https://doi.org/10.5194/essd-2019-242
Preprint. Discussion started: 28 February 2020

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Compilation of pollen productivity estimates and a taxonomically harmonised PPE dataset from Northern Hemisphere extratropics

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Abstract Pollen productivity estimates (PPEs) are fractionate values of relative pollen productivity, often in relation to *Poaceae*, that allow vegetation cover to be estimated from pollen counts. PPEs are especially used in the European and Chinese scientific community, with a few studies in North America. Here we present a comprehensive compilation of available PPE studies and their results arising from 40 publications with 49 sites and 99 taxa. This compilation allows scientists to identify the best PPE for their own studies and to identify data-gaps in need of further PPE analyses. We also present a taxonomically harmonised, unified PPE dataset, which we generated from the available studies. Studies which did not have *Poaceae* as reference taxon were not included unless they included taxa which would otherwise drop out of the dataset. The unified dataset is based on 30 publications and 34 sites, and gives the mean PPE per taxon excluding outliers as well as fall speeds, which are necessary to reconstruct vegetation cover from pollen counts and PPE values. It contains 58 PPEs and 57 fall speeds, with 54 taxa having values for both. This dataset can be applied to broad scale or long-term pollen-vegetation analyses. Data are openly available at https://doi.pangaea.de/10.1594/PANGAEA.908862 (Wieczorek and Herzschuh, 2019).

1 Introduction

Pollen records are widely used for the reconstruction of vegetation composition (e.g. Bartlein et al., 1984; Li et al., 2019). However, such records need to be interpreted carefully, as different taxa have different pollen productivities and dispersal abilities. While some taxa produce much and/or light pollen which is transported over large distances and thus overrepresented in the pollen records compared with vegetation, others produce little and/or heavy pollen which is hardly found in pollen records despite a high abundance of the taxon in the vegetation (e.g. Prentice, 1985; Prentice and Webb, 1986). To overcome these problems, pollen productivity estimates (PPE) and their fall speeds have been calculated for various regions and taxa (e.g. Baker et al., 2016; Broström et al., 2004; Commerford et al., 2013; Wang and Herzschuh, 2011). Most of these studies are limited to north/central Europe and China. Some major review studies provide PPEs for a number of sites and taxa (e.g. Broström et al., 2008; Li et al., 2018; Mazier et al., 2008), but a study compiling all available PPEs from the Northern Hemisphere - which would be useful to identify the most suitable dataset for a site-specific reconstruction - is lacking. Furthermore, an easy-to-apply unified PPE dataset for Northern Hemispheric pollen would help to reduce the bias of pollen dispersal and pollen productivities in vegetation reconstructions using broad-scale pollen datasets by adopting a consistent approach.

Here we present a compilation of available PPE-publications and a unified PPE and fall speed dataset for Northern Hemispheric pollen.

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2 Methods

2.1 Literature search

To find literature on pollen productivity estimates (PPEs), we conducted internet searches in Google Scholar (https://scholar.google.de/) and the Web of Science (https://apps.webofknowledge.com/) for the terms "PPE", "Pollen productivity", "Pollen productivity estimates", "PPE America" and various combinations of our search terms. Furthermore, we used literature cited in publications on PPEs to gain a profound overview of existing literature about Northern Hemispheric PPEs.

A PPE is a correction factor used to reconstruct vegetation from pollen counts. It is given as a fraction relative to a reference taxon, typically *Poaceae*. Publications which did not provide such fractionate correction factors for specific regions or consisted only of compilations of previously available PPE data were excluded from all further analyses. Thus, of the resulting 54 publications from our literature search, 13 were excluded a priori and are marked with an x in Table 1. The review of Li et al. (2018) does not contain newly calculated PPE, but is a collection of Chinese PPE studies, which of we incorporated those only available in Chinese language into our study. In the end, we use a total of 40 publications for our analyses.

2.2 PPE

In a first step, all PPE values and, if given, their standard deviation (SD) were collected from the literature. If the data were only presented as figures, values were extracted with the help of Corel Draw X6. Afterwards, all PPEs with SD>PPE and non-plausible PPEs >50 were excluded from the dataset. To obtain a reasonable taxonomic harmonisation, we assigned broader taxonomic levels to some taxa of the original publications and calculated means if more than one value of finer taxonomic levels was available (Table 2).

A complete compilation of PPE-data and their references is given in the Appendix. Some publications did not use Poaceae as the reference taxon: while it is possible to recalculate values relative to Poaceae (cf. Li et al., 2018; Mazier et al., 2012), we confined our analysis to publications with Poaceae as the reference taxon.

To achieve our goal of a unified PPE dataset for the whole Northern Hemisphere, boxplots of PPE per taxon were calculated with the help of R (version 3.5.3, R Core Team, 2019). A set of PPE-means per taxon was then created by calculating the mean of all values excluding outliers (defined as values outside the range of ±1.5 * interquartile-range). The SE was estimated using the delta method (Stuart and Ord, 1994). Subsequently, we looked at those taxa for which PPEs are available but do not have Poaceae as the reference taxon. These comprise Eleaganaceae, *Nitraria*, *Tsuga*, wild herbs and PoaceaeCrop. For studies that included Poaceae in the analysis set, we set Poaceae as 1 and recalculated the other PPEs based on that ratio (applies to Sugita et al., 1999). For all other studies (Calcote, 1995; Chaput and Gajewski, 2018; Li et al., 2015; Matthias et al., 2012; Theuerkauf et al., 2015), we recalculated the PPEs based on the original reference taxon. If, for example, Acer was used as the reference taxon, we assumed the Poaceae-to-Acer PPE to be the same as our calculated mean PPE for Acer and recalculated the other values based on that ratio. For Zhang et al. (2017) and Li et al. (2011) only values recalculated relative to Poaceae are available and extracted from Li et al. (2018), thus we did not conduct our own recalculations. Publications are not considered if neither Poaceae was used as a reference nor species included for which no PPE would be available without recalculation (applies to Andersen, 1967; Bunting

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et al., 2005; He et al., 2016; Li et al., 2015; Sjögren et al., 2008b; Theuerkauf et al., 2013; Twiddle et al., 2012; Wu et al., 2013; Zhang et al., 2017 (Changbai Mountains)).

