KWR 2019.098

Data-availability and potential locations to study the influence of N-deposition and climate on European coastal dune-ecosystems : Feasibility study

Date
21 October 2019

Client
DPWE-companies (Dunea, PWN, Waternet, Evides)

Status
This concise report is publicly available

Authors
Dr. C.J.S (Camiel) Aggenbach,
Dr. Y. Fuijta (Yuki)

Project number
402635-012

More information
T +31 30 606 9537 E
martin.van.der.schans@kwrwater.nl

Quality assurance
ir. M.L. (Martin) van der Schans

Project manager
ir. M.L. (Martin) van der Schans

Pagina
1/33

Table of content

1 Introduction 2

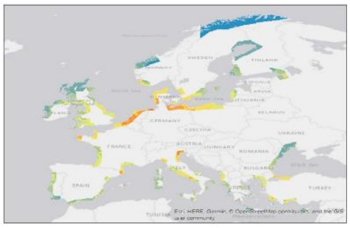
2 Climate and N deposition gradients of European coastal dunes 3
2.1 Distribution of coastal dunes in Europe 3
2.2 N deposition in Europe 4
2.3 Climate variation in European dunes 5
2.3.1 Environmental stratification 5
2.3.2 General temperature gradients 8
2.3.3 Drought stress in summer months 8

3 Assessment of locations for European-wide collaboration 10
3.1 Overview of potential partners and locations 10
3.2 Distribution of candidate sites in climate and N-deposition gradients 11
3.3 Calcareous versus decalcified dune grasslands 12
3.4 Salt concentration of seawater 16
3.5 Data availability 16

4 Methods to assess N-deposition with bio-indicators 20

5 Conclusions 22

6 References 23
I Calculation of Penman-Monteith potential evapotranspiration 24
II Criteria for site selection 26
III Reliability of weather and N deposition data of dunes derived from global dataset 29



1 Introduction

In 2019 the DPWE water companies (Dunea, PWN, Waternet, Evides) and KWR started a project on the "Consequences of climate change and atmospheric deposition on nature targets and groundwater recharge of dry dunes". The study will analyse how dune vegetation responds to both climate change and N-deposition. In order to trace the effects, field data will be used of several coastal dune areas in Europe, representing major gradients in climate and N-deposition. The geographical focus is the coastal dunes in NW-Europe (UK, France, Flanders, Netherlands, Germany, Denmark Poland, and Lithuania.

The first year of this study was aimed at identification of locations with different (high/ low) levels of N-deposition and temperature. Also, data availability was assessed as well as the willingness of European partner organisations to collaborate in the study. This report reflects the results of the first year of the study and is intended to support a go/ no go decision whether to continue with the remaining part of the study.

This report is organised as follows. First, an overview is given of the existing climate and N-deposition gradients in Europe (chapter 2). Then we zoom into the potential locations and discuss whether they harbour enough directly available data and cover the range of climate, N-deposition and calcareous levels (chapter 3). Next, we present a method to fill gaps in data about N-deposition (chapter 4). Finally, we draw conclusions on the feasibility of a next project phase.

2 Climate and N deposition gradients of European coastal dunes

2.1 Distribution of coastal dunes in Europe

The potential locations of coastal dunes in Europe are given by Doody 2001. Based on the map, a shape file of polygons of coastal dune area was created.

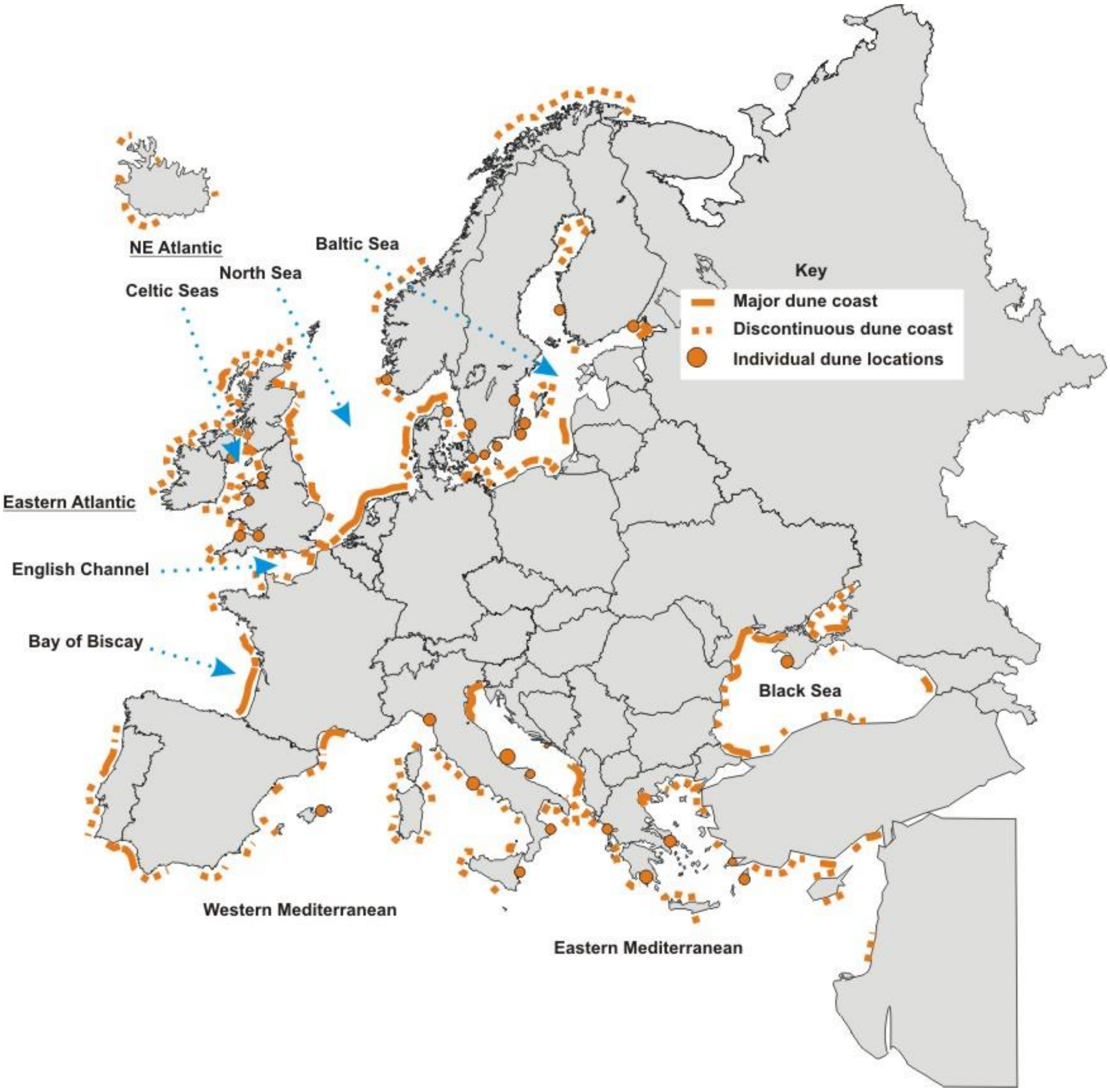


Figure 1. Potential location of coastal Dunes (Doody 2001)

2.2 N deposition in Europe

EMEP MSC-W modelled air concentrations and depositions. See EMEP Status Report for more details. Resolution of the data is 0.1˚ x 0.1˚ (long/lat). For this resolution, yearly data of 2015 and 2013 is available at EMEP website (https://www.emep.int/mscw/mscw_ydata.html). (For 50 km grids, data is available for more years.) Model results are stored as netCDF files. Available data includes dry reduced N deposition, dry oxidized N deposition, wet reduced N deposition, and dry reduced N deposition, all in unit of mgN/m2. For dry N deposition, deposition levels are also shown for different vegetation types (e.g. conifer forests, deciduous forests, seminatural grasslands).

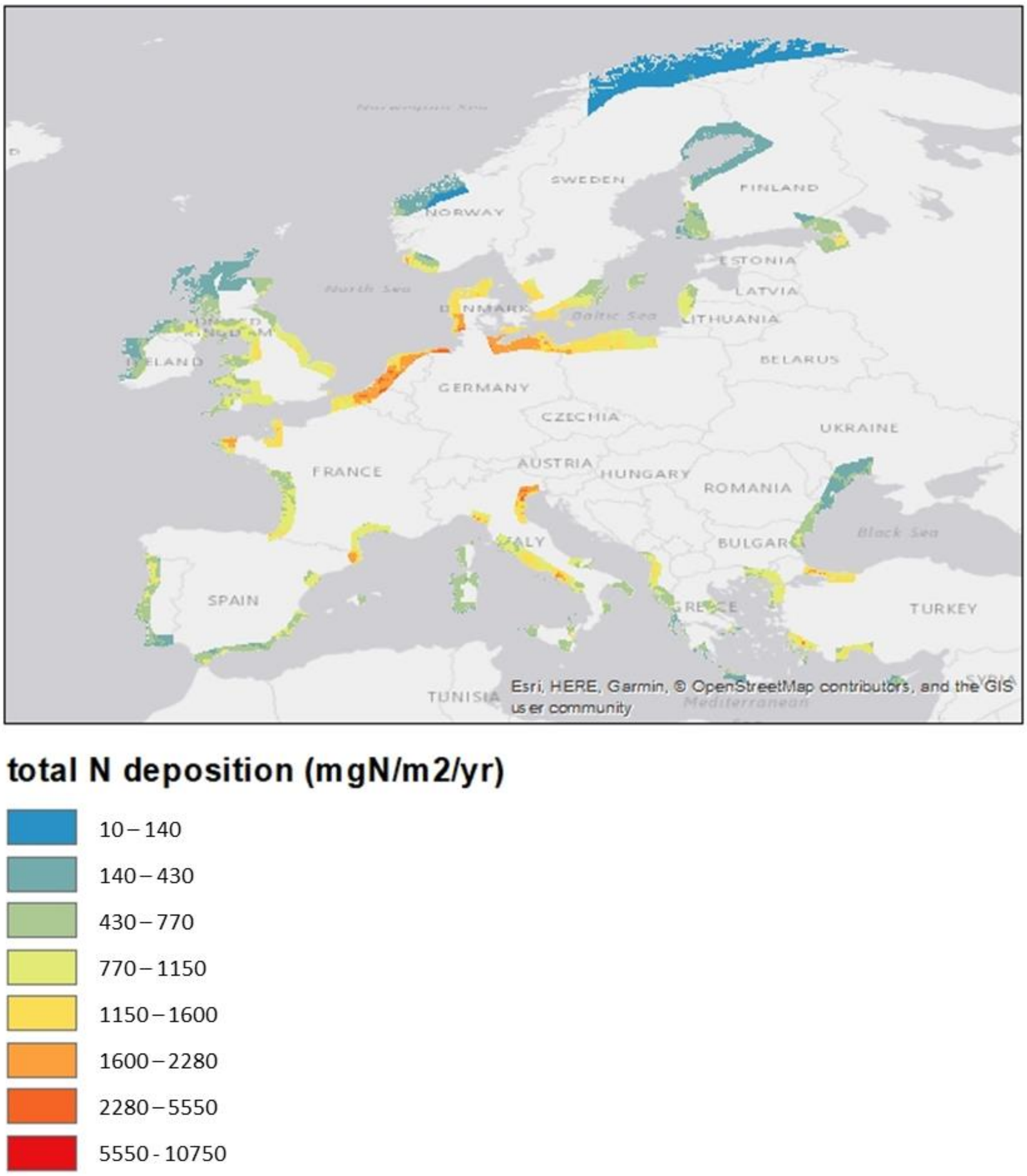


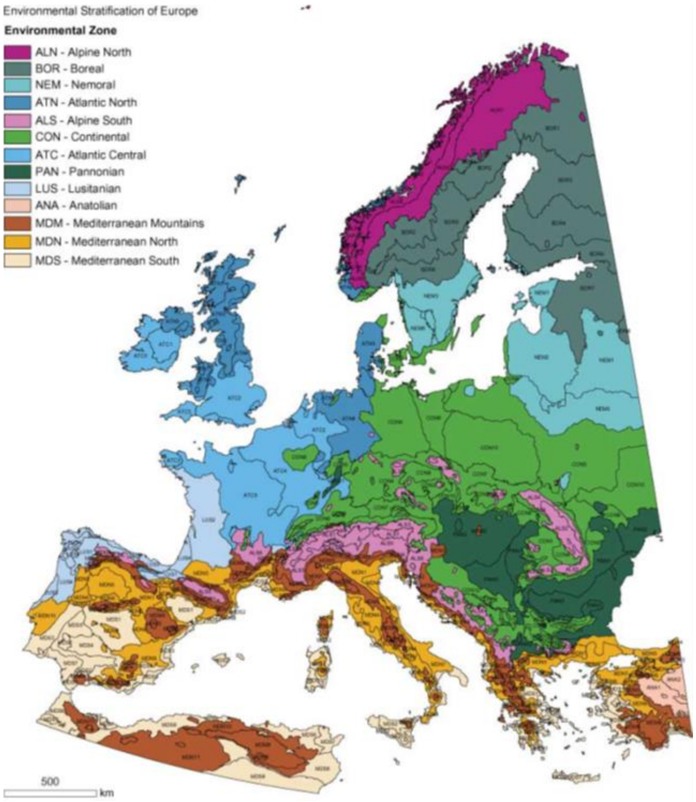
Figure 2.N-deposition (source: EMEP)

