

Palaearctic grassland vegetation – broad-scale patterns of biodiversity and community types and the utility of large vegetation-plot databases to study these

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Topics today

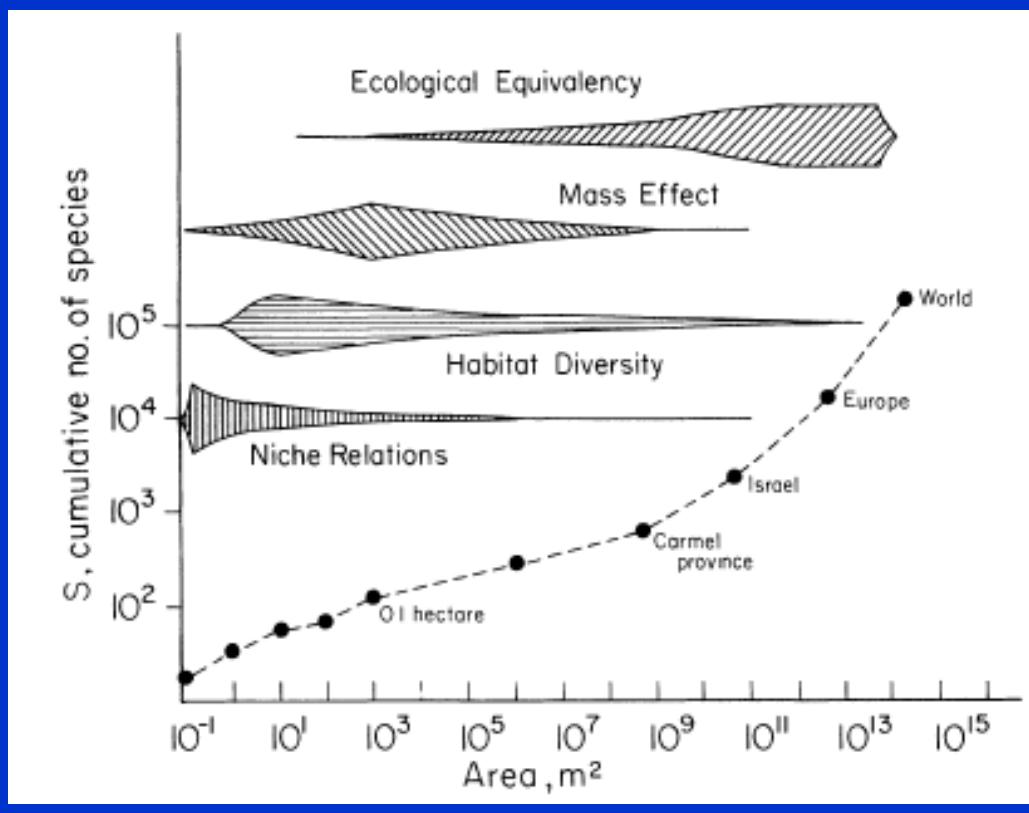
1. **Background: Why to study plot-scale diversity patterns of Palaearctic grasslands?**
2. **High-quality data from the EDGG Research Expeditions**
 - Transylvania
 - Öland
 - Combined data
3. **Vegetation-plot databases**
 - Organisation and content of EVA
 - sPlot – the global counterpart
 - National and supranational grassland databases
 - Publication plans

Part 1: Background

- Why to study plot-scale diversity patterns of Palaeartic grasslands?