2.3 Fall speeds

Fall speeds were extracted from all the compiled literature. If several values were available for one taxon (see Table A2), we calculated the mean. Taxonomic levels were combined according to Table 2.

3 Dataset

An overview of all locations is given in Figure 1, which clearly shows the absence of studies in Central Asia and large parts of Russia. Only a few studies have been conducted in North America. Of 40 publications covering 49 sites, a final number of 31 publications and 35 sites is included in the final PPE dataset (https://doi.pangaea.de/10.1594/PANGAEA.908862, Wieczorek and Herzschuh, 2019). Nine publications + the Changbai site from Zhang et al. (2017) were excluded from calculations because Poaceae was not the reference taxon. Eight studies did not have Poaceae as the reference, but did include PPE values for taxa which would otherwise not be represented in the final PPE-dataset (applies to Calcote, 1995; Filipova-Marinova et al., 2010; Li et al., 2011; Matthias et al., 2012; Sugita et al., 1999, 2006; Theuerkauf et al., 2015; Zhang et al., 2017 (site Taiyue)). These taxa are *Aesculus*, Elaeagnaceae, *Nitraria*, PoaceaeCrop, *Pterocrya*, *Tsuga* and wild.herbs (Table 3). The final dataset consists of PPE values for 58 taxa and fall speeds for 57 taxa, with 54 taxa having both PPE values and fall speeds available (Table 3). All PPE data in the final dataset are given relative to Poaceea, marked in red in Table 3.

4 Discussion

4.1 Data quality

While major taxa are available in the dataset, and often at the species level, a good geographic coverage is limited to central/northern Europe and China (Figure 1). PPE-studies in Russian and North American boreal forests as well as subtropical regions are largely lacking. The taxonomic resolution of available PPEs varies between studies and depends on the level to which pollen can be identified. Furthermore, while some taxa have a broad scale of available PPEs, for 22 of them only one or two values are available in the complete dataset (Appendix). In the subset used for the creation of a unified PPE-set, 30 taxa (i.e. 54%) have only one or two PPEs that could be used to calculate the mean.

Comparisons with taxa available in the compilations of Mazier et al. (2012, Europe) and Li et al. (2018, China) clearly show regional differences in PPE values for some taxa (Figure 3, upper panel). While Cyperaceae or *Fraxinus*, for example, have a similar range, PPEs for other taxa (e.g. *Artemisia*, *Betula*), strongly vary between the publications. The data used for our PPE dataset also show a high regional variability for some taxa (Figure 3, lower panel) and some PPEs vary strongly within a region. For example, in our dataset, values for *Artemisia* vary between 3.20 and 24.70 in China and *Pinus* varies from 1.35 to 21.58 in Europe (see Table A in the Appendix). Reasons for these variable PPE values have been discussed in detail by Broström et al. (2008) and Li et al. (2018), and are mainly methodological factors such as different sampling designs, environmental factors such as vegetation characteristics, and some uncertainty due to the use of inconsistent reference taxa. Most studies used *Poaceae*, a widespread family, whose pollen is easy to identify and often preserved in a good state. However, as discussed by Broström et al. (2008), the pollen cannot be identified to species level and different studies may thus have used different species of Poaceae for the reference. Other taxa such as *Quercus* or *Acer* are therefore sometimes used as the reference taxon (see Table A in the Appendix).

4.2 How to use the dataset

Using PPEs for pollen-based quantitative vegetation reconstruction (Sugita, 2007; Theuerkauf et al., 2016) has improved our understanding of environmental change (e.g. Marquer et al., 2014). In this paper, we present a dataset of Northern Hemispheric extratropical PPEs and corresponding fall speeds based on a compilation of studies. This open access dataset can be used to improve our understanding of past vegetation dynamics for a broad range of taxa rather than interpreting pollen counts or percentages alone.
To our knowledge, this is the first overview of available PPE studies covering the whole Northern Hemisphere. The compilation is useful for the identification of available PPE sets at specific sites and regions. Furthermore, it highlights where there are data gaps with respect to certain regions and taxa for future PPE studies.
The unified PPE dataset of Northern Hemispheric extratropical taxa allows a consistent approach to be applied to synthesised pollen data at a continental to hemispherical scale. Additionally, long-term pollen data, such as those collected as part of the ICDP drilling campaign (Andreev et al., 2012), comprise pollen spectra of varying taxa compositions and climate conditions, and PPEs from a nearby local study would not necessarily be best suited for their interpretation.

5 Data Availability

The PPE compilation as well as the taxonomically harmonised PPE dataset are available at https://doi.pangaea.de/10.1594/PANGAEA.908862 (Wieczorek and Herzschuh 2019).

6 Author Contribution

MW and UH designed the study and wrote the Manuscript, MW carried out the analyses and produced tables and figures.

7 Competing interests

The authors declare that they have no conflict of interest.