2.3 Climate variation in European dunes

Climate variables are multifold and it is difficult to describe variations in climate with a single metrics. Below is an attempt to show several metrics to distinguish different climate patterns across Europe.

2.3.1 Environmental stratification

Metzger et al. (2005) classified every 1 km^2 grids of Europe into 84 strata as well as into aggregated 13 environmental zones. The classification is based on PCA with 20 variables (altitude, latitude, slope, oceanicy, temperature, precipitation, sunshine) and therefore reflect the major axis of environmental/climatic variations. This climatic zonation corresponds generally with the pattern of biographical regions in Europe with is uses for N2000 (www.eea.europe.eu, 2016) (Figure 3). A relevant difference for coastal dunes is a north to south division of the Altlantic biogeographical region by the environmental zones Atlantic north, Atlantic central and Lusitanian. In the analyses of Metzger et al. (2005) the boundary between Atlantic central and Lusitanian correspondent with the mayor division of a north and south climatic region in Europe. Because the study will include SW-France a part of the southern region is included in this pre-study. The distinction between the environmental zones Continantal and Nemoral corresponds with those of the biogeographical regions Continental and Boreal.



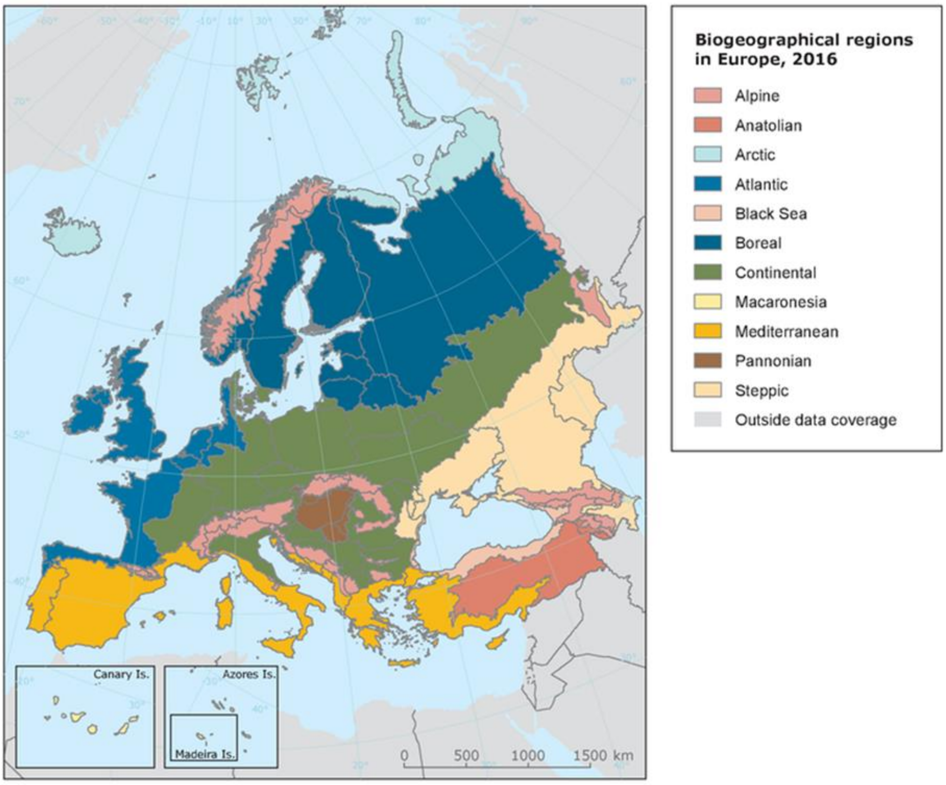


Figure 3: Environmental zones of Meltzger et al (2005) (top) and the biogeographical regions in Europe (www.eea.europe.eu, 2016; bottom).

The coastal dunes are spread across most environmental zones (except ‘ALS’ and ‘ANA’), but the majority locates in ‘ATN’ (Atlantic North), ‘ATS’ (Atlantic south), ‘MDN’ (Mediterranean North), and ‘MDS’ (Mediterranean South). For the region of interest of the DPWE study (UK, Ireland, France, Belgium, Netherlands, Germany, Poland, and Lithuania) the zones ‘ATN’ (Atlantic North), ‘ATS’ (Atlantic Central, ‘LUS’ (Lusitanian), 'CON' (Continental) are completely or for major part included.

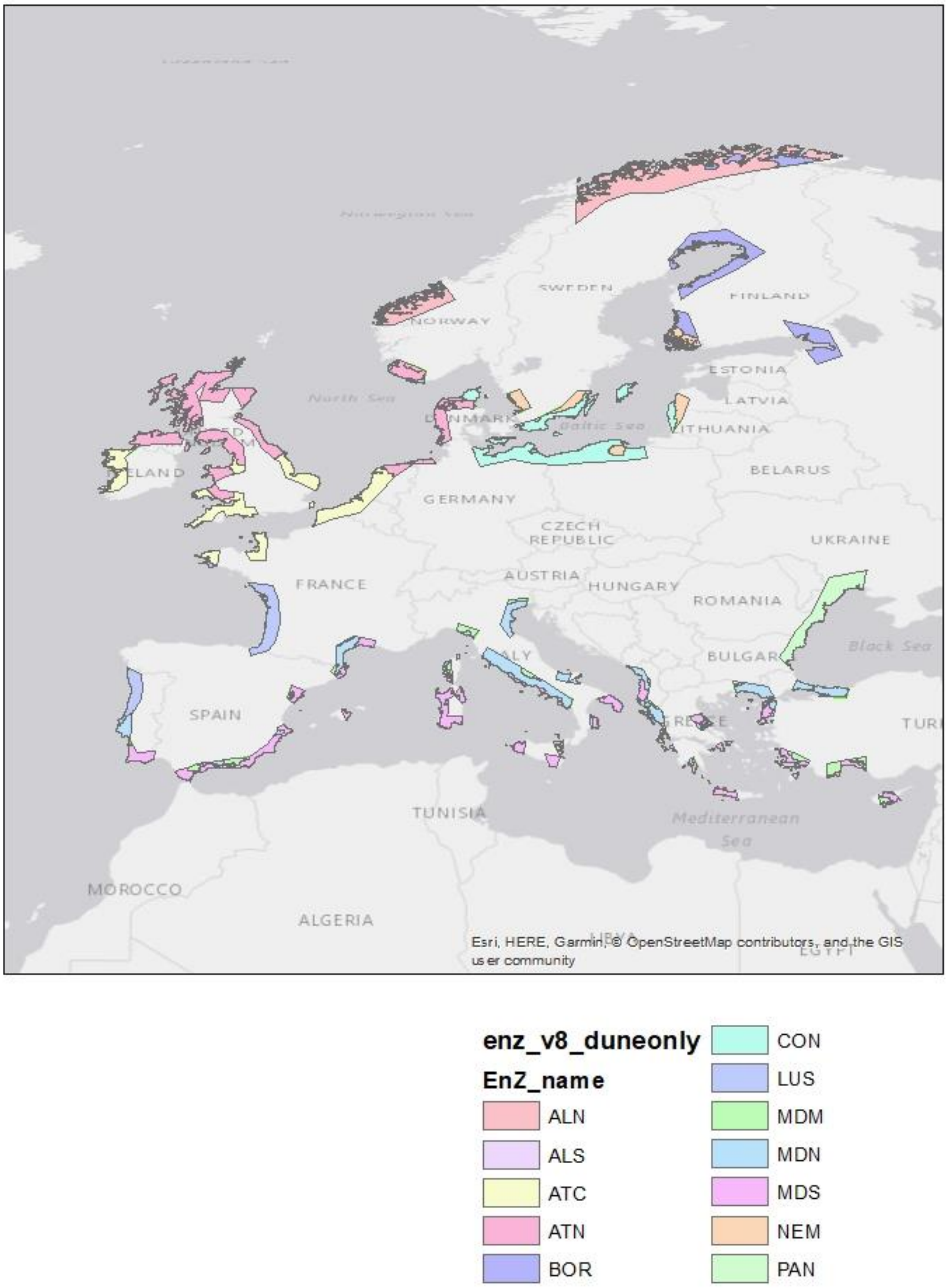


Figure 4. Environmental zones of coastal dunes (Metzger et al. 2005)

2.3.2 General temperature gradients

In the PCA analysis of Metzger et al. (2005), the first PCA axis explains 88% of total variations, and represents the temperature gradient across Europe. It is strongly correlated with the MARS annual temperature sum the MARS growing season (Metzger et al. 2005). Thus, this axis values can be used as a proxy of the temperature of the area.