Scale dependency in ecology and biodiversity

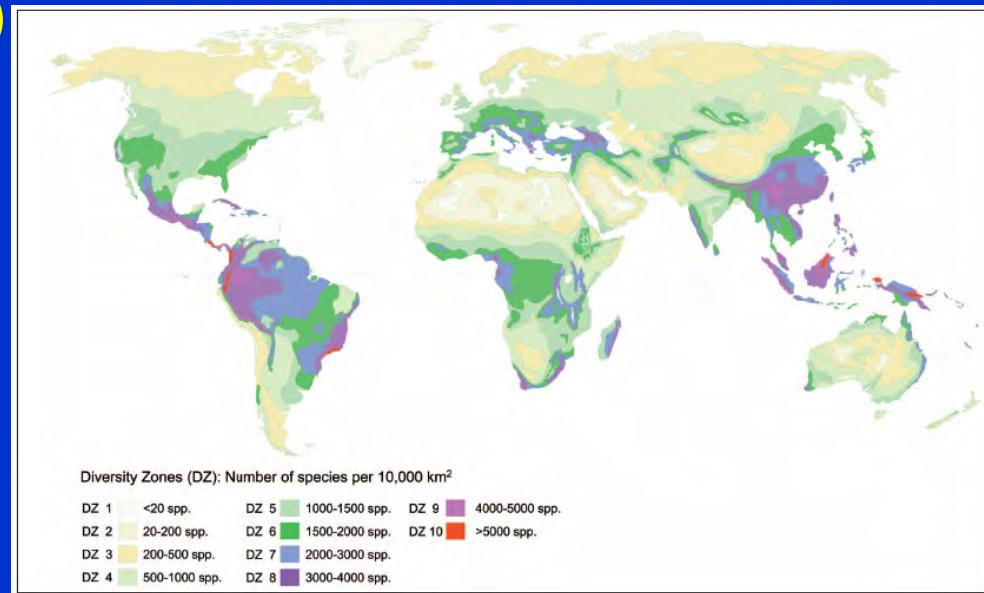
- **Species-area relationship (SAR)**
(Arrhenius 1921, Gleason 1922)
- **Scale-dependence of drivers of biodiversity:** conceptual model
(Shmida & Wilson 1985, *J. Biogeogr.* 12: 1–20)



- **Factors influencing species composition depend on grain size**
(Reed et al. 1993, *J. Veg. Sci.* 4: 329–340)
- **Factors influencing species richness depend on grain size**
 - few individual studies (e.g. Giladi et al. 2011, *J. Veg. Sci.* 22: 983–996)
 - recent meta-analyses (Field et al. 2009, *J. Biogeogr.* 36: 132–147; Siefert et al. 2012, *J. Veg. Sci.* 23: 942–951)
- **Practically all aspects of biodiversity depend on grain size**
 - ordinations (Otýpková & Chytrý 2006, *J. Veg. Sci.* 17: 465–472)
 - frequency of species, frequency distribution, and thus classification (Dengler et al. 2009, *J. Veg. Sci.* 20: 754–766)
 - ranking of biodiversity hotspots (Wilson et al. 2012, *J. Veg. Sci.* 23: 796–802)
 - etc. etc.
- **Other aspects of scale dependence** (in the wider sense)
 - dependence on spatial extent, time, or taxonomic resolution
 - differences between α -, β - and γ -diversity
 - differences among biodiversity indices (richness, evenness, combined)

Combining large extent with small grain

Global diversity patterns of vascular plants reasonably known at large spatial grain sizes (e.g. 10,000 km²)