8 Acknowledgements

The study was supported by and conducted as part of the ERC consolidator grant “GlacialLegacy” (Call: ERC-2017-COG, Project Reference: 772852) and PalMod Initiative (Grant 01LP1510C). We thank all scientists conducting research on pollen productivity, whose previous work and published data made our compilation possible. We thank C. Jenks for language correction. This study is a contribution to the Past Global Changes (PAGES) LandCover6k working group project.

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TABLES

330 **Table 1: Publications returned by our literature research on pollen productivity estimates (PPEs). Literature not included in all further analyses is given in italics and marked with an x.**

Abraham and Kozáková, 2012	Li et al. in prep (from Li et al. 2018)
Andersen, 1967	Matthias et al., 2012
Baker et al., 2016	Mazier et al., 2008
x Binney et al., 2011	*x Mazier et al., 2012*
x Broström, 2002	*x McLauchlan et al., 2011*
x Broström et al., 2008	Nielsen, 2004
Broström et al., 2004	Niemeyer et al., 2015
Bunting et al., 2005	Poska et al., 2011
x Bunting and Hjelle, 2010	Räsänen et al., 2007
Bunting et al., 2013	Sjögren, 2013
Calcote, 1995	Sjögren et al., 2008a
Chaput and Gajewski, 2018	Sjögren et al., 2008b
Commerford et al., 2013	*x Sjögren et al., 2006*
x Duffin and Bunting, 2008	Soepboer et al., 2007
Filipova-Marinova et al., 2010	*x Soepboer et al., 2008*
Ge et al., 2015 (from Li et al. 2018)	Sugita et al., 1999
Han et al., 2017	*x Sugita et al., 2010*
He et al., 2016 (from Li et al. 2018)	Sugita et al., 2006
x Heide and Bradshaw, 1982	Theuerkauf et al., 2015
x Hellman et al., 2008	Theuerkauf et al., 2013
Hjelle, 1998	*x Trondman et al., 2015*
Hjelle and Sugita, 2012	Twiddle et al., 2012
Hopla, 2017	von Stedingk et al., 2008
Li et al., 2017	Wang and Herzschuh, 2011
Li et al., 2018 (review)	Wu et al., 2013 (from Li et al. 2018)
Li et al., 2011 (from Li et al. 2018)	Xu et al., 2014
Li et al., 2015	Zhang et al., 2017 (from Li et al. 2018)

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Table 2: Combination of taxonomic levels.

Taxon	Original Taxa
Acer	*Acer* + *Acer rubrum* + *Acer saccharum*
Alnus	*Alnus* + *Alnus*_shrub + *Alnus*_tree
Asteraceae	Asteraceae + *Ambrosia* + Asterac SF Cichor + Aster-Anthemis type + Compositae + Compositae SF Cichorioideae + *Leucanthemum vulgate*
Betula	*Betula* + *Betula*_shrub + *Betula*_tree
Brassicaceae	Brassicaceae + *Sinapis*
Campanulaceae	Campanulaceae + *Campanula gieseckiana*
Cornaceae	Cornaceae + *Cornus*
Elaeagnaceae	Elaeagnaceae + *Hippohae*
Ericales	Ericales + Ericaceae + *Calluna* + *Calluna vulgaris* + *Empetrum* + *Vaccinium*
Fabaceae	Fabaceae + *Robinia Sophora* + Cercis
Juniperus	*Juniperus*
Lamiaceae	Lamiaceae + *Mentha* type *Thymus* + *Thymus praecox* + *Vitex negundo*
Moraceae	Moraceae + *Maclura*
Orobanchaceae	Orobanchaceae + *Rhinanthus* type
Pinus	*Pinus* + *Pinus cembra*
Plantaginaceae	Plantaginaceae + *Plantago* + *Plantago lanceolata* + *Plantago media* + *Plantago montana* type + *Plantago maritima*
Poaceae	Poaceae + Graminae
PoaceaeCrop	*Avena triticum* + *Avena* type + *Avena* type b + *Hordeum* type + *Secale* + *Triticum* type
Ranunculaceae	Ranunculaceae + *Ranunculus acris* type + *Trollius europaeus*
Rosaceae	Rosaceae + *Filipendula* + *Potentilla* t.
Rubiaceae	Rubiaceae + *Galium* type
Rumex	*Rumex* + *Rumex* sect. *acetosa* + *Rumex acetosella*
Thymelaeaceae	Thymelaeaceae + *Stellera*
Tilia	*Tilia* + *Tilia begoniifolia* + *Tilia tomentosa*

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Table 3: Overview of Northern Hemispheric pollen productivity estimate (PPE) values with their standard error (SE) and pollen fall speed. Unknown SE are given with 0. PPE for taxa marked with an asterisk are recalculated relative to Poaceae .

