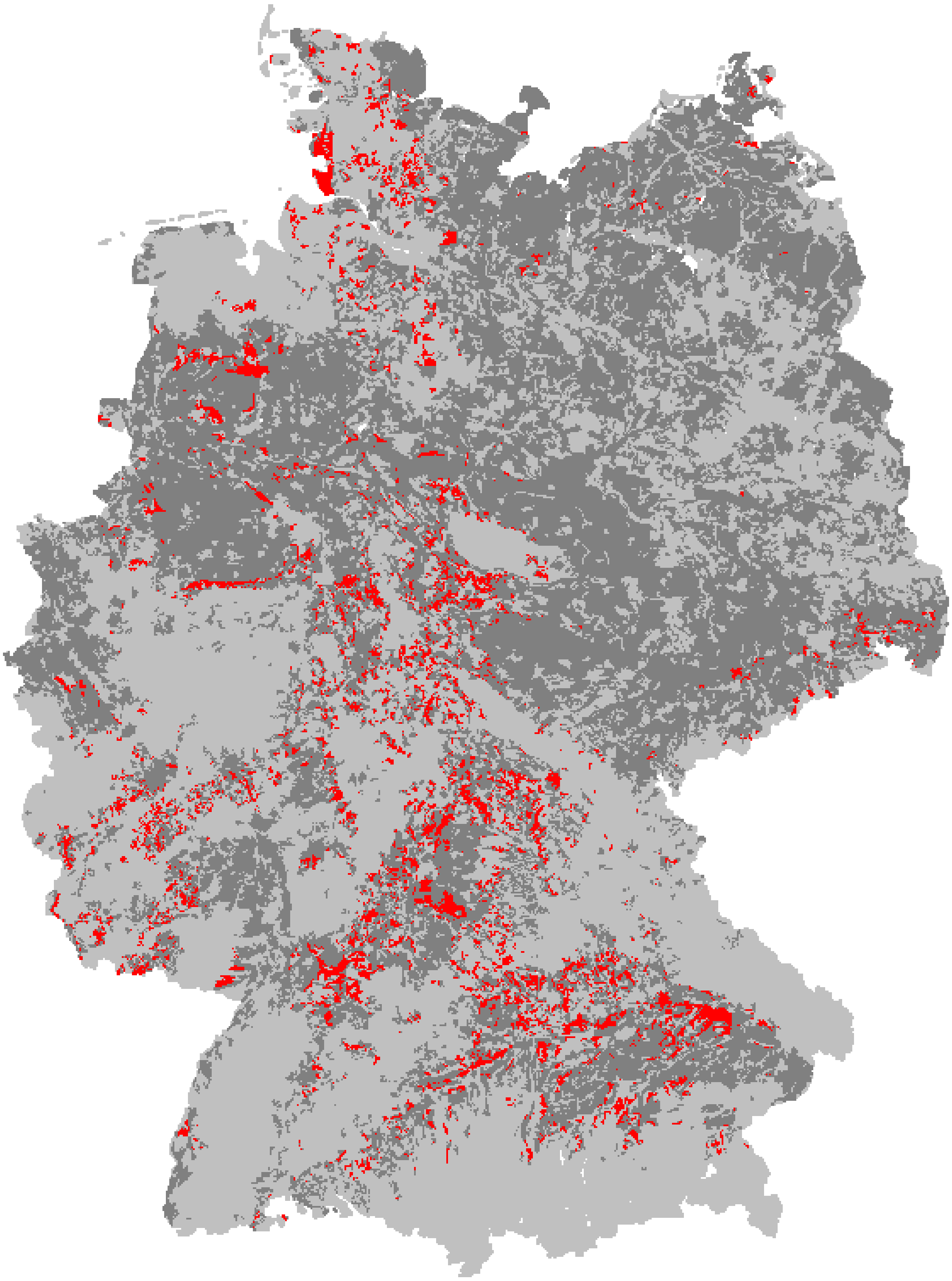

Figure 4-38: Distribution of the 80 ± 5th spatial percentile of the 80th temporal percentiles of annual concentrations (Maize, Kf_{oc} 480 L/kg- $DegT_{50}$ 160 d)