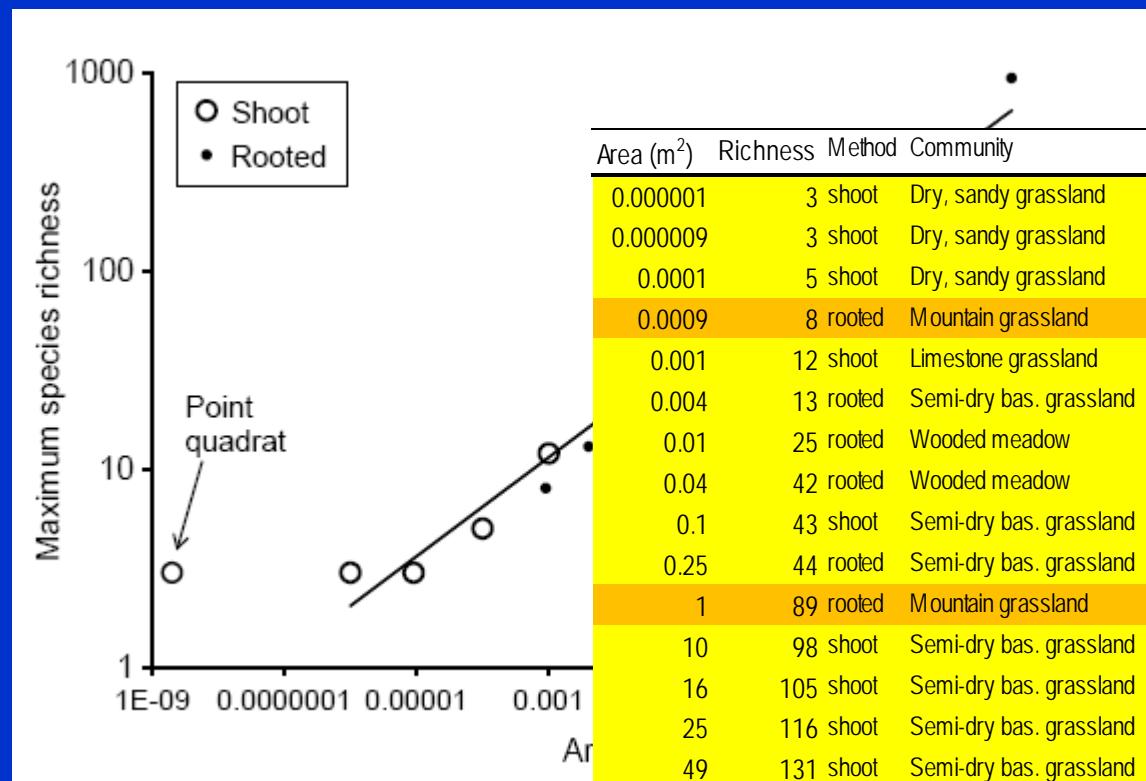
Barthlott, W., Mutke, J., Rafiqpoor, D., Kier, G., Kreft, H. (2005): Global centers of vascular plant diversity. – *Nova Acta Leopoldina N. F.* 92: 61–83.

But what about small (1 m² - 10 ha) and medium grains (1-1000 km²)?

- With a few exceptions, no representative datasets for larger extents
(Beck et al. 2012: What is on the horizon for macroecology, *Ecography* 35: 673–683)
- However:**
 - most ecological processes act at small scales
 - medium scales are particularly conservation-relevant

Global maxima of vascular plant species richness

(Wilson, Peet, Dengler & Pärtel 2012, *J. Veg. Sci.* 23: 796–802)



Area (m ²)	Richness	Method	Community	Region	Reference
0.000001	3	shoot	Dry, sandy grassland	Germany	J. Dengler et al. (unpubl.; see Dengler et al. 2004)
0.000009	3	shoot	Dry, sandy grassland	Germany	J. Dengler et al. (unpubl.; see Dengler et al. 2004)
0.0001	5	shoot	Dry, sandy grassland	Germany	J. Dengler et al. (unpubl.; see Dengler et al. 2004)
0.0009	8	rooted	Mountain grassland	Argentina	J.J. Cantero (unpubl.)
0.001	12	shoot	Limestone grassland	Sweden	van der Maarel & Sykes (1993) ¹
0.004	13	rooted	Semi-dry bas. grassland	Czech Republic	Klimeš et al. (2001)
0.01	25	rooted	Wooded meadow	Estonia	Kull & Zobel (1991)
0.04	42	rooted	Wooded meadow	Estonia	Kull & Zobel (1991)
0.1	43	shoot	Semi-dry bas. grassland	Romania	Dengler et al. (2009)
0.25	44	rooted	Semi-dry bas. grassland	Czech Republic	Klimeš et al. (2001)
1	89	rooted	Mountain grassland	Argentina	Cantero et al. (1999)
10	98	shoot	Semi-dry bas. grassland	Romania	Dengler et al. (unpubl.; see Dengler et al. 2009)
16	105	shoot	Semi-dry bas. grassland	Czech Republic	Z. Otýpková (unpubl.)
25	116	shoot	Semi-dry bas. grassland	Czech Republic	Z. Otýpková (unpubl.)
49	131	shoot	Semi-dry bas. grassland	Czech Republic	Z. Otýpková (unpubl.)
100	233	rooted	Tropical lowland rainforest	Costa Rica	Whitmore et al. (1985)
1000	313	rooted	Tropical lowland rainforest	Colombia	Duivenvoorden (1994)
4000	489	rooted	Tropical lowland rainforest	Colombia	Galeano et al. (1998)
10000	942	rooted	Tropical rainforest	Ecuador	Balslev et al. (1998)