Taxa	PPE	SE	Fall Speed (m/s)	Taxa	PPE	SE	Fall Speed (m/s)
Abies	6.88	1.44	0.120	Lamiaceae	1.06	0.13	0.016
Acer	0.32	0.09	0.056	Larix	0.52	0.00	0.107
*Aesculus	3.43	0.00	0.042	Liliaceae	1.49	0.11	
Alnus	7.46	0.15	0.021	Moraceae	1.10	0.55	0.016
Apiaceae	0.24	0.00		*Nitraria	20.00	0.00	0.016
Artemisia	9.60	0.12	0.012	Orobanchaceae	0.33	0.04	0.038
Asteraceae	0.41	0.06	0.032	Picea	2.29	0.07	0.056
Betula	4.40	0.09	0.027	Pinus	10.47	0.70	0.035
Brassicaceae	4.19	0.19	0.019	Plantaginaceae	2.09	0.13	0.026
Campanulaceae	2.29	0.14	0.022	**Poaceae**	**1.00**	**0.01**	**0.023**
Carpinus	4.52	0.43	0.042	*PoaceaeCrop	5.50	0.90	0.065
Caryophyllaceae	0.74	0.07	0.034	Populus	0.67	0.09	0.026
Castanea	11.49	0.49	0.004	*Pterocarya	26.84	0.00	0.029
Cerealia	1.13	0.23	0.065	Quercus	3.33	0.11	0.023
Chenopodiaceae	4.01	0.32	0.016	Ranunculaceae	1.66	0.16	0.014
Convolvulaceae	0.18	0.03		Rosaceae	1.10	0.09	0.010
Cornaceae	1.72	0.14	0.044	Rubiaceae	1.85	0.16	0.019
Corylus	1.97	0.13	0.025	Rumex	1.61	0.15	0.015
Cupressaceae	1.11	0.09	0.010	Salix	0.57	0.03	0.022
Cyperaceae	0.76	0.03	0.024	Sambucus nigra-type	1.30	0.12	0.013
*Elaeagnaceae	8.88	1.30	0.016	Sanguisorba	24.07	3.50	
Ephedra	0.96	0.14	0.015	Selaginella			0.041
Equisetum	0.09	0.02	0.021	Solanaceae			0.027
Ericales	0.59	0.01	0.032	Thalictrum	3.86	0.26	0.009
Fabaceae	0.33	0.04	0.025	Thymelaeaceae	33.05	3.78	0.031
Fagus	1.96	0.08	0.057	Tilia	1.17	0.13	0.031
Fraxinus	1.25	0.11	0.020	*Tsuga	1.12	0.11	0.056
Humulus	16.43	1.00	0.010	Ulmus	7.32	1.23	0.021
Iridaceae			0.012	Urtica	10.52	0.31	0.007
Juglans	0.30	0.05	0.033	*wild herbs	0.11	0.11	0.034
Juniperus	9.80	0.67	0.016				

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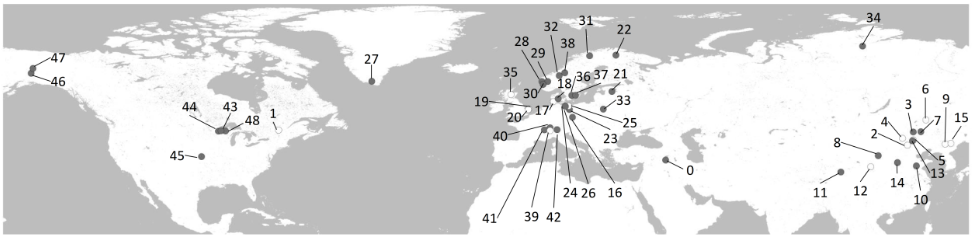
FIGURES



● Publication included in final dataset ○ Publication not included in final dataset

0 Filipova-Marinova et al., 2010
1 Chaput & Gajewski 2018
2 Ge et al., 2015°
3 Han et al., 2017°
4 He et al., 2016° Hulunbeier
5 He et al., 2016° Xilinhaote
6 He et al., 2016° Sunitezuoq
7 Li et al. In prep°
8 Li et al., 2011°
9 Li et al., 2015
10 Li et al., 2017
11 Wang and Herzschuh, 2011
12 Wu et al., 2013°
13 Xu et al., 2014
14 Zhang et al. 2017° Taiyue
15 Zhang et al. 2017° Changbai
16 Abraham and Kozáková, 2012
17 Andersen 1967
18 Nielsen 2004
19 Bunting et al., 2005 Calthorpe
20 Bunting et al., 2005 Wheatfen
21 Poska et al., 2011
22 Räsänen et al., 2007
23 Matthias et al., 2012
24 Theuerkauf et al. 2013 small lake
25 Theuerkauf et al. 2013 medium lake
26 Theuerkauf et al. 2015
27 Bunting et al., 2013
28 Hjelle 1998 Coast
29 Hjelle 1998 Inland
30 Hjelle and Sugita, 2012
31 Sjögren 2013 Dividalen
32 Sjögren 2013 Budalen
33 Baker et al., 2016
34 Niemeyer et al., 2015
35 Twiddle et al. 2012
36 Broström et al., 2004
37 Sugita et al., 1999 (from Gaillard 1994)
38 von Stedingk et al., 2008
39 Sjögren et al., 2008a
40 Soepboer et al., 2007
41 Mazier et al., 2008
42 Sjögren et al. 2008b
43 Calcote 1995 Sylvania
44 Calcote 1995 Wisconsin
45 Commerford et al. 2013
46 Hopla 2017 Alaska (Denali)
47 Hopla 2017 Alaska (Boreal Forest)
48 Sugita et al., 2006

Figure 1: Location overview of studies on pollen productivity estimates, Studies in italics do not have Poaceae as reference taxon and are not included in the final dataset. Studies with ° are extracted from Li et al. 2018.