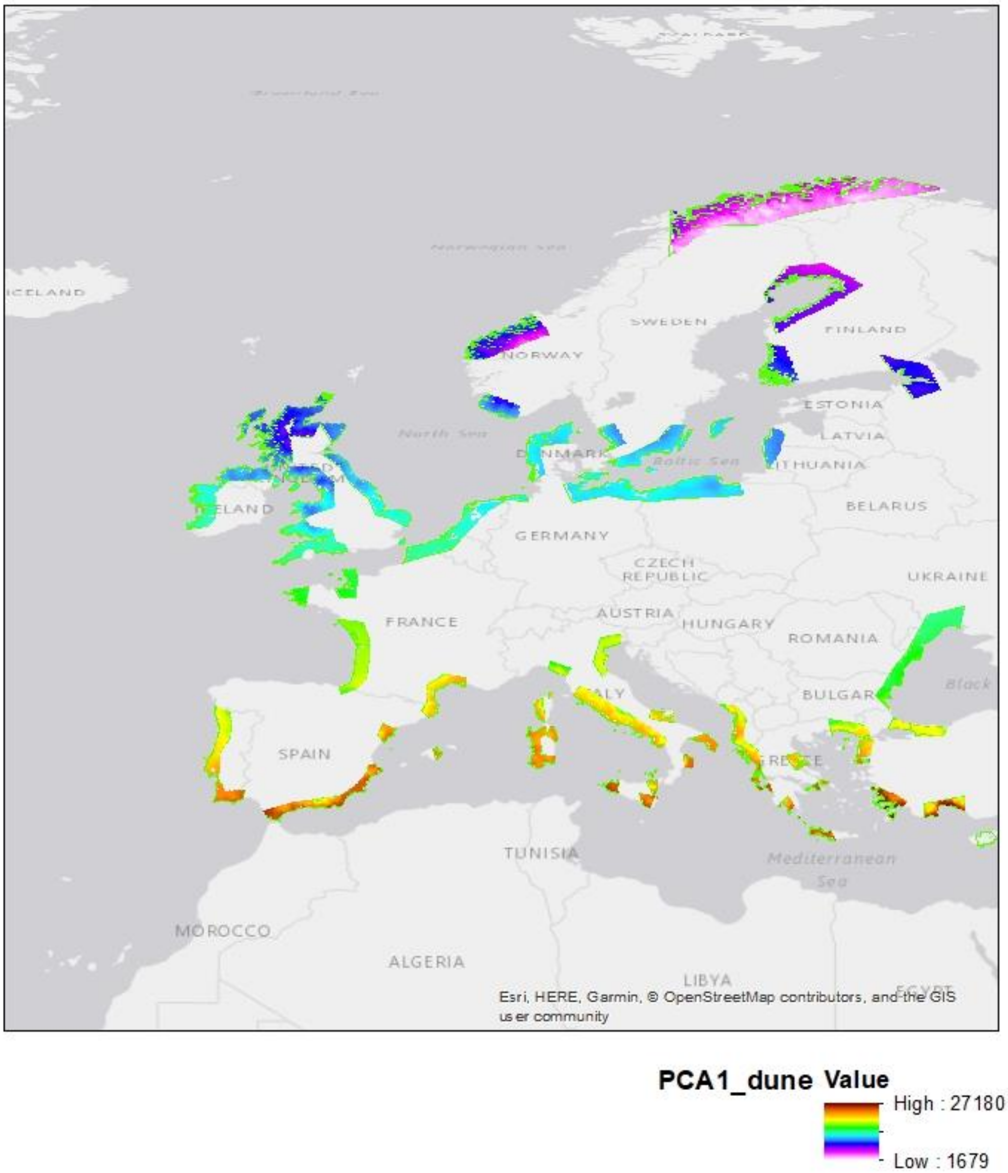


Figure 5. PCA 1 values of Metzger et al. (2005), which represents temperature gradients.

2.3.3 Drought stress in summer months

Monthly climate data was retrieved from ERA5 (https://www.ecmwf.int/en/forecasts/datasets/archive-datasets/reanalysis-datasets/era5), via KNMI website (https://climexp.knmi.nl/selectfield_rea.cgi?id=someone@somewhere), on 19 February 2019. The resolution is 0.28° steps, and monthly data is available for Jan1979 to Dec2018. Data were retrieved only for the following range: 30 – 75 N, -15 – 40E.

For each grid, potential evapotranspiration of Penman-Monteith (PET) was calculated following the FAO method, using the following data: Near-Surface Air Temperature, Daily Maximum Near-Surface Air Temperature, Daily Minimum Near-Surface Air Temperature, Precipitation, Near Surface Wind Speed, Net Surface Solar Radiation. PET was calculated only for the period of January 2008 – September 2018, as the dataset was only complete for that period. See Appendix I for details of the calculation.

As a proxy of drought stress, the difference between precipitation and PET (= precipitation surplus) was calculated for summer months (June – August) from 2008 to 2018 (N=33). For each grid, 25th percentile of that values are computed as a proxy for drought level. The 25th percentile was selected as a proxy for strong influence of dry summers, based on the provisory assumption that the precipitation deficit of summers have a stronger effect on vegetation than the average precipitation deficit.

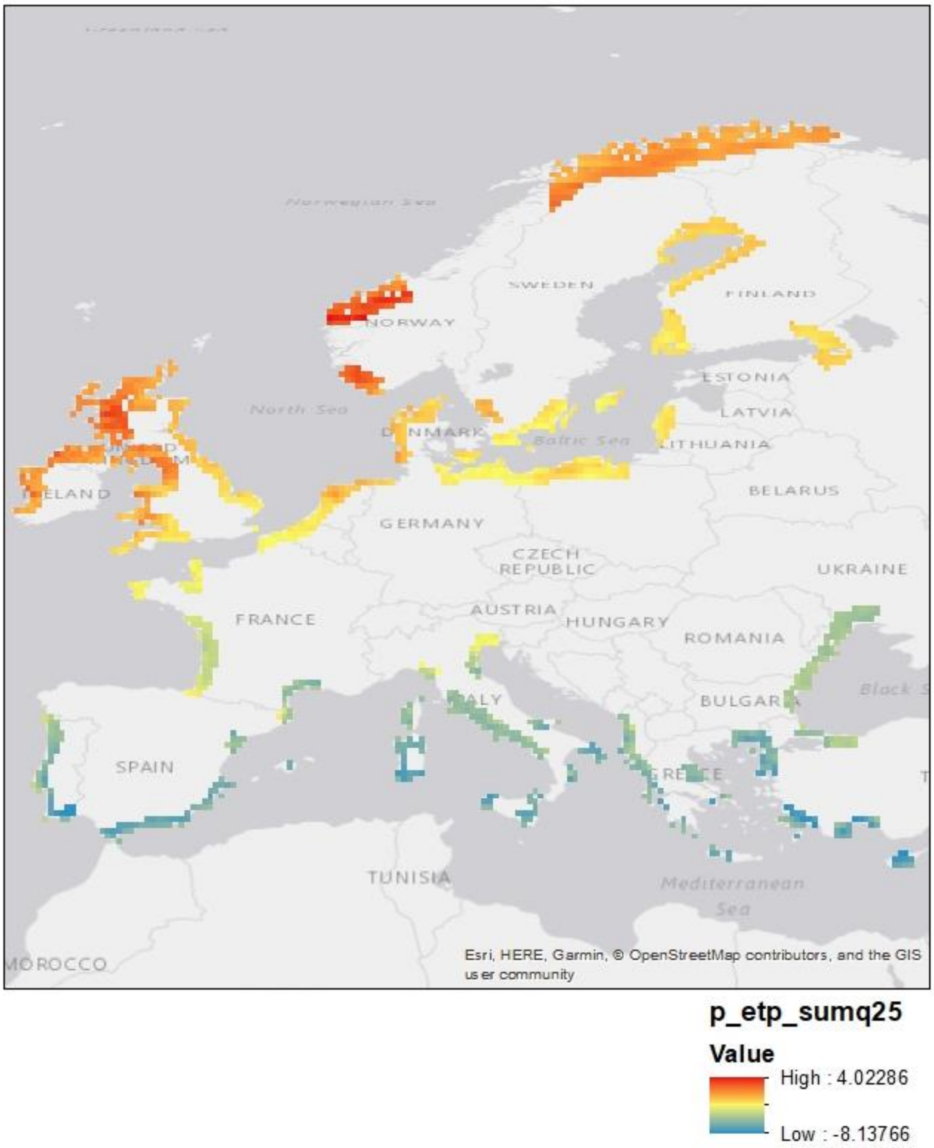


Figure 6. Precipitation minus potential evapotranspiration (mm/day) of summer month (June, July, August). 25th percentiles of the year 2008 – 2018 are shown. Blue means that the area is under high drought stress.

3 Assessment of locations for European-wide collaboration

3.1 Overview of potential partners and locations

Candidate collaborators were sought for according to the criteria of site conditions (Appendix II). We asked the candidate collaborators about data availability (see Appendix II for the list of needed data). Table 1 illustrate summary of the candidate dataset. See Excel file (DPWE2019_metadata.xlsx) for more details. Most of the intended partners are also interested in applying for international funding. Derek Jackson is also interested to link research to effects of climate change and N deposition on aeolian activity.

Table 1. Overview of candidate dataset

code	Researcher	Institute	country	location of dune ecosystems	Calcareous levels	Number/extent of sites
Luchterduinen	Camiel aggenbach	KWR	Netherlands	Luchterduinen (Dutch coastal dune)	calcareous and decalcified	
Meijendel	Camiel aggenbach	KWR	Netherlands	Meijendel (Dutch coastal dune)	calcareous and decalcified	
Midden-Oostduinen	Camiel aggenbach	KWR	Netherlands	Middel- en Oostduinen (Dutch coastal dune)	calcareous and decalcified	
BTO_Nmit_LD	Camiel aggenbach	KWR	Netherlands	Luchterduinen (Dutch coastal dune)	calcareous and decalcified	5 control, 7 sand-deposited, 6 on slope (soil data limited)
Netherlands Waddeneilanden	Annemiek Kooijman	U.v. Amsterdam	Netherlands	Several islands	Decalcified	@no reaction yet@
BTO_Nmit_NB	Laurence Jones	CEH	UK	Newborough Warren (coastal dune in North Wales)	calcareous	6 control, 9 sand-deposited, 6 on slope (soil data limited)
UK2	Laurence Jones	CEH	UK	coastal dunes in Wales?	calcareous and decalcified	~3 acidic, ~7 calcareous sites + extra ~25 sites
N-Ireland	Derek Jackson [1]	Centre for Coastal & Marine Research	N-Ireland	Coastal dune areas in N-Ireland, also contacts in Ireland	Calcarerous?	Some soildata in Umbra Nature reserve, no vegetation relevees
N-Ireland	Dario Fornara	Agri Food and Biosceiences Institute				
Flemish	Sam Provoost	INBO	Belgium	Flemish coastal dune	calcareous and decalcified	86 sites (a part of 400 PQ's)
NW_Germany	Maike Isermann	Univ. Bremen	Germany	NW coast of Germany (Niedersachsen)		a part of 18,000 vegetation records from the coasts of Germany. Some PQ of dunes.
Spiekeroog	Maike Isermann	Univ. Bremen	Germany	Spiekeroog (Wadden sea)	calcite-poor	chronosequence data of acidic dunes.

[1] worked on climate change and eaolian activity

code	Researcher	Institute	country	location of dune ecosystems	Calcareous levels	Number/extent of sites
NE_Germany	Maike Isermann	Univ. Bremen	Germany	NE coast of Germany (between Rostock and Polish border)	calcite-poor	ca. 1000 vegetation records + soil data
N_France	Christophe Blondel	Conservatoire botanique national de Bailleul	France	coastal dune in North France	calcareous and decalcified	A large vegetation dataset of from Seine estuary to Belgian border. This include PQs (~20 years) in dune grassland and dune slack vegetation between Dunkirk and De Panne.
Lithuania	Ramunas Povilanskas	Klaipeda University, Nature Research Centre	Lithuania	Lithuanian side of Curonian Spit (sand dune on Baltic sea coast)	calcite-poor	Sites to be sorted out, additional site at meteostation on Curonian Spit
SW_France	Loïc Gouguet	Office National des Forets	France	SW France (Aquitaine)	Most calcite rich, partly calcite poor	200 transects with relevees –in collaboration U. Bordeaux/ Office National des Forest
SW_France	Didier Alard	University of Bordeaux, Community Ecology Lab				
Poland, Lithuania, Latvia, Estonia, Denmark, Poland[2]	Eva Remke	B-WARE		S-Baltic	calcite-poor	2 Gemany, 3 Latvia, 3 Estonia, 3 Lithuania, 4 Denmark, 1 Poland
NE-Germany Hiddensee	Eva Remke	B-WARE	Germany	Hiddensee (island NE Germany)	calcite-poor	
Lithuania	Ramunas Povilanskas	EUCC Baltic Office	Lithuania -> contact in Russian part Curonian Split	Curonian Split, other sites	calcite-poor	

3.2 Distribution of candidate sites in climate and N-deposition gradients

The locations of the candidate sites are shown in the map (Figure 7). Note that Veluwe and De Bilt, were added just for reference purpose.
The candidate locations covers a wide range of climatic conditions (Figure 9), ranging from high-drought regions (SW France) to relatively moist regions (e.g. coastal NW Germany) and N-Ireland as an extreme most region. Note that the climate data were rather unreliable due to their high spatial resolution (0.28), while weather data of coastal dunes are influenced by data of sea (See Appendix III), and coastal dunes can be positioned in steep climatic gradient. Atmospheric N deposition ranges between ca. 0.6 – 30 kgN/ha/year in 2015.
The biplot of annual precipitation and average temperature (Figure 4) shows a big cluster of sites in the northern part of the study area in the precipitation range of 600 to 1100 mm/y and temperature range of 6 to 11°C. The coast form N-France to the Netherlands spans a precipitation gradient with more or less the same temperature. Sites in NW-Germany are slightly cooler at relatively high precipitation, while the Baltic sites tend to cooler and drier climate. N-Ireland is the wet extreme at moderate temperature. The site in SW-France have the warmest climate, and span a mayor part of the precipitation gradient. In the high precipitation range there are only a few sites filling in the temperature gradient possibly sites in UK can be added here to fill this gap.