- Maxima < 100 m²: temperate grassland; ≥ 100 m²: neotropical rain forests

Part 2: High-quality data from the EDGG Research Expeditions

- **Transylvania (and general sampling design)**
- **Öland**
- **Combined data (and future expeditions)**



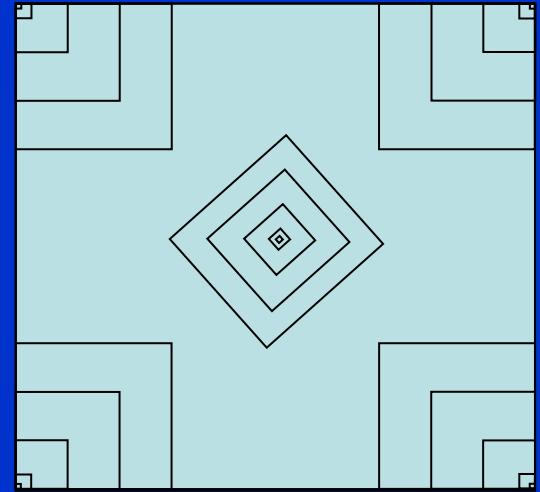
EDGG Research Expeditions (now: Field Workshops)

- 2009 Transylvania; 2010 Ukraine; 2011 Bulgaria; 2012 Sicily & N Greece; 2013 South Siberia; 2014 North Spain; 2015 South Poland
(similar datasets from Öland (Sweden), Saaremaa (Estonia), NE Germany)
- Providing high-quality biodiversity data from undersampled regions for large-scale comparisons:
 - characterisation of plant diversity at different spatial scales
 - dependence on environmental parameters
 - description and analysis of species-area relationships



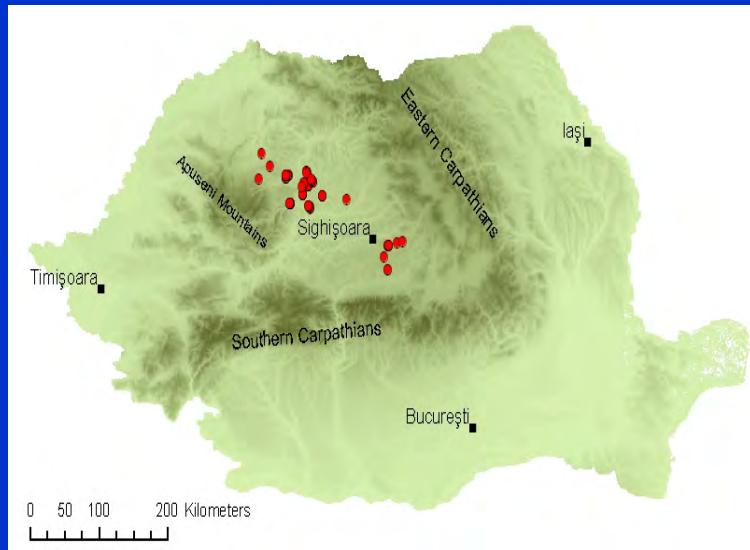
Sampling design

- All terricolous taxa (vascular plants, bryophytes, lichens)
- **20 “biodiversity plots”**
 - Multi-scale sampling
(Dengler 2009, *Ecol. Indic.* 9: 1169–1178)
 - Shoot presence (any-part system)
 - 0.0001, 0.001, 0.01, 0.1, 1, 10 and 100 m²
 - smaller plots with 2 replicates
- **80 relevés** (10 m²) with abiotic variables
(topography, soil texture, soil reaction, humus content, land use)