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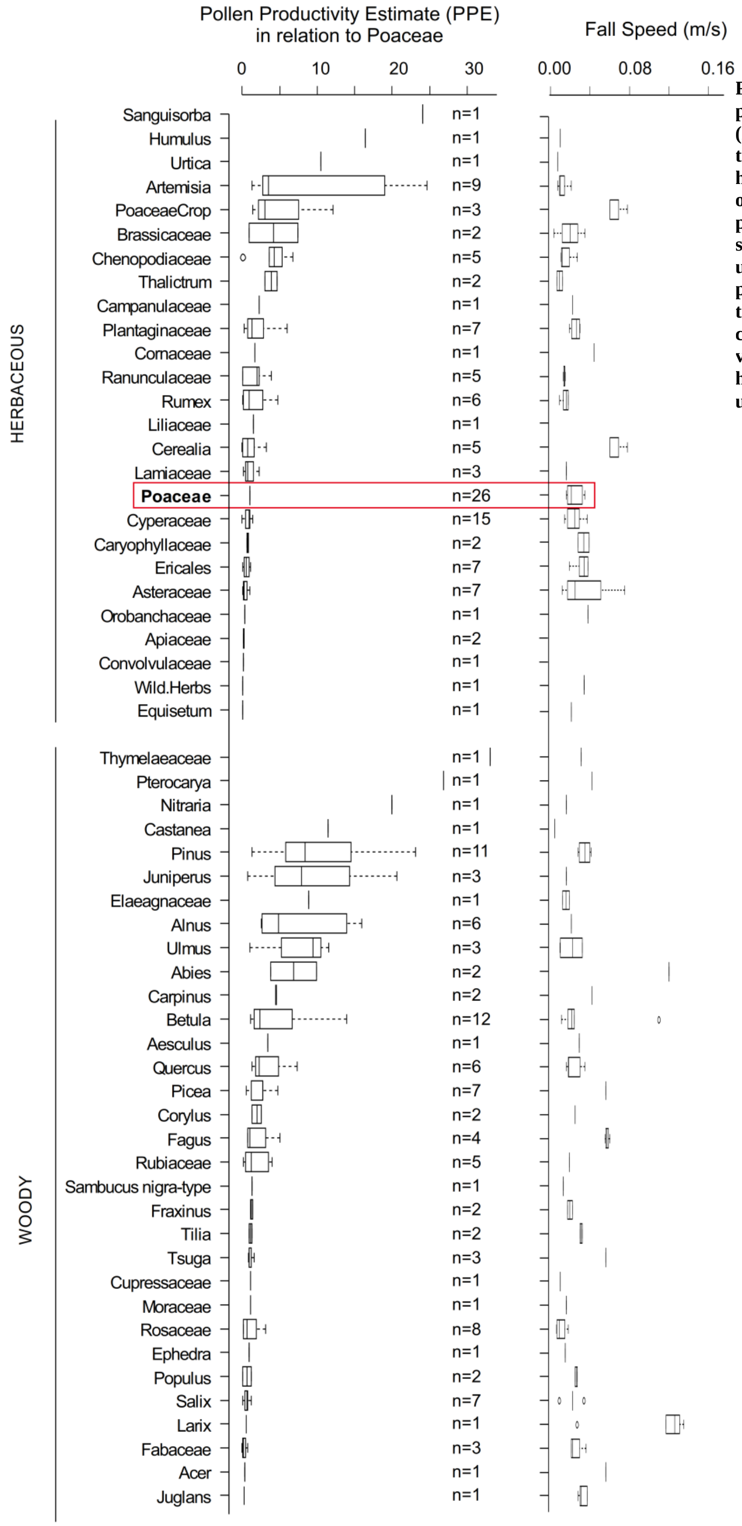

Figure 2: Overview of all pollen productivity estimate (PPE) values (left panel) which were included in the calculation of a mean PPE. The higher the PPE, the higher the overrepresentation of a taxon in a pollen sample and vice versa. Fall speeds (right panel) which have been used to calculate a mean fall speed per taxon. The lower the fall speed, the farther a pollen grain can be carried through the air and vice versa. Pollen with a low PPE and a high fall speed are thus highly underrepresented in pollen samples.

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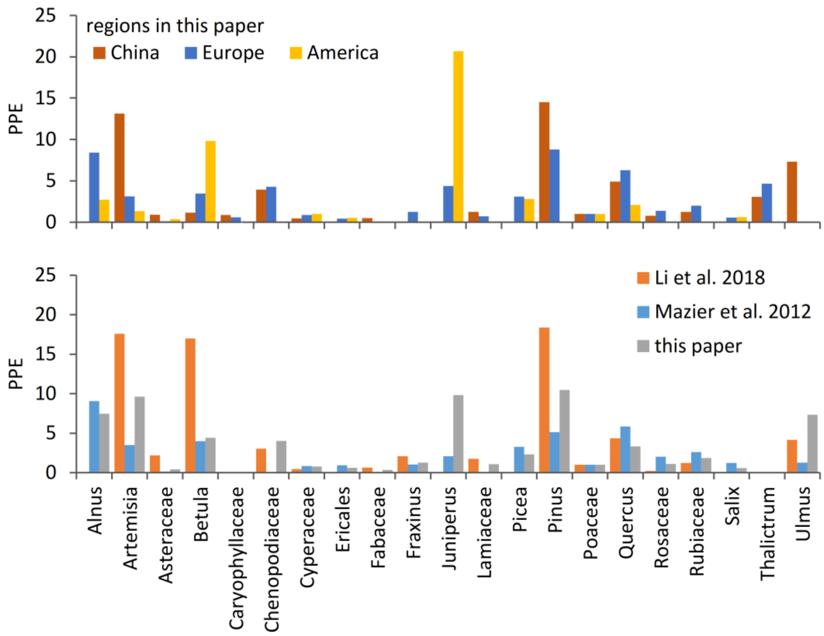

Figure 3: Pollen productivity estimate (PPE) values for selected species, compared between different regions within this paper (upper panel) and different studies (lower panel), showing similar values for some and a high variability for other taxa. We chose those taxa which are present in at least two study regions or two publications.

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Appendix

Table A1 Overview of available studies and their PPE values.