[2] Are in paper of Eva Remke, we choose not to include?

In the biplot of precipitation surplus in summer and average temperature (Figure 9) SW-France gets separated in the low range of precipitation surplus from the other regions. Ireland stays then in the wettest extreme with 0 Precipitation surplus. The biplots also indicates a weak negative correlation between precipitation surplus in summer and average temperature.
Looking at the distribution on the biplot of drought gradient vs N deposition gradient (Figure 10), we miss candidate plots which have high N deposition level AND strong drought stress (i.e. top-left corner). This gap cannot be filled in based on the climate and N deposition data we used. However the EMEP data may be too coarse to show small N-deposition hotspots. In the southern part of the Aquitaine (SW-France) N-deposition is relatively high because of industry in the San Sebastian region, as is indicated by the recent national model of France (personal communication Didier Alard). When using output of national N-deposition models the distribution along the N-gradient can be different. Moreover, when using the N-content of mosses as a proxy for atmospheric N-load, the picture could also change. The critical load for calcareous dune grasslands (1500 mgN/m2/y) and for acidic dune grasslands (10 mgN/m2/y; Van Dobben et al. 2012) are in the N-deposition gradient of the biplot.
In addition, there is large variation in composition of N deposition between regions (Figure 11), with Dutch, Baltic and N-Irish sites having relatively high proportion of oxidized N deposition.

3.3 Calcareous versus decalcified dune grasslands

For the study distinction between calcareous versus decalcified (acidic) dune grasslands is relevant because acidic dune grasslands are more sensitive to N-deposition than calcareous. The dune water companies therefore want acidic dune grasslands to be included in the study. However, not in every region both types are present due to its geology. E.g. in the Baltic region only acidic dune grasslands occur and at most of the Wadden islands acidic dune grasslands prevail. In contrast, at the SW-France coast and in Wales calcareous dune grasslands are pre-dominant. N-France, Flanders and the Netherlands have a mix of both types.
Implications: it is not possible to cover the climatic and N-deposition gradient of the candidate sites for each type completely/ balanced. Because of a lack of calcareous dune grasslands in the Baltic, the low temperature, low precipitation, moderate drought stress and low N-deposition will not be covered for this type. For acidic dune grasslands high temperature, high drought stress will possibly be covered poorly.

Figure 7. Distribution of candidate plots. De Bilt and Veluwe were added for reference purpose.

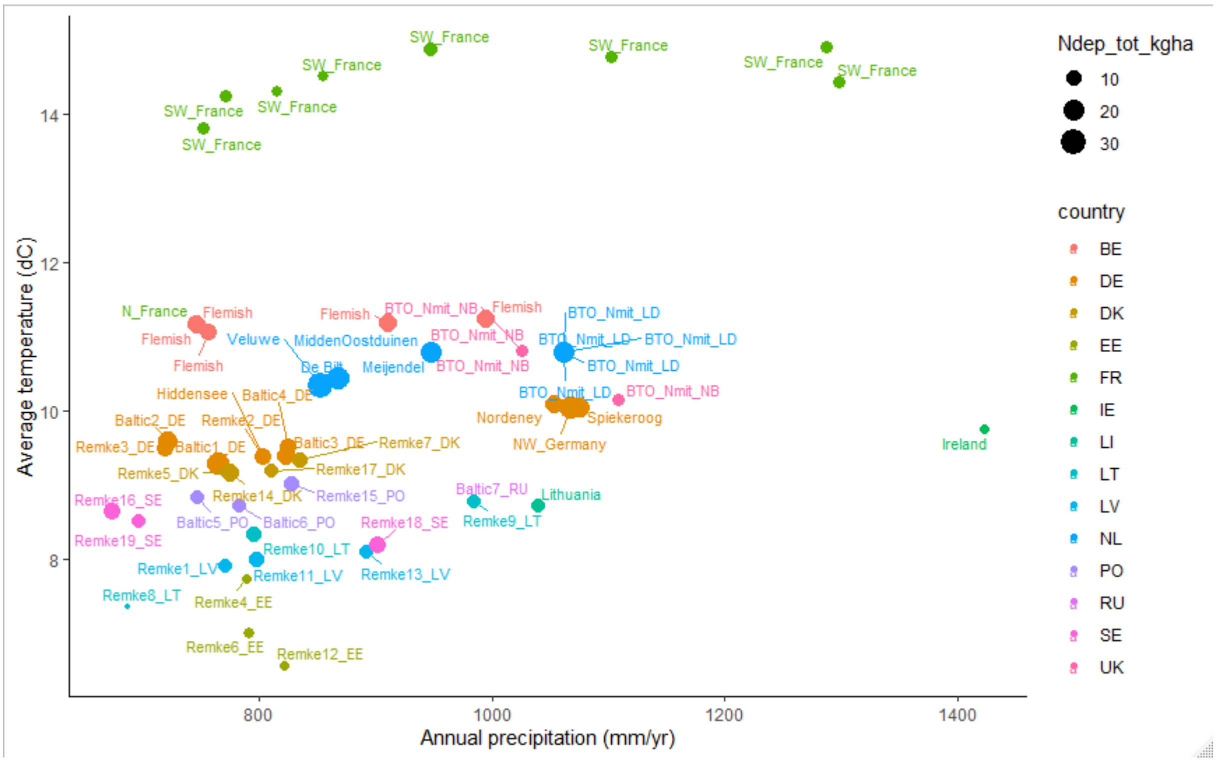


Figure 8. Annual precipitation (average over 2008-2018) and annual average air temperature (average over 2008-2018) for candidate dune areas. Size of the circles depict annual total N deposition in 2015 (kg/ha/year, modelled for 0.1° grids). De Bilt and Veluwe were added for reference purpose.

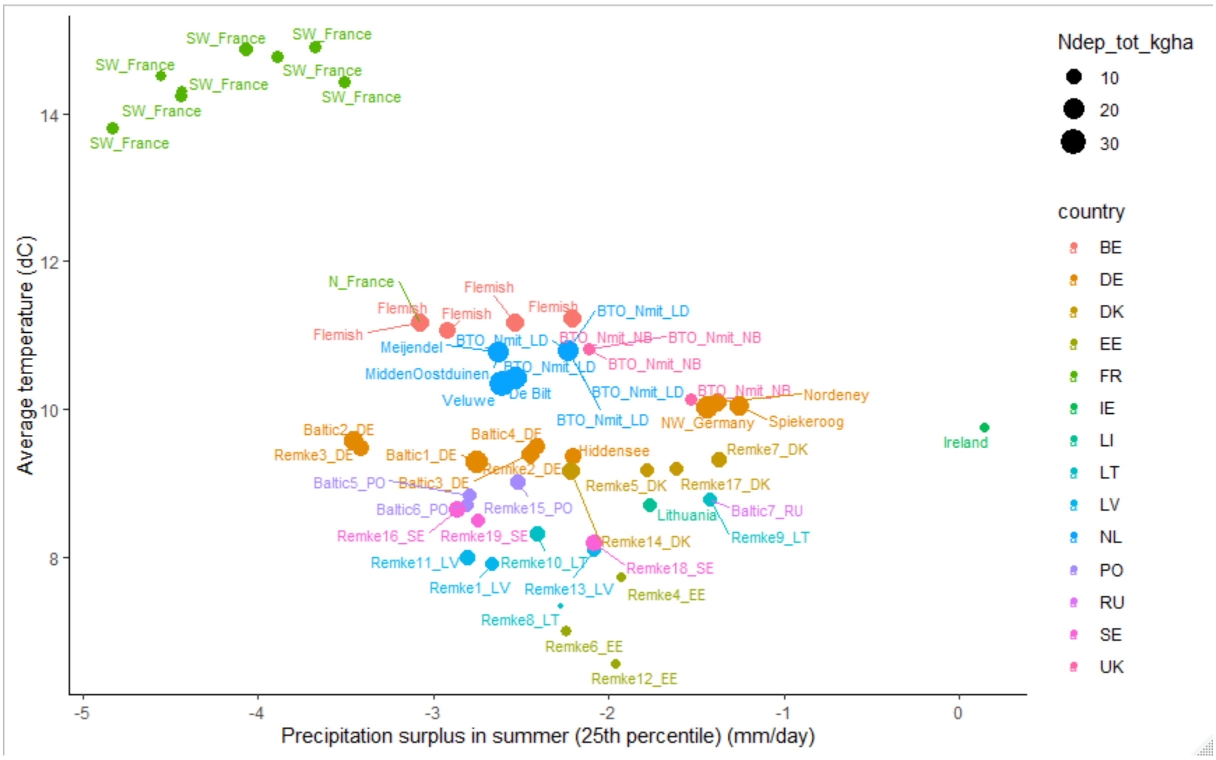


Figure 9. Precipitation surplus in summer (average over 2008-2018) and annual average air temperature (average over 2008-2018) for candidate dune areas. Size of the circles depict annual total N deposition in 2015 (kg/ha/year, modelled for 0.1° grids). De Bilt and Veluwe were added for reference purpose.

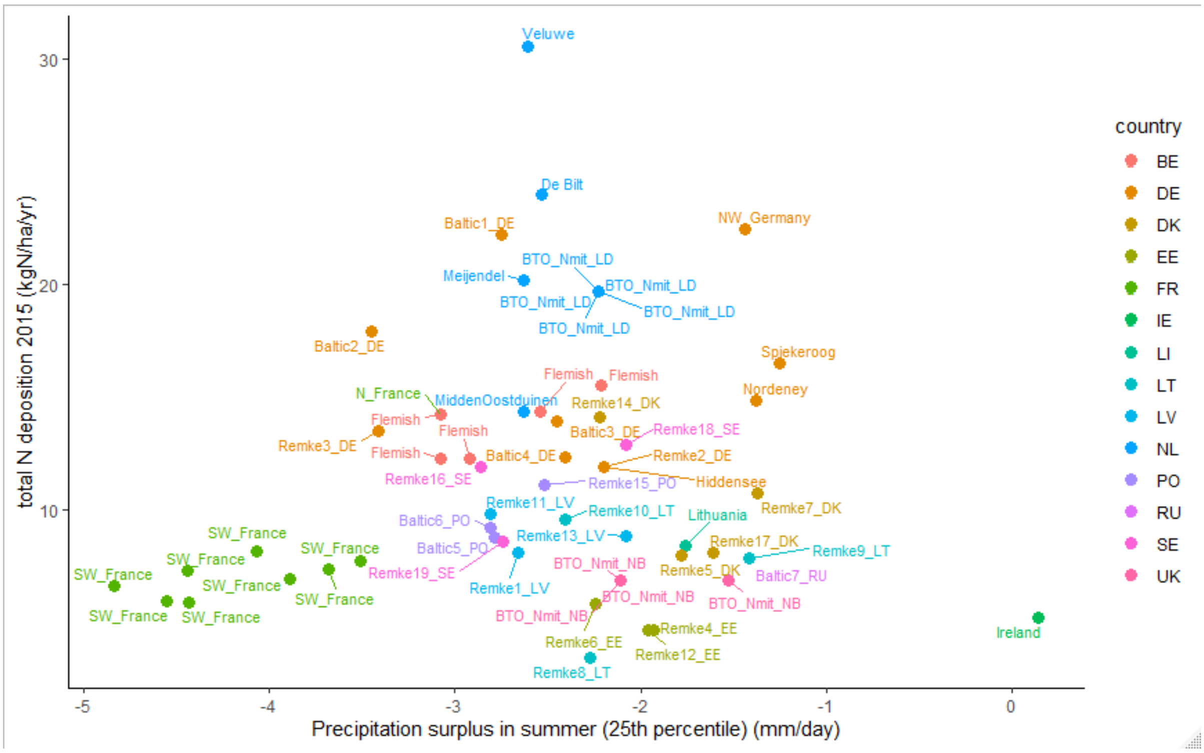


Figure 10. Annual total N deposition in 2015 (kg/ha/year modeled for 0.1° grids) and precipitation surplus in summer for candidate dune areas. Precipitation surplus is expressed as 25th percentile of June, July, and August of 2008 – 2018, calculated based on 0.28˚ grid monthly weather data. De Bilt and Veluwe were added for reference purpose. The critical load for calcareous dune grasslands is 1500 mgN/m2/y and for acidic dune grasslands 10 mgN/m2/y (Van Dobben et al. 2012).