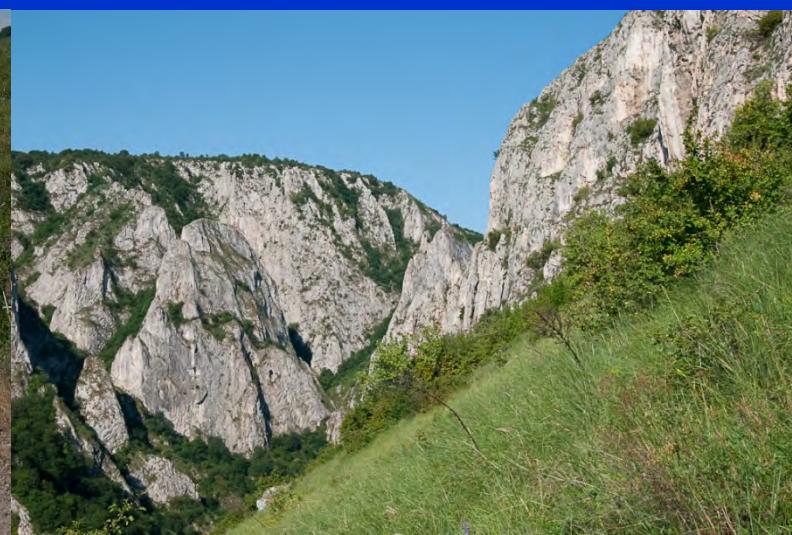
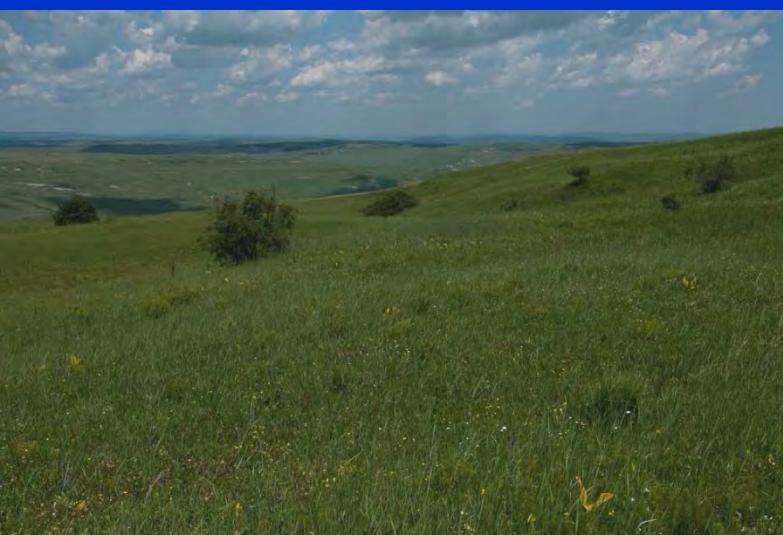
First EDGG Research Expedition in Romania 2009

(Dengler et al. 2012, Tuexenia 32: 319-359)



Transylvanian Plateau

- Hilly region, about 300-700 m a.s.l.
- Mostly marly substrates, rarely hard limestone
- Subcontinental climate (annual precipitation: 520-650 mm)
- Large areas of low-intensity grasslands with long history



Richness values

(Turtureanu et al. 2015, Agric. Ecosyst. Environ. 182: 15-24)

Area [m ²]	All taxa			Vascular plants	Bryophytes	Lichens
	Min	Max	Mean ± SD			
0.0001	0	5	2.6 ± 1.5	2.3 ± 1.4	0.2 ± 0.4	0.0 ± 0.0
0.001	0	9	4.6 ± 2.4	4.2 ± 2.1	0.4 ± 0.6	0.0 ± 0.0
0.01	3	20	10.2 ± 5.1	9.6 ± 4.7	0.6 ± 0.7	0.0 ± 0.0
0.1	7	45	22.8 ± 10.3	21.1 ± 9.9	1.5 ± 1.1	0.2 ± 0.5
1	18	82	40.0 ± 15.5	37.5 ± 15.3	2.2 ± 1.3	0.4 ± 0.7
10	37	101	60.5 ± 17.4	57.2 ± 17.4	2.8 ± 1.7	0.6 ± 1.0
100	58	134	88.2 ± 24.0	83.3 ± 24.2	3.8 ± 2.2	1.2 ± 2.3

■ Vascular plants

world records on 0.1 m² (43 species) and 10 m² (98 species)

■ Cryptogams

play an usually small role (only approx. 5% of the richness)



Semi-dry basiphilous grassland near Cluj-Napoca: World records in vascular plant species richness at 0,1 and 10 m²

Diversity-environment relationships at different grain sizes

(Turtureanu et al. 2015, Agric. Ecosyst. Environ.)