See attached pdf "Table A1 or https://doi.pangaea.de/10.1594/PANGAEA.908862 - Compilation of pollen productivity estimates from Northern Hemisphere extratropics.

Table A2 Raw fall speeds with original pollen type, target taxon as used for our dataset, fall speed in m/s, the original publication of the value and the publication we are citing from

Pollen morphological type	**Target taxon**	**FS (m/s)**	**Original publication**	**Found in:**
Abies	Abies	0.12	Eisenhut, 1961	Cao et al., 2019
Abies	Abies	0.12	Mazier et al., 2012	Chaput and Gajewski, 2018
Acer	Acer	0.056	Mazier et al., 2012	Chaput and Gajewski, 2018
Acer	Acer	0.056	Sugita, 1993, 1994	Sugita et al., 1999
Achillea	Asteraceae	0.017		Bunting et al., 2013
Aesculus	Aesculus	0.029	Knoll, 1932	Flilipova-Marinova et al. , 2010
Alnus	Alnus	0.021	Eisenhut, 1961	Cao et al., 2019
Alnus	Alnus	0.021	Eisenhut, 1961	Cao et al., 2019
Alnus	Alnus	0.021	Gaillard et al., 2008	Hjelle and Sugita, 2012
Amaranthaceae/Chenopodiaceae	Chenopodiaceae	0.027		Li et al., 2017
Ambrosia	Asteraceae	0.019		Commerford et al., 2013
Artemisia	Artemisia	0.007	Han et al., 2017	Li et al., 2018
Artemisia	Artemisia	0.007	Zhang et al., 2017	Li et al., 2018
Artemisia	Artemisia	0.009	Ge et al., 2015	Li et al., 2018
Artemisia	Artemisia	0.009	Li et al., in prep.	Li et al., 2018
Artemisia	Artemisia	0.009	Zhang et al., 2017	Li et al., 2018
Artemisia	Artemisia	0.0093		Xu et al., 2014
Artemisia	Artemisia	0.01	Li et al., 2011	Li et al., 2018
Artemisia	Artemisia	0.01	Wu et al., 2013	Li et al., 2018
Artemisia	Artemisia	0.0101		Wang and Herzschuh, 2011
Artemisia	Artemisia	0.013		Commerford et al., 2013
Artemisia	Artemisia	0.014		Abraham and Kozáková, 2012
Artemisia	Artemisia	0.021	He et al., 2016	Li et al., 2018
Artemisia	Artemisia	0.021		Poska et al., 2011
Artemisia	Artemisia	0.015		Li et al., 2017
Aster/Anthemis-type	Asteraceae	0.025		Li et al., 2017
Asteraceae	Asteraceae	0.0118		Xu et al., 2014
Asteraceae	Asteraceae	0.014		Commerford et al., 2013
Asteraceae	Asteraceae	0.051	Broström, 2002	Cao et al., 2019
Asteraceae SF	Asteraceae	0.028		Li et al., 2017
Avena-Triticum group (m)	PoaceaeCrop	0.06	Gregory, 1973	Theuerkauf et al., 2015
Avena-Typ (b)	PoaceaeCrop	0.06	Gregory, 1973	Theuerkauf et al., 2015
Avena-type	PoaceaeCrop	0.078	Soepboer et al., 2007	Matthias et al., 2012

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Pollen morphological type	**Target taxon**	**FS (m/s)**	**Original publication**	**Found in:**
Betula	Betula	0.011	Wu et al., 2013	Li et al., 2018
Betula	Betula	0.011	Zhang et al., 2017	Li et al., 2018
Betula	Betula	0.017	Zhang et al., 2017	Li et al., 2018
Betula	Betula	0.018		Bunting et al., 2013
Betula	Betula	0.019	Han et al., 2017	Li et al., 2018
Betula	Betula	0.019		Li et al., 2015
Betula	Betula	0.024	Eisenhut, 1961	Cao et al., 2019
Betula	Betula	0.024	Eisenhut, 1961	Cao et al., 2019
Betula	Betula	0.024	Gaillard et al., 2008	Hjelle and Sugita, 2012
Betula	Betula	0.024	Jackson and Lyford, 1999	Bunting et al., 2013
Betula	Betula	0.024	Mazier et al., 2012	Chaput and Gajewski, 2018
Betula	Betula	0.11		Bunting et al., 2013
Brassicaceae	Brassicaceae	0.0034		Xu et al., 2014
Brassicaceae	Brassicaceae	0.02		Li et al., 2017
Calluna vulgaris	Ericales	0.038	Gaillard et al., 2008	Hjelle and Sugita, 2012
Calluna vulgaris	Ericales	0.038		Broström et al., 2004
Campanula	Campanulaceae	0.022		Bunting et al., 2013
Cannabis/Humulus	Humulus	0.01		Li et al., 2017
Carpinus	Carpinus	0.042	Eisenhut, 1961	Cao et al., 2019
Caryophyllaceae	Caryophyllaceae	0.028		Bunting et al., 2013
Caryophyllaceae	Caryophyllaceae	0.039		Li et al., 2017
Castanea	Castanea	0.004		Li et al., 2017
Cercis	Fabaceae	0.023	Dyakowska, 1936	Flilipova-Marinova et al. , 2010
Cerealia	Cerealia	0.06	Broström et al., 2004	Poska et al., 2011
Cerealia	Cerealia	0.06	Gregory, 1961	Abraham and Kozáková, 2012
Cerealia	Cerealia	0.078		Soepboer et al., 2007
Cerealia type	Cerealia	0.06	Gregory, 1973	Sugita et al., 1999
Chenopodiaceae	Chenopodiaceae	0.0108		Xu et al., 2014
Chenopodiaceae	Chenopodiaceae	0.011		Commerford et al., 2013
Chenopodiaceae	Chenopodiaceae	0.0117		Wang and Herzschuh, 2011
Chenopodiaceae	Chenopodiaceae	0.019		Abraham and Kozáková, 2012
Cichorioideae				
Comp. SF Cichorioideae	Asteraceae	0.051		Broström et al., 2004
Cornus	Cornaceae	0.044		Commerford et al., 2013
Corylus	Corylus	0.025	Gregory, 1973	Cao et al., 2019
Corylus	Corylus	0.025	Knoll as cited in Gregory, 1973	Soepboer et al., 2007
Cupressaceae	Cupressaceae	0.01	Li et al., 2017	Li et al., 2018
Cupressaceae	Cupressaceae	0.01		Li et al., 2017
Cyperaceae	Cyperaceae	0.014	Li et al., in prep.	Li et al., 2018