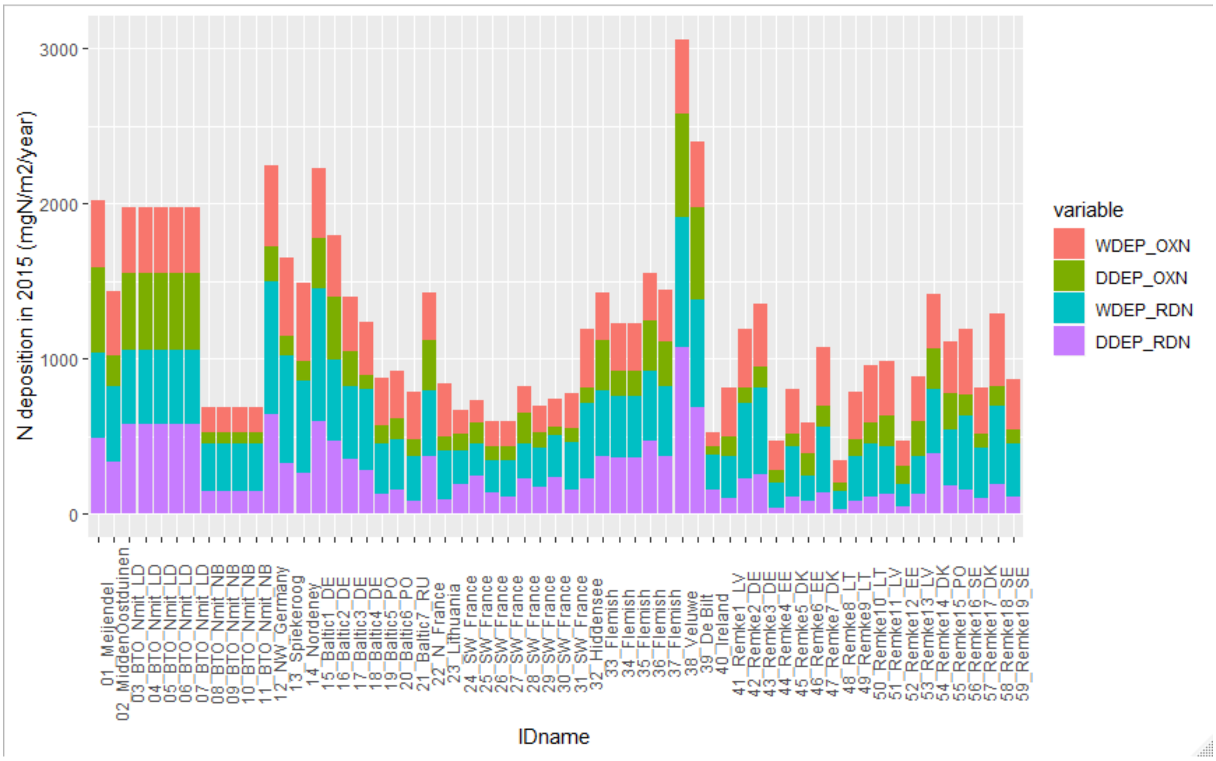


Figure 11. Composition of modelled atmospheric N deposition in 2015, retrieved for each candidate plot. The total deposition was split into wet oxidized (WDWP_OXN), wet reduced (WDEP_RDN), dry oxidized (DDEP_OXN), and dry reduced (DDEP_RDN) fractions. The N deposition were modeled with EMEP MSC-W model, with spatial resolution of 0.1°x 0.1°.

3.4 Salt concentration of seawater

Salt-spray is a factor which effects directly the species composition of dune vegetation. It also may interfere with the effects of NHx deposition on vegetation. The Baltic Sea has a strong gradient in Cl-concentration. Therefore it is useful to include Cl-concentration of the sea water the analyses of the patterns in the gradient study.

3.5 Data availability

In table 2 an overview of the available data of the candidate sites is listed. For most sites coordinates, and vegetation records are present. For a major part also soil analyses of the topsoil are present. Part of the sites have no soil profile data. N-France needs probably additional soil fieldwork and labanalyses. N-Ireland needs complete data collection.
Data on climate and N-deposition have to extracted from European and national data bases/ models (see above). An estimate of the recent local N-deposition can be derived from the N-content in mosses (see above). This will need moss collection and lab analyses.

Table 2: Overview of available data for the candidate sites.

dataset ID	code	Researcher	Institute	country	location of dune ecosystems	Calcareous/decalcified/calcite-poor	Number/extent of sites	existing data vegetation relevee	existing data soil	Received data	Note	Lon_rough	Lat_rough
d1	Luchterduinen	Camiel aggenbach/ Yuki Fujita	KWR	Netherlands	Luchterduinen (Dutch coastal dune)	calcareous and decalcified		1	1	own data	Many plots, but probably no calcareous plots on slopes.	4.525981	52.345378
d2	Meijendel	Camiel aggenbach/ Yuki Fujita	KWR	Netherlands	Meijendel (Dutch coastal dune)	calcareous and decalcified		1	1	own data	no plots on slopes	4.33	52.13
d3	MiddenOostduinen	Camiel aggenbach	KWR	Netherlands	Middel- en Oostduinen (Dutch coastal dune)	calcareous and decalcified		1	1	own data	No plots on slopes? To be checked.	4.3	52.12
d4	BTO_Nmit_LD	Camiel aggenbach/ Yuki Fujita	KWR	Netherlands	Luchterduinen (Dutch coastal dune)	calcareous and decalcified	5 control, 7 sand-deposited, 6 on slope (soil data limited)	1	1	own data		see tab 'xy_BTONmi	
d5	BTO_Nmit_NB	Camiel aggenbach/ Yuki Fujita/ Laurence Jones	CEH	UK	Newborough Warren (coastal dune inNorth Wales)	calcareous	6 control, 9 sand-deposited, 6 on slope (soil data limited)	1	1	own data		see tab 'xy_BTONmi tigatie'	
d6	UK2	Laurence Jones	CEH	UK	coastal dunes in Wales?	calcareous and decalcified	~3 acidic, ~7 calcareous sites + extra ~25 sites	1	1		Both gradient studies were set up to look at N deposition		
d7	Flemish	Sam Provoost	INBO	Belgium	Flemish coastal dune	calcareous and decalcified	86 sites (a part of 400 PQ's)	1	1	all data received		c(3, 2.55)	c(51.25, 51.0)
	Spiekeroog	Maike Isermann	Univ. Bremen	Germany	Spiekeroog (Wadden sea)	calcite-poor	15 site recorded in aug 2019	1	1				
d8	NW_Germany	Maike Isermann	Univ. Bremen	Germany	NW coast of Germany (Niedersachsen)	calcite-poor	a part of 18,000 vegetation records from the coasts of Germany. Some	1	0?	(Maike will send in april 2019)	Inland dune data may also be available??	7.49	53.7
d9	Spiekeroog	Maike Isermann	Univ. Bremen	Germany	Spiekeroog (Wadden sea)	calcite-poor	chronosequence data of acidic dunes.	1	0?		data collection in 2019	7.7346	53.7727
d10	NE_Germany	Maike Isermann	Univ. Bremen	Germany	NE coast of Germany (between Rostock and Polish border)	calcite-poor	ca. 1000 vegetation records + soil data	1	1	(Maike will send in 2019)	This is partly overlapping with the dataset below?		
d12	N_France	Christophe Blondel	Conservatoire botanique national de	France	coastal dune in North France	calcareous and decalcified	A large vegetation dataset of from Seine estuary to Belgian border. This	1	0?			2.526079	51.07751
d13	Lithuania	Ramunas Povilanskas	Klaipeda University, Nature Research	Lithuania	Lithuanian side of Curonian Spit (sand dune on Baltic sea coast)	calcite-poor		1	1		Ca is not present in the soils of the Curonian Spit	21.0995	55.5134
d14	SW_France	Loïc Gouguet/ Didier Alard	Office National des Forets/ University of	France	SW France (near Bordeaux)		200 transects	1?	1	XY coordinate of plots ('pt_gps_transect_flore.xlsx');	David ROSEBERY has soil data. They will contact Marie-Lise	-1.2522165	44.503188
d15		Eva Remke	B-WARE	Germany, Denmark, Lithuania	Baltic sites	calcite-poor		1	1	all data received			
d16	Hiddensee	Eva Remke	B-WARE	Germany	Hiddensee (iland NE Germany)	calcite-poor		1	1	all data received		13.1	54.55

dataset ID	code	coordinates of the site	altitude of the site	slope + exposition	vegetation relevee	vegetation structure: cover (%) of shrub, vascular, moss+lichens, litter	humus profile	profile of soil CaCO3 content / decalfication depth	pH of topsoil	organic matter content or dry bulk density or organic C content	soil age/ history eaolian activity	management history	climatic variabels (e.g. precipiation, temperature, potential evapotra
d1	Luchterduinen	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
d2	Meijendel	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
d3	MiddenOostduinen	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
d4	BTO_Nmit_LD	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
d5	BTO_Nmit_NB	Yes	Yes?	Yes	Yes	Yes	Yes	Yes	Yes	Yes (OM and Corg (not for	Yes	Yes	Monthly data?
d6	UK2	Yes			Yes			25 sites (some	Yes?	Yes?	Yes?		
d7	Flemish	Yes	Yes	Yes	Yes	?		yes profile +	Yes 0-10 cm	Yes SOM and C	Yes part of sites		some weather
	Spiekeroog	Yes	Yes	Yes	Yes			no (all are decalcifie	to be done	to be done			to be done
d8	NW_Germany	Yes	can be determin		Yes	Yes, but often not	Can be determin	Can be determin	can be samples	can be samples	Yes	Yes	some weather
d9	Spiekeroog	Yes			Yes	Yes?			Yes?	Yes?	Yes		
d10	NE_Germany	Yes (accurcy			Yes	Yes?			Yes?	Yes?	Yes?		
d12	N_France				Yes								
d13	Lithuania	Yes	Yes	Can be determin	Yes	Yes	Can be determin	Irrelevant for the	Can be determin	Can be determin	Can be determin	Yes	Yes
d14	SW_France	Yes			Yes			Yes (CaCO3	Yes	Yes (OM, C, N)			
d15		Yes	No	Yes	Yes, 3 per site	only height vascular	yes, German way – Of,	tried it several times, but	all available 0-10 cm	organic matter content,	I've checked the soil	Yes (if available, I ve got it)	not a lot, but very much
d16	Hiddensee	Yes	No	Yes	yes, several –	only height	yes, German	tried it several	all available	organic matter	air photogra	Yes – in detail	yes, in detail

dataset ID	code	organic matter content, dry bulk density, pH of subsoil	pH profile	total Ca, Fe, P, N, C	extractable nutrients	slib content (<63um)	(Peak) standing crop vascular plants	Plant productivity crop vascular plants	standing crop living moss biomass	Local atmospheric N deposition data
d1	Luchterduinen	Yes	Yes							
d2	Meijendel	Yes	Yes							
d3	MiddenOostduinen	Yes	Yes							
d4	BTO_Nmit_LD	Yes	Yes				Yes	Yes		
d5	BTO_Nmit_NB	Yes	Yes				Yes	Yes		Yes
d6	UK2							probably not		Yes
d7	Flemish	no	no	Yes 0-10 cm	Polsen, Pox, Feox	Yes				
	Spiekeroog	to be done								
d8	NW_Germany	can be samples	no	no	no		no	no	no	N deposition measurement
d9	Spiekeroog									
d10	NE_Germany									
d12	N_France									
d13	Lithuania	Can be determin	Can be determin	Can be determin	Can be determin		Yes	Can be determin	Can be determin	
d14	SW_France									
d15		Yes	no	Yes	Yes		don't know if peak, but	no	no only together with	
d16	Hiddensee	Yes	no	Yes	Yes		don't know if	no	no only together	

