Plant species richness of the central European landscape on different spatial scales measured with a new approach

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Background

'Biodiversity' has been an important catchphrase both in science and in politics for some 15 years now. Well-funded research programs, countless publications, and even complete new journals have been devoted to the study of biodiversity, its patterns and causations as well as its decline and how this can be halted.

Besides this enormous efforts, some very basic pieces of knowledge are still missing, even in such well-studied regions as central Europe. The question how rich in species the central European landscape is on average can well be answered for scales from quadrants of topographic map sheets onwards (> 25 km²) but not for scales below. However, square metres or some dozens or hundreds of square metres are the scales on which studies dealing with the conservation or restoration of biodiversity are usually focussing.

Yet, these studies are still lacking a well-founded benchmark to evaluated their results. Moreover, the few available studies/reviews with data of species densities on small scales (e.g. Hobohm 1998, Dengler 2005) usually provide only values for preconceived plant community types without actually knowing (a) how representative the used relevés are for the respective community and (b) what proportions of a landscape are covered by the different types. Finally, most studies on plant diversity so far only deal with vascular plants and exclude bryophytes and lichens.

Aims

The basic aims of our study thus are:

1. to quantify average species densities for vascular plants, bryophytes, and lichens (mean values, frequency and spatial distributions) on scales from square centimetres to hundreds of square metres in an objective manner;
2. to determine the most appropriate functions for the species-area relationships (SAR) and their parameters;
3. to compare the values of (1) and (2) across geographic regions and for different landscape types.

However, our study can provide answers on many other questions as well, e.g.:

4. What are the most frequent species on these small scales?
5. Are neophytes an actual threat to the native plant diversity?
6. How do the components of the total plant diversity such as subgroups arranged according to their taxonomic position, their PFTs or their floristic status (indigenous, archaeophytic, neophytic, ephemerophytic, cultivated) interact?
7. How is plant diversity on these scales related to environmental and structural factors or spatial heterogeneity?

Methods

Within a study area, we selected the positions of the nested-plot series **totally at random and irrespectively of structural and/or floristic homogeneity**. In the field, the 'starting points' were then located with the help of a GPS. From a starting point, the largest plot (100 m²) was delimited as a square that reaches 10 m to the north and 10 m to the east.

Within this largest plot, we placed **series of nested sub-plots** in each of the four corners. To enable unbiased analyses of the SARs, the sizes of the subplots approximately form a geometric series: **0.0001 m², 0.0009 m², 0,01 m², 0.09 m², 1 m², and 9 m²**. We recorded species lists (shoot presence) of vascular plants, bryophytes and lichens (including non-terricolous taxa) for all sub-plots and the complete plot. For the 9 m² plots, additionally regular phytosociological relevés were made and various structural and environmental parameters (e.g. soil properties) were measured or estimated.

Up to now, we have applied this method to two contrasting landscapes in the north German lowlands.

(1) In **NE Brandenburg**, we analysed 6 km² within the topographic map sheet **TK 3049** (16 series of nested plots) arround the village of Brodowin in the Biosphere reserve 'Schorfheide-Chorin' (subcontinental climate; ca. 30 % forest, 30 % arable land, 30 % grassland, 10 % settlement and others)

(2) In **NE Lower Saxony**, we analysed the entire topographic map sheet **TK 2728** (ca. 120 km²; preliminary results, 34 series of nested plots so far) around Lüneburg (subatlantic climate; ca. 40 % forest, 25 % arable land, 15 % grassland, 20 % settlement).

Results and discussion

Species densities

Area [m²]	*Mean ± SD*		*Difference*	*Absolute*	
	TK 2728	*TK 3049*		*Minimum*	*Maximum*
0.0001	**1.8** ± 1.2	NA	NA	0	5
0.0009	**2.6** ± 1.7	**2.7** ± 1.8	4%	0	9
0.01	**3.7** ± 2.4	**4.2** ± 2.5	14%	0	13
0.09	**5.3** ± 3.5	**6.2** ± 3.3	17%	0	15
1	**8.9** ± 6.1	**11.0** ± 5.9	24%	0	28
9	**15.6** ± 10.3	**18.1** ± 8.6	16%	1	52
100	**40.6** ± 26.6	**42.9** ± 22.2	6%	4	135

The **mean species densities** for the different plot sizes were rather similar in both regions, however somewhat higher in NE Brandenburg throughout. Potential explanations for this difference are a higher regional species pool, a structurally richer landscape or a lower intensity of land-use there.

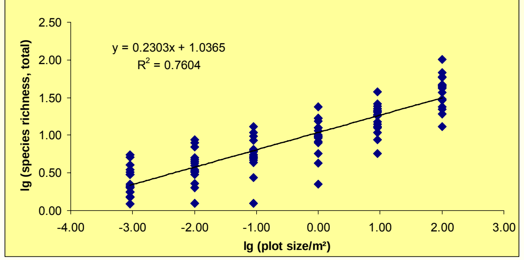
The **variance of the species density** was nearly scale-invariant with a coefficient of variation (CV) that ranges from 65-69% in Lower Saxony and from 47-65% in Brandenburg. This contrasts to the findings of Dengler (2006) within certain vegetation types. The lower values in Brandenburg can be explained by the smaller study area (6 km² vs. 120 km²).

Non-vascular plants contributed a significant share to the total species richness. On 100 m², they sum up for approximately one quarter of the species composition (22% in TK 2728, 27% in TK 3049).

Species-area relationships

The SARs for the total species composition as well as for different subgroups could well be described by **power functions (*S* = *c A*^z^)** throughout the studied range of plot sizes (six orders of magnitude!). Neither exponential functions nor saturation functions resulted in a reasonable fit.