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Pollen morphological type	Target taxon	FS (m/s)	Original publication	Found in:
Cyperaceae	Cyperaceae	0.0152		Xu et al., 2014
Cyperaceae	Cyperaceae	0.017	Han et al., 2017	Li et al., 2018
Cyperaceae	Cyperaceae	0.019	Zhang et al., 2017	Li et al., 2018
Cyperaceae	Cyperaceae	0.023	Wu et al., 2013	Li et al., 2018
Cyperaceae	Cyperaceae	0.026		Bunting et al., 2013
Cyperaceae	Cyperaceae	0.028	He et al., 2016	Li et al., 2018
Cyperaceae	Cyperaceae	0.0291		Wang and Herzschuh, 2011
Cyperaceae	Cyperaceae	0.035		Sugita et al., 1999
Cyperaceae	Cyperaceae	0.037		Li et al., 2017
Elaeagnaceae	Elaeagnaceae	0.012	Zhang et al., 2017	Li et al., 2018
Elaeagnaceae	Elaeagnaceae	0.019	Zhang et al., 2017	Li et al., 2018
Empetrum	Ericales	0.019		Räsänen et al., 2007
Ephedra	Ephedra	0.015		Xu et al., 2014
Equisetum	Equisetum	0.021		Bunting et al., 2013
Ericaceae	Ericales	0.034	Broström et al., 2004	Cao et al., 2019
Fabaceae	Fabaceae	0.021		Commerford et al., 2013
Fagus	Fagus	0.055	Knoll as cited in Gregory, 1973	Soepboer et al., 2007
Fagus	Fagus	0.057	Gregory, 1973	Mazier et al., 2008
Fagus	Fagus	0.057	Mazier et al., 2012	Chaput and Gajewski, 2018
Fagus	Fagus	0.0603	Dyakowska, 1936	Flilipova-Marinova et al. , 2010
Filipendula	Rosaceae	0.006		Broström et al., 2004
Fraxinus	Fraxinus	0.017		Li et al., 2015
Fraxinus	Fraxinus	0.022	Eisenhut, 1961	Cao et al., 2019
Gramineae	Poaceae	0.035		Sugita et al., 1999
Hordeum (m)	PoaceaeCrop	0.06	Gregory, 1973	Theuerkauf et al., 2015
Hordeum-type	PoaceaeCrop	0.06		Matthias et al., 2012
Iridaceae	Iridaceae	0.0121		Xu et al., 2014
Juglans	Juglans	0.028	Zhang et al., 2017	Li et al., 2018
Juglans	Juglans	0.03		Li et al., 2015
Juglans	Juglans	0.031	Zhang et al., 2017	Li et al., 2018
Juglans	Juglans	0.037	Bodmer, 1922	Li et al. 2015
Juglans regia	Juglans	0.037		Li et al., 2017
Juniperus	Juniperus	0.016	Eisenhut, 1961	Broström et al., 2004
Larix	Larix	0.027	Zhang et al., 2017	Li et al., 2018
Larix	Larix	0.117	Zhang et al., 2017	Li et al., 2018
Larix	Larix	0.126	Eisenhut, 1961	Cao et al., 2019
Larix	Larix	0.131	Eisenhut, 1961	Li et al., 2015
Larix	Larix	0.135		Li et al., 2015
Lespedeza-type	Fabaceae	0.036		Li et al., 2017
Maclura	Moraceae	0.016		Commerford et al., 2013
Nitraria	Nitraria	0.016	Li et al., 2011	Li et al., 2018
Picea	Picea	0.056	Eisenhut, 1961	Cao et al., 2019
Picea	Picea	0.056	Mazier et al., 2012	Chaput and Gajewski, 2018