4 Methods to assess N-deposition with bio-indicators

Critical for a gradient study which assesses the effects of N-deposition, will be a reliable estimate of the local N-deposition of selected sites. Using outputs of models for N-deposition has the risk that a strong bias is introduced. Even national models might over- or underestimate N-deposition. E.g. in the Netherlands a strong gradient in N-deposition is present from coast to inland. Moreover in regions with a strong contribution of reduced N-deposition large errors can occur because of the local behaviour of reduced N deposition and a lack of information on emissions.
Bias by deposition models can be partly avoided by using the N-content of pleurocarp mosses and lichens (Cladina) as a proxy for recent N-deposition. The N-content in mosses as bio-indicator has been applied in NW-Europe in the ICP Vegetation monitoring (Harmens et al. 2015; Figure 7) and correlated to measured N-deposition (Harmens et al 2014; Figure 8). At a level above 20 kg N/ha/y the mosses become saturated for N. Because the current N-deposition is expected to be for a major part lower than 20 kgN/ha/y, using mosses as a proxy for N-deposition can work for coastal dune grasslands. An advice is to use it as a relative estimate, and not as an absolute one (personal communication Harry Harmens). Most of the moss species used in the ICP study are common in dune grasslands. In a gradient study of acidic dune grass in the Baltic region Remke et al. (2009) used successfully N-content in Cladina as proxy. A limitation of N-content of mosses as proxy is the saturation for N above a deposition above 20 kg N/ha/y. This implies the method cannot discriminate in the high range of N-deposition in e.g. The Netherlands, Flanders and NW-Germany.

The Netherlands is not involved in the ICP-monitoring of N-content in mosses, because in policy there was low interest in monitoring the effects of air pollution on ecosystem level. For 2020 an 2021 a next sampling campaign is planned in the ICP program. KWR conducts in 2019 a small pilot with measuring N-content a Dutch and Welsh dune area (BTO-project). It is an option for the project to include measurements of N-content in mosses and share data with the ICP program.

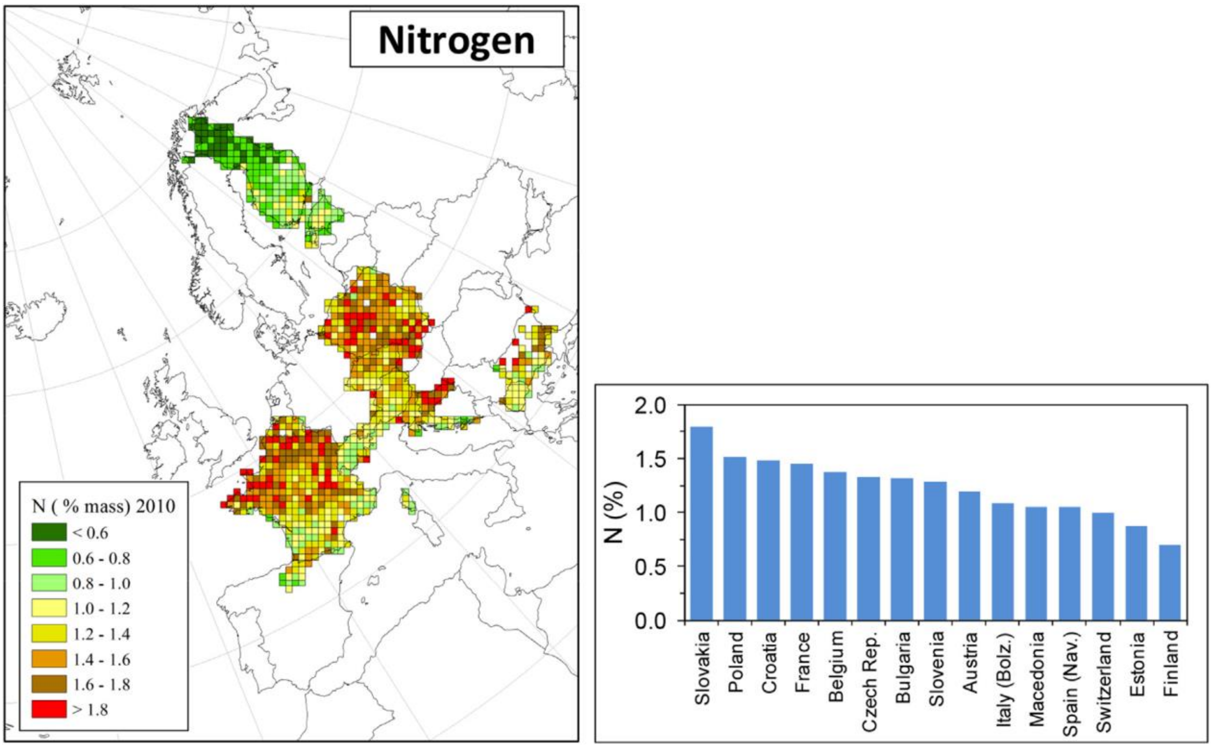


Figure 7: Mean nitrogen (N) concentration in mosses per EMEP grid square (50 km 50 km) in Europe in 2010 (left) and medium value per country (right) (from Harmens et al. 2015).

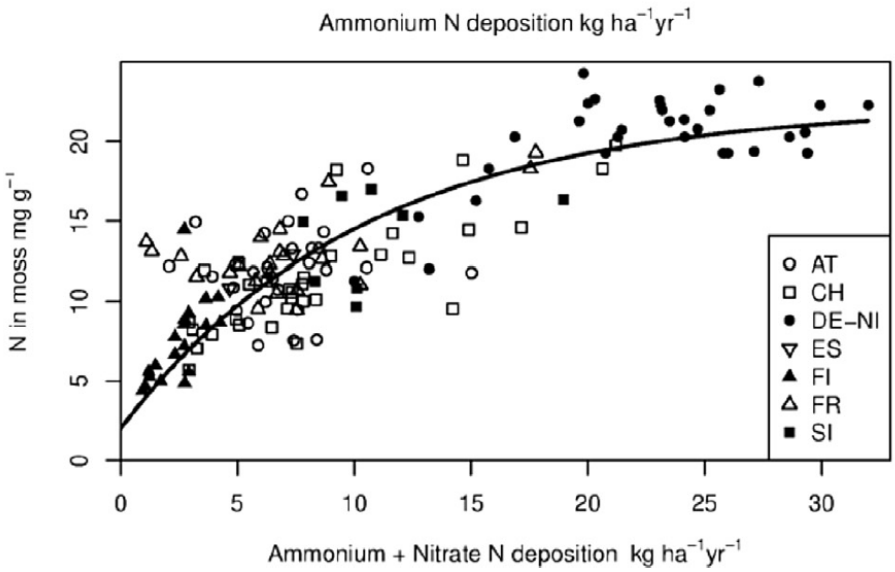


Figure 8: The relation between N-content in pleurocarp mosses and measured total N-deposition in NW-Europe (from Harmens et al. 2014). Symbols indicate different regions.

5 Conclusions

The reconnaissance for potential international partners resulted in enthusiastic reactions of researchers. There is a great willingness to cooperate and share existing data. Because of this positive attitude a gradient study in Europe on the influence of climate and N-deposition in dune grasslands is feasible. The partners will be involved in the study without current funding. For them the important benefit of the study will be a joined scientific paper.

The candidate sites cover a mayor part of the climatic and N-deposition gradient in NW-Europe. Because SW-France is included in the candidate sites, the gradient study will include the region with the probably future climate of the Netherlands. Outcomes of the empirical study are therefore useful for modelling the effects of climate and N-deposition scenarios for the Netherlands.

It is therefore deemed feasible to continue with the next phase of data collection and analysis of the available data. Some of the regions will need additional vegetation recording. Part of the regions additional recording of soil profile and analyses of top soil organic matter content will make it possible to calculate the effect of climate of drought stress on plot scale (method available at KWR), and relate this to properties of the vegetation.

In this pre-study we used large scale datasets for climate and N-deposition with a coarse spatial resolution to explore the major gradient in Europe. A main problem with such coarse data is that coastal dunes locate (inevitably) next to the coast, whereas weather conditions are strongly different between land and sea. Thus, as far as spatial resolution of dataset is large (which is the case for the large scale dataset), the retrieved values of weather for coastal dunes are subject to sea influence. This may cause a strong differences in the value of climatic parameters between large scale data and local data (see Appendix III). For N-deposition the spatial resolution of models may have a strong effect on the predicted pattern, especially when reduced N has a large proportion in the total N-deposition. Additional effort is needed to refine the information on the climate and N-deposition based on local data and/or national/ regional datasets and models. This will need input (where to get data, access to data) from local partners.

Several partners indicated to have interest in applying for international funding for this research. A quick scan of possibilities for scientific funding by the European community revealed that there are no suitable calls on a short time (H2020, ERA, Joint Programming Initiative). When a suitable call will take place, the current partners offer a good opportunity to apply for funding with a consortium. At that moment a consideration te enlarge the geographical scope of the consortium by extending to it to southern Europe and northern parts (N-Baltic, Scotland).

6 References

Doody, J.P., 2001. Coastal Conservation and Management: an Ecological Perspective. Kluwer, Academic Publishers, Boston, USA, 306 pp. Conservation Biology Series, 13

Harmens H, Schnyder E, Thoni L, Cooper DM, Mills G, Leblond S, et al. 2014. Relationship between site-specific nitrogen concentrations in mosses and measured wet bulk atmospheric nitrogen deposition across Europe. Environmental Pollution 194:50-9.

Harmens H, Norris DA, Sharps K, Mills G, Alber R, Aleksiayenak Y, et al. 2015.Heavy metal and nitrogen concentrations in mosses are declining across Europe whilst some "hotspots" remain in 2010. Environmental Pollution 200:93-104.

Metzger, M. J., et al. (2005). "A climatic stratification of the environment of Europe." Global Ecology and Biogeography 14(6): 549-563.

Transboundary particulate matter, photo-oxidants, acidifying and eutrophicating components, EMEP Status Report 1/2017, ISSN 1504-6109 (print), ISSN 1504-6192 (online)

I Calculation of Penman-Monteith potential evapotranspiration

Penman-Monteith potential evapotranspiration was calculated according to the equation of FAO (http://www.fao.org/3/X0490E/x0490e08.htm#chapter%204%20%20%20determination%20of%20eto). The input weather variables are shown in Table.