Species-area relationship in the study area TK 3049
(*n* per plot size = 16)



The increments of the power functions (*z* values) for the two study regions were identical to three decimal places (0.231). This value is somewhat lower than the often assumed values 0.25 (Sugihara 1981) or 0.262 (Preston 1962) but higher than the value 0.20 estimated as a mean for central European herbaceous plant communities (Hobohm 1998).

Species group	*TK 2728*		*TK 3049*	
	c	*z*	*c*	*z*
all plant taxa	1.028	**0.231**	1.086	**0.231**
vascular plants	0.924	**0.228**	0.984	**0.220**
bryophytes	0.215	**0.207**	0.341	**0.248**
lichens	-0.257	**0.368**	-0.836	**0.672**
indigenous taxa	NA		0.985	**0.221**
archaeophytes	NA		-0.077	**0.336**
neophytes	NA		-0.478	**0.275**
cultivated taxa	NA		-0.646	**0.183**

The *z* values for vascular plants and bryophytes were very similar to the total values but the SAR was much steeper for lichens, indicating a highly clumped distribution of lichen diversity in the studied landscapes. As regards the floristic status, neophytes and particularly archaeophytes had higher *z* values (heterogeneous diversity distribution) and cultivated taxa lower *z* values (homogeneous diversity distribution) than indigenous taxa.

Scale dependence of *z* values

Size range [m²]	*TK 2728*	*TK 3049*	*Berkshire (UK)**
0.0001–0.0009	0.178	NA	NA
0.0009–0.01	0.150	0.178	NA
0.01–0.09	0.164	0.172	0.18
0.09–1	0.215	0.231	0.10
1–9	0.264	0.243	0.20
9–100	0.366	0.346	0.20
1000–100	NA	NA	0.37
1000–10000	NA	NA	0.39

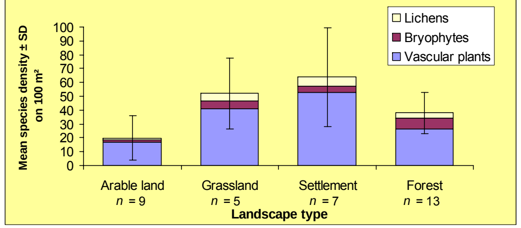
* Crawley & Harral (2001: only vascular plants)

Whereas one general power function results in a reasonable fit throughout the studied plot sizes, there is some degree of scale dependence of the *z* values. They slightly increase from small to moderate plot sizes as previously shown by Crawley & Harral (2001) whereas they approach 0 for very small plots (cf. Dengler 2005).

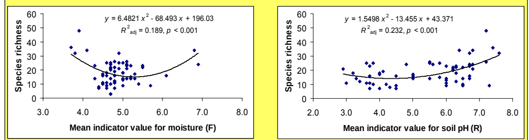
Factors influencing species densities

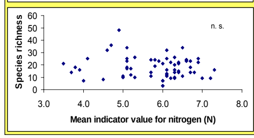
There were large differences in the mean species richness of plots in different landscape types. Due to a considerable variance and a relatively low number of studied plots, however, only the difference between arable land (20 species on 100 m²) vs. settlement (64 species on 100 m²) was significant .

Total plant species richness in different landscape types on TK 2728 (Lower Saxony)



Total plant species richness in relation to Ellenberg indicator values for 9 m² plots on TK 3049 (Brandenburg)





Species densities showed a u-shaped relation both to F and R values. Thus, higher species densities were found on wet and dry sites compared to intermediate ones, and species densities also increased from low to high pH values with an increasing increment. Astonishingly, we found no correlation between N value and species densities.

The most frequent taxa on 100 m²

The most frequent taxa highly coincide between the two study areas. Six taxa occurred on more than 1/3 of the plots both in Lower Saxony and in Brandenburg (**bold**). They include two grasses, two bryophytes (B), and one lichen (L). Most common in both regions was the moss *Brachythecium rutabulum*. Most of the frequent taxa are indigenous (I), and only one archaeophyte (A) and one neophyte (N) are included in the list.

TK 2728 - Lower Saxony				*TK 3049 - Brandenburg*			
Brachythecium rutabulum	**B**	**I**	**65%**	**Brachythecium rutabulum**	**B**	**I**	**81%**
Holcus lanatus		I	53%	**Hypnum cupressiforme var. cupressiforme**	**B**	**I**	**63%**
Quercus robur		I	50%	**Elymus repens ssp. repens**		**I**	**56%**
Taraxacum spec. (mostly sect. Ruderalia)		**I**	**50%**	Stellaria media		I	56%
Elymus repens ssp. repens		**I**	**47%**	**Taraxacum spec. (mostly sect. Ruderalia)**		**I**	**56%**
Agrostis capillaris		I	44%	Impatiens parviflora		N	50%
Lolium perenne		I	44%	Bryum spec. (excl. B. argenteum)	B	I	44%
Dactylis glomerata agg.		I	41%	Fagus sylvatica		I	44%
Festuca rubra agg.		I	38%	**Lepraria incana**	**L**	**I**	**44%**
Galium aparine		I	38%	**Lolium perenne**		**I**	**44%**
Hypnum cupressiforme var. cupressiforme	**B**	**I**	**38%**	Lophocolea heterophylla	B	I	44%
Lepraria incana	**L**	**I**	**35%**	Poa trivialis ssp. trivialis		I	44%
				Urtica dioica		I	44%
				Cerastium holosteoides		I	38%
				Chenopodium album		A/I	38%
				Dicranella heteromalla	B	I	38%
				Pinus sylvestris		I	38%
				Plantago major		I	38%
				Polygonum aviculare agg.		I	38%
				Rubus idaeus		I	38%

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