- Generalized linear model (GLM) with binomial distribution + overdispersion
- Full model with all environmental parameters that were not highly correlated:
 - heat load index
 - micro relief (linear and squared)
 - litter
 - humus content (linear & squared)
 - pH
 - soil texture
 - mean temperature (WorldClim)
 - minimum temperature (WorldClim)
 - altitude
 - land-use type
- Model evaluation of all possible models (parameter combinations) via AICc

Diversity-environment relationships at different grain sizes

(Turtureanu et al. 2015, Agric. Ecosyst. Environ.)

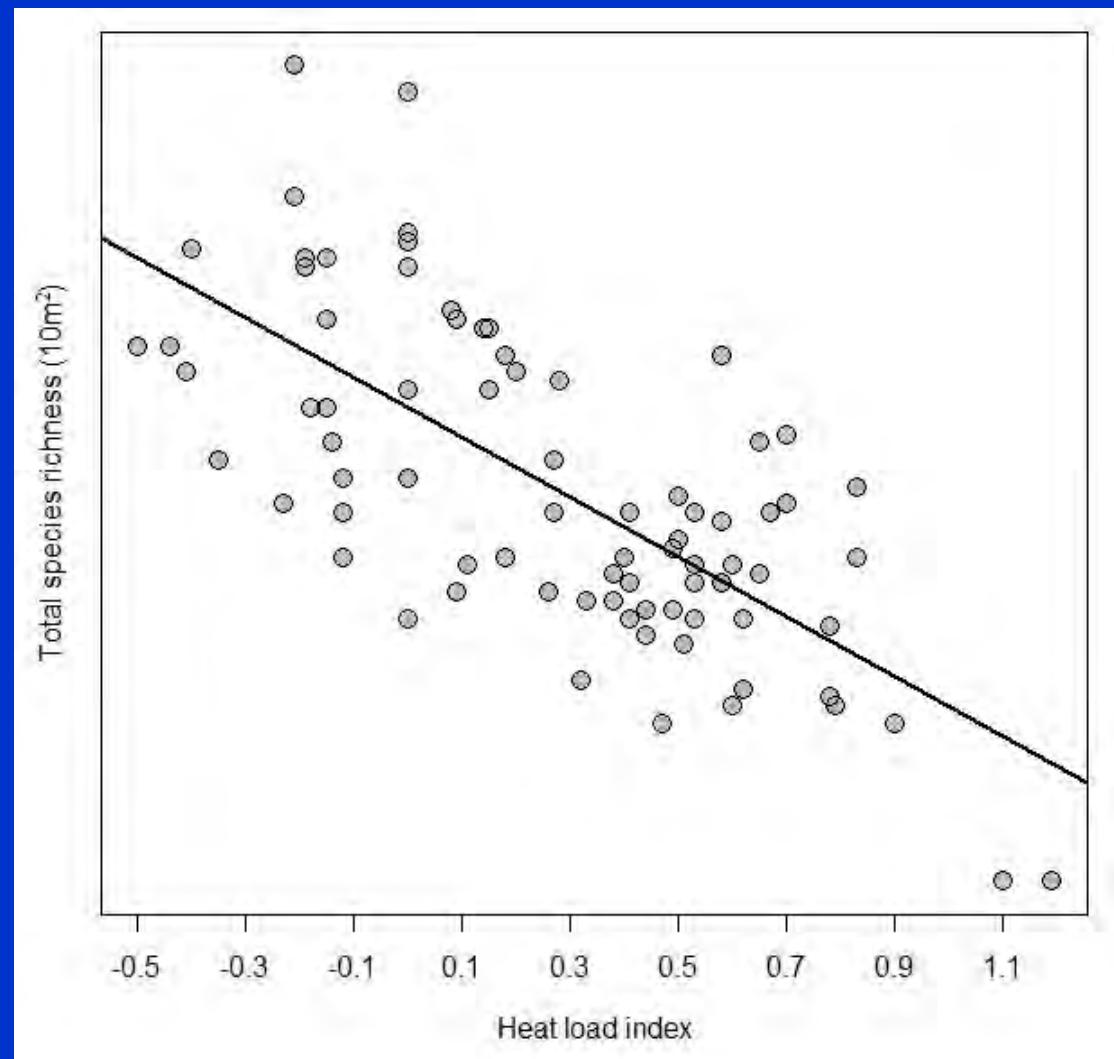
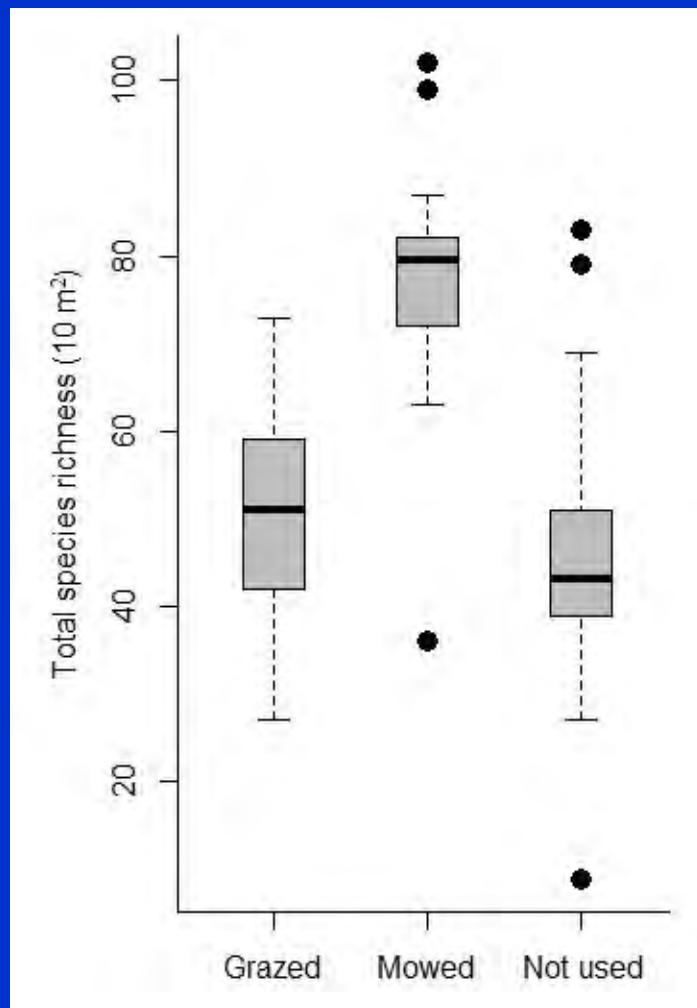
Parameter importance:

Akaike weights summed over all models including a certain parameter

	Heat	Rel	Rel ²	Litt	Hum	Hum ²	pH	Clay	Silt	Temp	MinTemp	Altitude	Unused vs. Grazed	Mown vs. Grazed
0.0001 m ²	0.38	0.24	0.23	0.33	0.70	0.65	0.26	0.26	0.27	0.22	0.20	0.23	0.29	0.28
0.001 m ²	0.26	0.36	0.26	0.23	0.97	0.97	0.29	0.26	0.24	0.21	0.20	0.22	0.24	0.24
0.01 m ²	0.37	0.24	0.21	0.63	0.83	0.83	0.43	0.19	0.21	0.26	0.20	0.21	0.29	0.38
0.1 m ²	0.29	0.50	0.34	1.00	0.89	0.89	0.25	0.19	0.21	0.49	0.52	0.24	0.27	0.96
1 m ²	0.61	0.96	0.46	1.00	0.45	0.34	0.21	0.25	0.22	0.29	0.91	0.60	0.39	1.00
10 m ²	0.69	0.68	0.50	1.00	0.31	0.26	0.21	0.43	0.19	0.20	1.00	0.66	0.33	1.00
100 m ²	0.12	0.91	0.81	0.37	0.14	0.13	0.11	0.12	0.09	0.10	0.98	0.31	0.38	1.00
z-value	0.62	0.20	0.26	0.64	0.23	0.20	0.36	0.15	0.19	0.17	0.42	0.20	0.11	0.13