Table 2. Obtained monthly ERA5 data via KNMI website

Variable	Variable long name	unit	Time coverage	Time unit
t2m	Near-Surface Air Temperature	Celsius	From 1979-01-15 to 2018-12-15	months since 1979-01-01 (N=480)
tmax	Daily Maximum Near-Surface Air Temperature	Celsius	From 2008-01-30 to 2018-09-30	months since 2008-01-01 (N=129)
tmin	Daily Minimum Near-Surface Air Temperature	Celsius	From 2008-01-30 to 2018-09-30	months since 2008-01-01 (N=129)
Tp	Precipitation	mm/day	From 1979-01-15 to 2018-12-15	months since 1979-01-01 (N=480)
wspd	Near Surface Wind Speed	m/s	From 1979-01-15 to 2018-12-15	months since 1979-01-01 (N=480)
ssr	Net Surface Solar Radiation	W/m2	From 1979-01-15 to 2018-12-15	months since 1979-01-01 (N=480)

ET_o reference evapotranspiration [mm day^{-1}] was calculated as follows:

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34 u_2)}$$

R_n net radiation at the crop surface [MJ m^{-2} day^{-1}]
'ssr' (Net Surface Solar Radiation) was multiplied with 86.4e-3 to convert from W/m2 to MJoule/m2/day
G soil heat flux density [MJ m^{-2} day^{-1}]
assumed to be 0.
T air temperature at 2 m height [°C]
't2m'
u_2 wind speed at 2 m height [m s^{-1}]
' wspd'
e_s saturation vapour pressure [kPa]
$e_s = [(e°(T_{max}) + e°(T_{min})]/2$
where

$$e^o(T) = 0.6108 \exp\left[\frac{17.27T}{T + 237.3}\right]$$

e_a actual vapour pressure [kPa]
$e_a = e^{\circ}(T_{min})$

Δ slope vapour pressure curve [kPa °C^{-1}]
Table 2.4 or Eq.13 (Annex II). Function of average temperature

$$\Delta = \frac{4098\left[0.6108 \exp\left(\frac{17.27T}{T + 237.3}\right)\right]}{(T + 237.3)^2}$$

γ psychrometric constant [kPa °C^{-1}]
Table 2.2, function of altitude (m)

$$P = 101.3\left(\frac{293 - 0.0065z}{293}\right)^{5.26}$$

II Criteria for site selection

II.I Criteria for site conditions

Criteria	Source	Remark
stratified for climate (drought stress) and N-deposition (total N)	calculated from European-wide database of climate and N deposition	The following combinations need to be included: extremely dry & N-low, wet & N-low, wet & N-high, dry & N-high
Stratified for calcareous (decal. depth < 10cm; pH topsoil>6.2) and acidic (decl. depth>20cm, pH topsoil <6.2) sites	Local soil data	some regions probably only have calcareous or acidic soils
stratified for slope and exposition (flat / south-facing slope / north-facing slope)	Local measurements or DEM	flat (slope <2°), north (slope >10°), south (slope >10°). Preferably all types of slope are included in an area.
old soils	general expert knowledge of the area, or, sequential aerial images	> 50 year old, preferably without clear effect of sand deposition from aeolian activity
Presence of organic-rich top soil, which is clearly distinguishable from subsoil underneath	Local soil data	Ah-C or Ah-AC-C profile; depth of organic-rich top soil > 3 cm
groundwater independ	judged from absence of freatophytes/ landscape setting	judgement of presence freatophytes from local knowledge vegetation
not fertilized	judged from management history and species composition	
not fertilized in past	judged from species composition	Not much encroachment of woody species
distance from sea??	map	for excluding eaolian sand input from beach/ front wall; > 200 m

II.II Criteria for data availability

Data	Importance	Remark
	A = always needed, B = less important but when available then useful, C= only useful for some additional info	
coordinates of the site	A	as precise as possible (xy < 10 m)
altitude of the site	B	This can be calculated if a fine-scale DEM (digital elevation model) is available or local measurements
slope + exposition	B	Preferably by local measurements; can also be calculated if a fine-scale DEM (digital elevation model) is available.
vegetation relevee	A	Including vascular plants, mosses, and lichens. Species identification and abundance (in % cover or a scale which can be converted to % cover)
vegetation structure: cover (%) of shrub, vascular, moss+lichens, litter, bare sand; height of vascular, shrub; height layer vascular plants and shrub	A	cover bare sand is interesting because it is probably affected by climate
humus profile	A	Description of humus type and depth of each soil layer.
profile of soil $CaCO_3$ content / decalcification depth	B	Decalcification depth can be determined by e.g. in-situ HCl test at different depths.
pH of topsoil	A	either in H_2O extract, in KCl extract
organic matter content or dry bulk density or organic C content of topsoil	A (at least one of them)	preferely both because relation bulk density and organic matter can differ for areas/ regions

soil age/ history eaolian activity	B	This can also be estimated from a time-series of aerial photos.
management history	A	general description
climatic variables (e.g. precipitation, temperature, potential evapotranspiration)	B	At least on a monthly scale, of the past decades. We have climate records with a rough resolution (ca. 0.28° grid), but local weather data is preferable.
Additional data		
organic matter content, dry bulk density, pH of subsoil	C	
pH profile	C	pH records through soil depth by in situ measurements with soil electrode (shallow - deep gradient)
total Ca, Fe, P, N, C	C	In relation to effects of N-deposition existing data on Fe and P content are useful
extractable nutrients	C	
slib content (<63um)		
(Peak) standing crop vascular plants	C	Peak standing crop, or annual productivity (measured in enclosures)
Plant productivity crop vascular plants	C	
standing crop living moss biomass	C	
Local atmospheric N deposition data	B	We have N deposition records with a rough resolution (0.1° grid) from a large scale model, but local data or results of a national model are preferable.

III Reliability of weather and N deposition data of dunes derived from global dataset

It is now possible to show, for any point of European coastal dune, climate data of 2008 - 2018 and N deposition data of 2015. However, the reliability of using these dataset for evaluating local-level weather is questioned. A main problem is that coastal dunes locate (inevitably) next to the coast, whereas weather conditions are strongly different between land and sea. Thus, as far as spatial resolution of dataset is large (which is the case for the global dataset), the retrieved values of weather for coastal dunes are subject to sea influence. To have some idea about the effect of sea on precipitation surplus, see Figure 12.

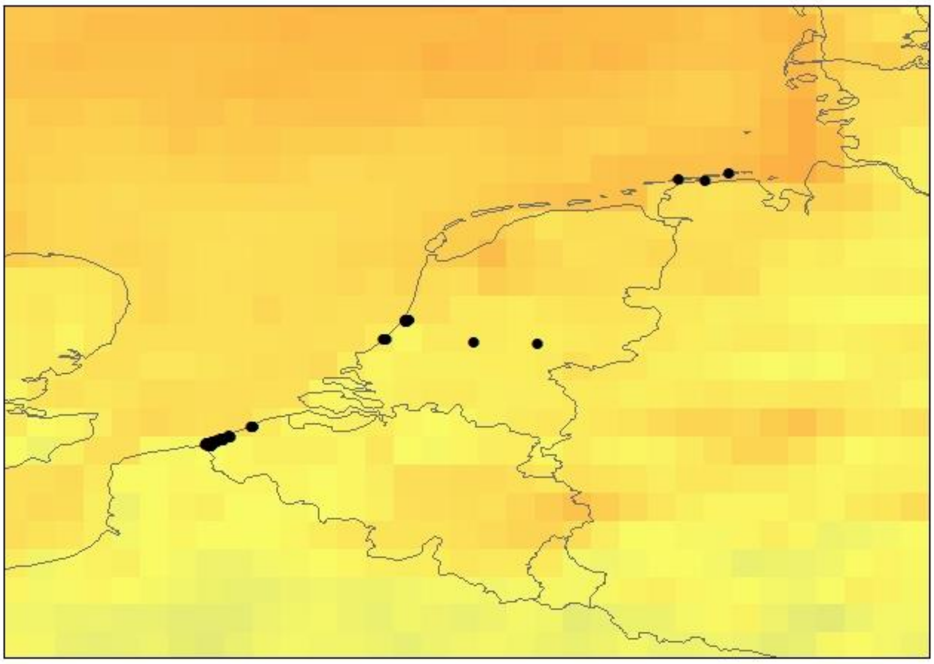


Figure 12. Precipitation surplus, computed on 0.28˚steps. Black dots are candidate study locations (plus Veluwe and De Bilt, just as reference). The color is darker (=more surplus) on sea, because of higher precipitation.

Below some examples are shown for climate data of Luchterduinen (LD; 52.3, 4.5) and New Borough Warren (NB; 53.1, -4.4), obtained from the large scale ERA5 dataset of 0.28˚resolution (Figure 13). The average precipitation derived from the global dataset (i.e. 1018 mm for NB, 1053mm for LD) is higher than data obtained from local stations (850 mm in NB, 805 mm in LD and ; Figure 14). [3]

[3] National weather data are of long period with increase of precipitation!

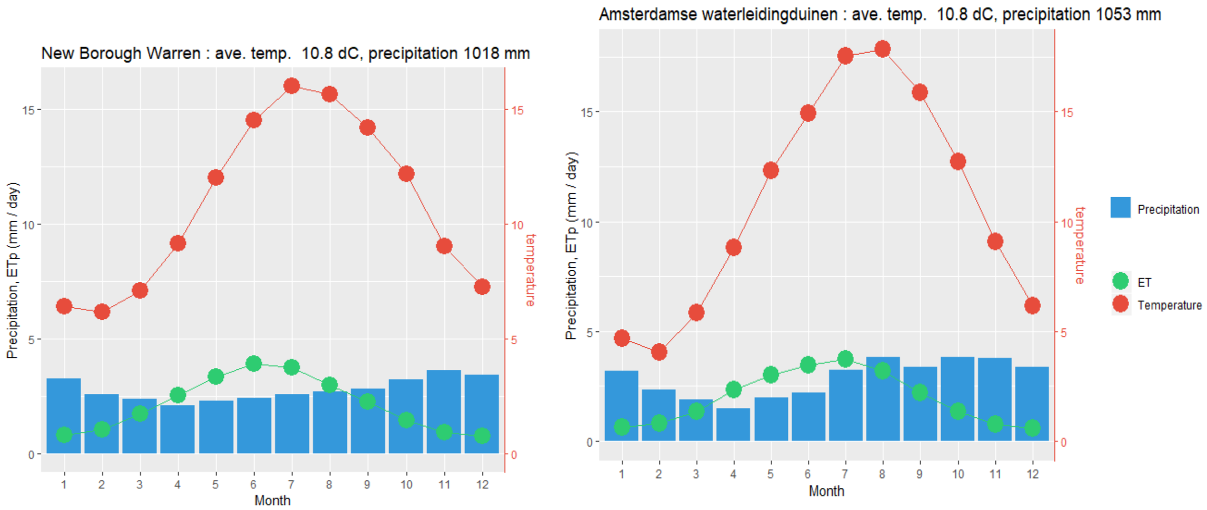


Figure 13. Mean monthly weather data of 2008 – 2018 calculated from ERA5 data (resolution 0.28˚), for the grid where New Borough Warren (left) and Luchterduinen (right) situates,

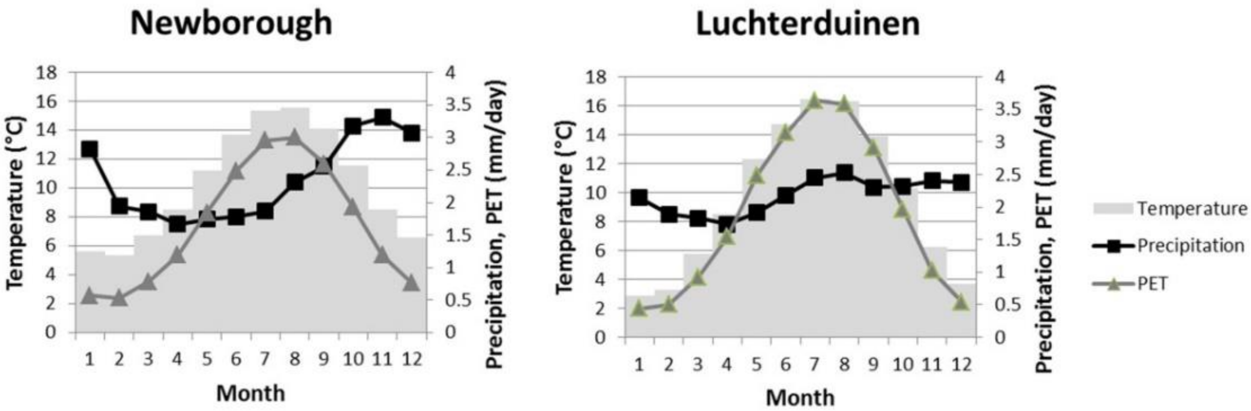


Figure 14. Mean monthly weather data of 1931 and 2014, obtained from local weather station data.