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Pollen morphological type	Target taxon	FS (m/s)	Original publication	Found in:
Pinus	Pinus	0.028	Li et al., 2017	Li et al., 2018
Pinus	Pinus	0.03	Zhang et al., 2017	Li et al., 2018
Pinus	Pinus	0.031	Eisenhut, 1961	Cao et al., 2019
Pinus	Pinus	0.039	Han et al., 2017	Li et al., 2018
Pinus	Pinus	0.039		Li et al., 2015
Pinus	Pinus	0.041	Dyakowska, 1936	Soepboer et al., 2007
Pinus	Pinus	0.041	Zhang et al., 2017	Li et al., 2018
Pinus	Pinus	0.028		Li et al., 2017
Plantago	Plantaginaceae	0.024		Mazier et al., 2008
Plantago	Plantaginaceae	0.03		Mazier et al., 2008
Plantago lanceolata	Plantaginaceae	0.019		Bunting et al., 2013
Plantago lanceolata	Plantaginaceae	0.029		Broström et al., 2004
Poaceae	Poaceae	0.016		Xu et al., 2014
Poaceae	Poaceae	0.016	Xu et al., 2014	Li et al., 2018
Poaceae	Poaceae	0.017	Li et al., in prep.	Li et al., 2018
Poaceae	Poaceae	0.017		Bunting et al., 2013
Poaceae	Poaceae	0.017	Zhang et al., 2017	Li et al., 2018
Poaceae	Poaceae	0.0185		Wang and Herzschuh, 2011
Poaceae	Poaceae	0.02	Zhang et al., 2017	Li et al., 2018
Poaceae	Poaceae	0.022	Han et al., 2017	Li et al., 2018
Poaceae	Poaceae	0.022		Li et al., 2017
Poaceae	Poaceae	0.023	Li et al., 2011	Li et al., 2018
Poaceae	Poaceae	0.032	He et al., 2016	Li et al., 2018
Poaceae	Poaceae	0.034	Wu et al., 2013	Li et al., 2018
Poaceae	Poaceae	0.035	Sugita et al., 1999	Mazier et al., 2008
Populus	Populus	0.025	Eisenhut, 1961	Matthias et al., 2012
Populus	Populus	0.027		Commerford et al., 2013
Potentilla type	Rosaceae	0.0066		Xu et al., 2014
potentilla type	Rosaceae	0.011		Bunting et al., 2013
Potentilla type	Rosaceae	0.018		Broström et al., 2004
Pterocarya	Pterocarya	0.042	Eisenhut, 1961	Flilipova-Marinova et al. , 2010
Quercus	Quercus	0.016	Zhang et al., 2017	Li et al., 2018
Quercus	Quercus	0.018	Han et al., 2017	Li et al., 2018
Quercus	Quercus	0.018		Li et al., 2015
Quercus	Quercus	0.018	Wu et al., 2013	Li et al., 2018
Quercus	Quercus	0.019	Zhang et al., 2017	Li et al., 2018
Quercus	Quercus	0.035	Eisenhut, 1961	Cao et al., 2019
Quercus	Quercus	0.035	Mazier et al. 2012	Chaput and Gajewski, 2018
Quercus	Quercus	0.025		Li et al., 2017
Ranunculaceae	Ranunculaceae	0.014		Broström et al., 2004
Ranunculaceae	Ranunculaceae	0.015		Bunting et al., 2013
Rhinantus-type	Orobanchaceae	0.038		Bunting et al., 2013
Robinia/Sophora	Fabaceae	0.021		Li et al., 2017

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Pollen morphological type	Target taxon	FS (m/s)	Original publication	Found in:
Rubiaceae	Rubiaceae	0.019		Broström et al., 2004
Rumex acetosa	Rumex	0.013		Bunting et al., 2013
Rumex acetosa	Rumex	0.018	Jackson and Lyford, 1999	Bunting et al., 2013
Rumex acetosa type	Rumex	0.018		Broström et al., 2004
Rumex acetosella	Rumex	0.009	Broström et al., 2004	Bunting et al., 2013
Rumex acetosella	Rumex	0.016		Bunting et al., 2013
Salix	Salix	0.009		Bunting et al., 2013
Salix	Salix	0.022	Gregory, 1973	Sugita et al., 1999
Salix	Salix	0.022	Jackson and Lyford, 1999	Bunting et al., 2013
Salix	Salix	0.022	Sugita et al., 1999	Poska et al., 2011
Salix	Salix	0.034	Gregory, 1973	Cao et al., 2019
Sambucus nigra-type	Sambucus nigra-type	0.013		Abraham and Kozáková, 2012
Saussurea/Carduus/Cirsium-type	Asteraceae	0.075		Li et al., 2017
Secale cereale (m)	PoaceaeCrop	0.06	Gregory, 1973	Theuerkauf et al., 2015
Selaginella	Selaginella	0.041		Li et al., 2017
Sinapis type (m)	Brassicaceae	0.035		Theuerkauf et al., 2015
Solanum nigrum-type	Solanaceae	0.027		Li et al., 2017
Thalictrum	Thalictrum	0.0066		Xu et al., 2014
Thalictrum	Thalictrum	0.012		Bunting et al., 2013
Thymus	Thymelaeaceae	0.031		Bunting et al., 2013
Tilia	Tilia	0.03		Li et al., 2015
Tilia	Tilia	0.032	Gregory, 1973	Cao et al., 2019
Triticum	PoaceaeCrop	0.078	Soepboer et al., 2007	Matthias et al., 2012
Triticum-Typ (b)	PoaceaeCrop	0.06	Gregory, 1973	Theuerkauf et al., 2015
Trollius europaeus	Ranunculaceae	0.013		Mazier et al., 2008
Tsuga	Tsuga	0.056	Gaillard et al., 2008	Chaput and Gajewski, 2018
Ulmus	Ulmus	0.0095		Xu et al., 2014
Ulmus	Ulmus	0.01	Xu et al., 2014	Li et al., 2018
Ulmus	Ulmus	0.022	Han et al., 2017	Li et al., 2018
Ulmus	Ulmus	0.022		Li et al., 2015
Ulmus	Ulmus	0.032	Gregory, 1973	Cao et al., 2019
Ulmus	Ulmus	0.032		Li et al., 2017
Urtica	Urtica	0.007		Abraham and Kozáková, 2012
Vaccinium	Ericales	0.029		Räsänen et al., 2007
Vitex negundo	Lamiaceae	0.016		Li et al., 2017
wild herbs	wild herbs	0.0343		Matthias et al., 2012
Zea mays		0.185		Li et al., 2017

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Fall speeds

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