N deposition levels obtained from the European-scale model (EMEP MSC-W) agrees reasonably with the levels estimated with more accurate national-level models. For example, total N deposition levels of Luchterduinen and New Borough Warren in 2015 estimated with EMEP MCS-W model are ca. 20 and 7 kg/ha/year, which falls in the same range as the estimates from the national models (Figure 15-16).

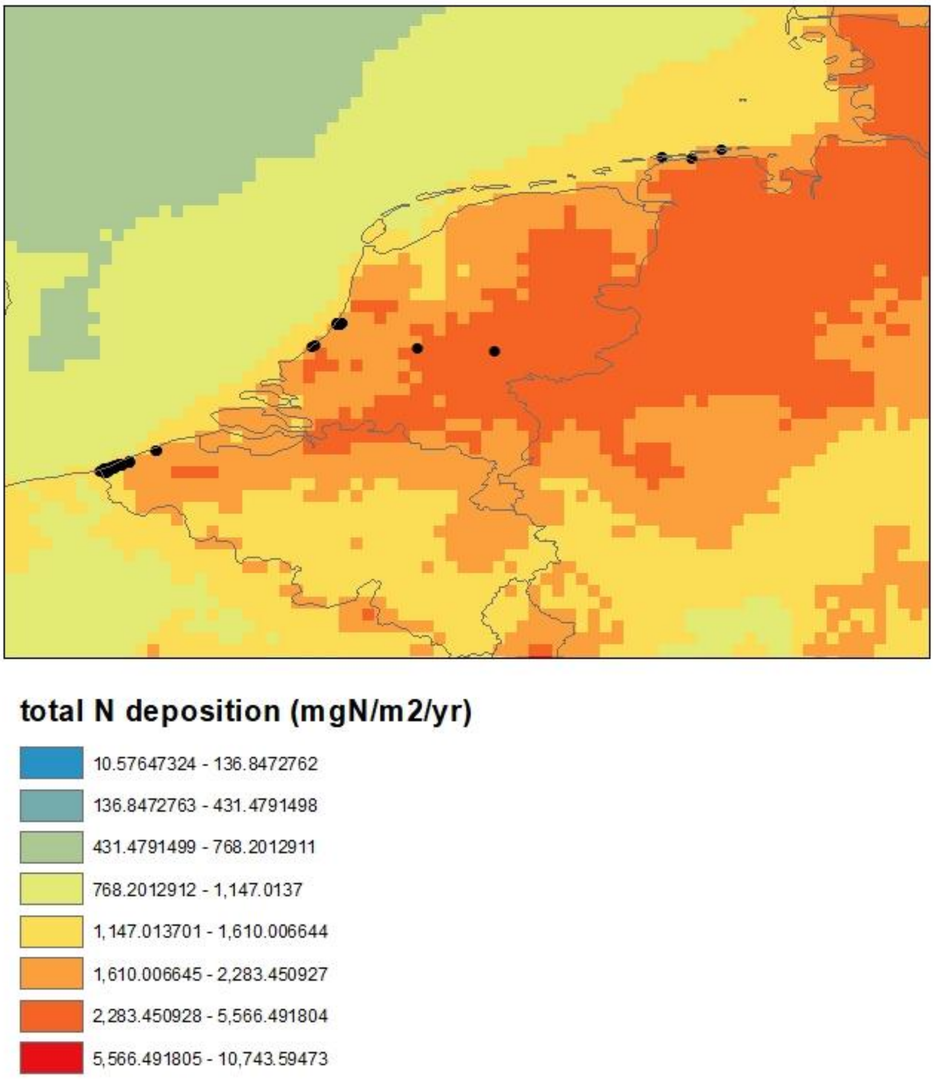
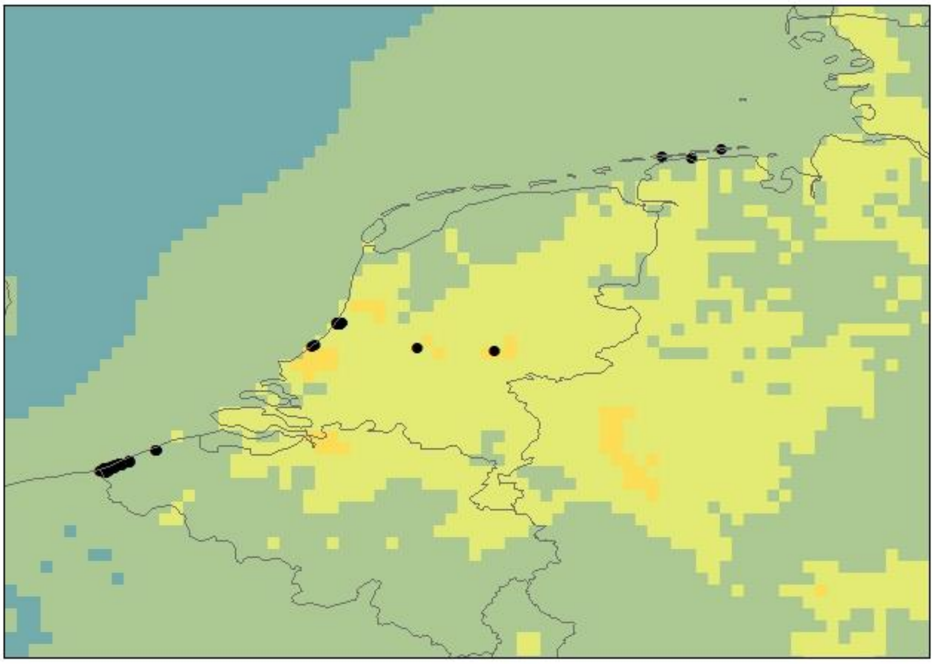
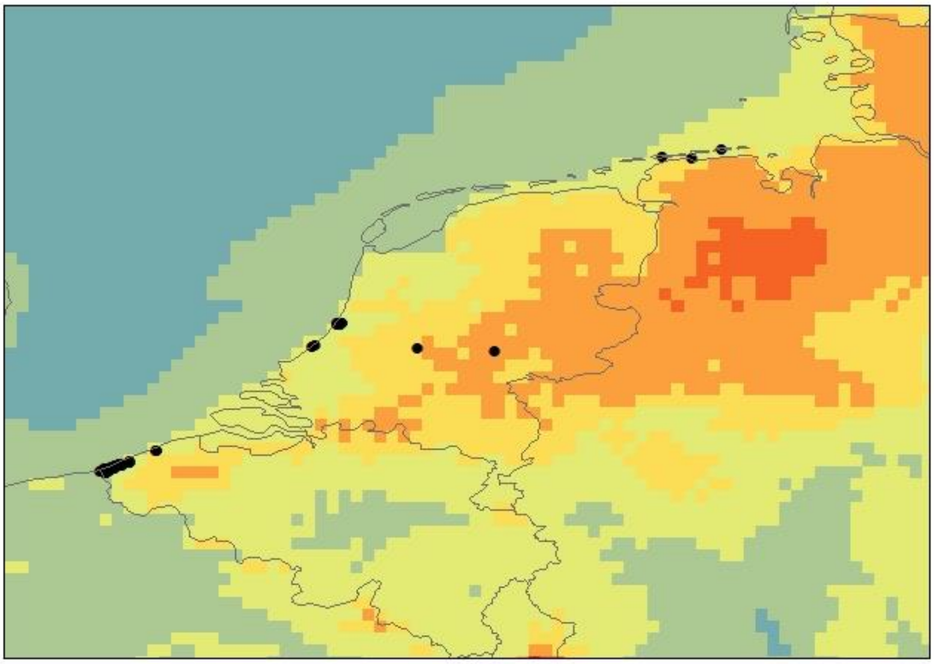


Figure 15. Zoom-up of total N deposition levels (mgN/m2/year in 2015), estimated with the European-scale model (EMEP MSC-W). Black dots are candidate study locations (plus Veluwe and De Bilt, just as reference). The critical load for calcareous dune grasslands is 1500 mgN/m2/y and for acidic dune grasslands 10 mgN/m2/y (Van Dobben et al. 2012).



oxn_N deposition (mgN/m2/yr)



rdn_N deposition (mgN/m2/yr)

Figure 16. Zoom-up of N deposition levels (mgN/m2/year in 2015), split into oxidized (above) and reduced (below) nitrogen. Both wet and dry deposition are included.

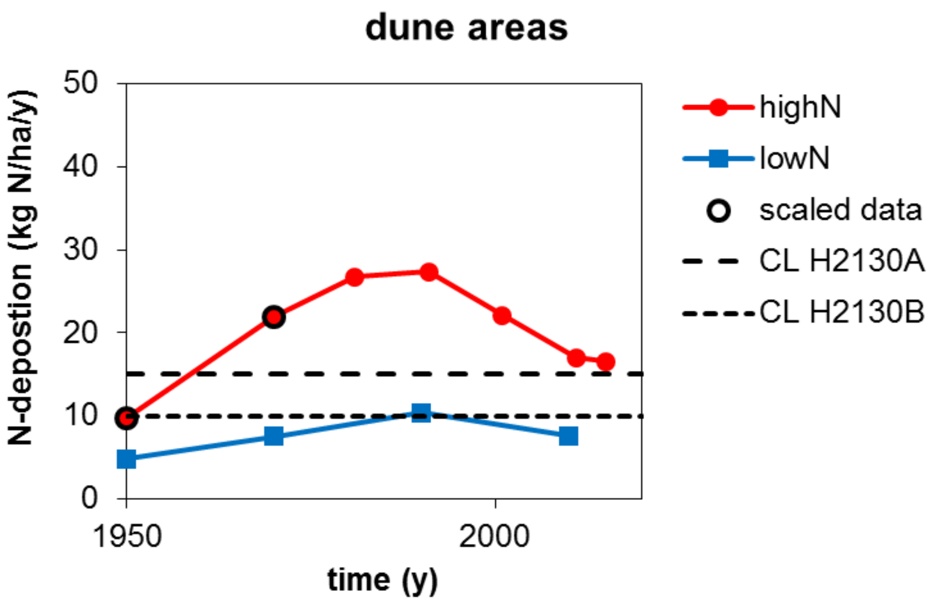


Figure 17. Total N deposition levels of Luchterduinen ('highN') and New Borough Warren ('lowN') estimated with national models. Critical loads for habitat Grey Dunes are also indicated: H2139A = calcareous variant, H2130B = acidic variant.

Year of publishing
2019

More information
ir. M.L. (Martin) van der Schans (KWR),
T +31 30 606 9537
E martin.van.der.schans@kwrwater.nl

Keywords
Nitrogen deposition, climate change, coastal dune grasslands

Groningenhaven 7
Postbus 1072
3430 BB Nieuwegein
The Netherlands

T +31 (0)30 60 69 511
F +31 (0)30 60 61 165
E info@kwrwater.nl
I www.kwrwater.nl

KWR 2019.098 | 21 oktober 2019 ©KWR