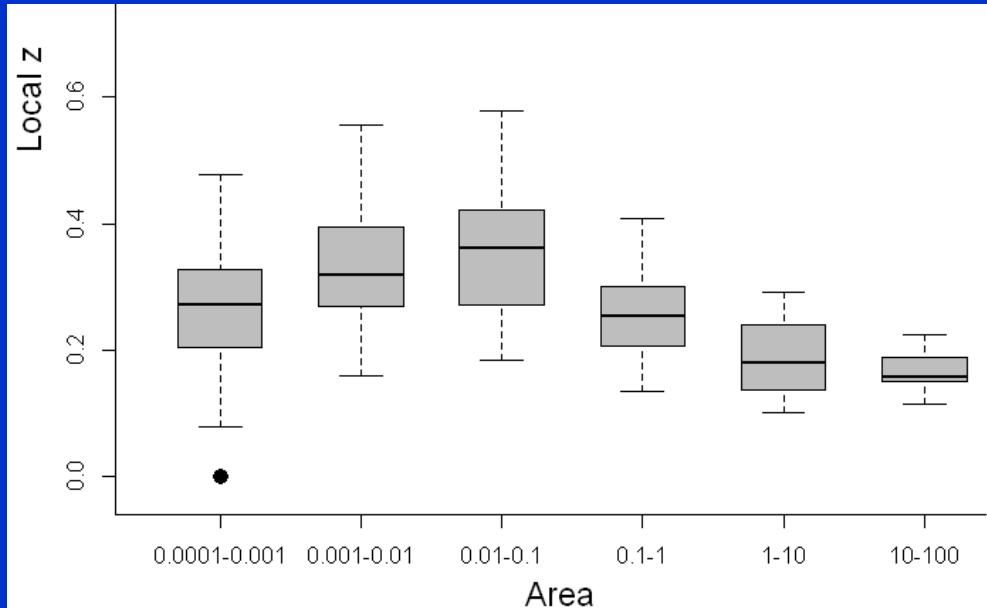
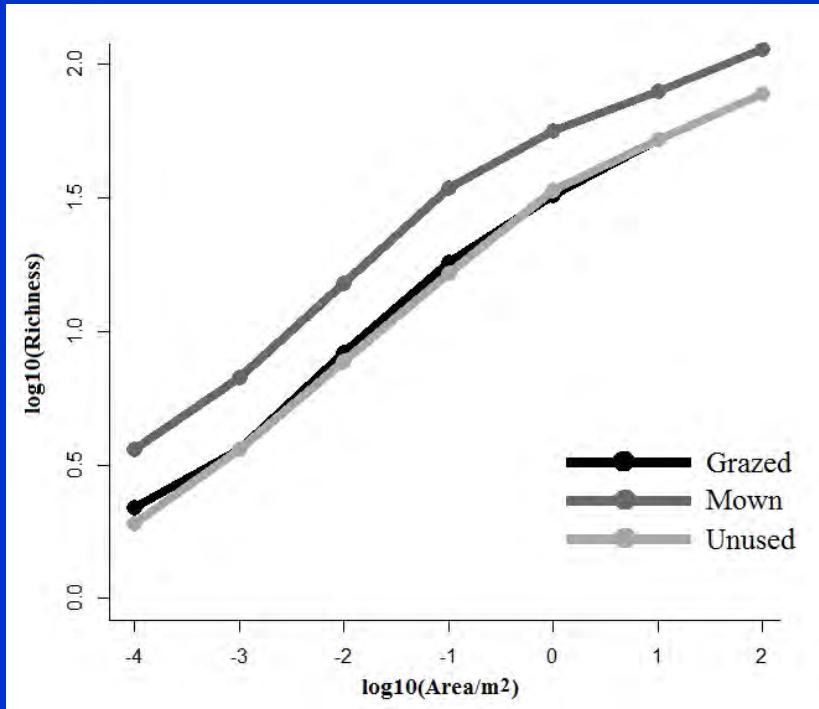
Most influential parameters for vascular plants at 10 m²

(Turtureanu et al. 2015, Agric. Ecosyst. Environ.)



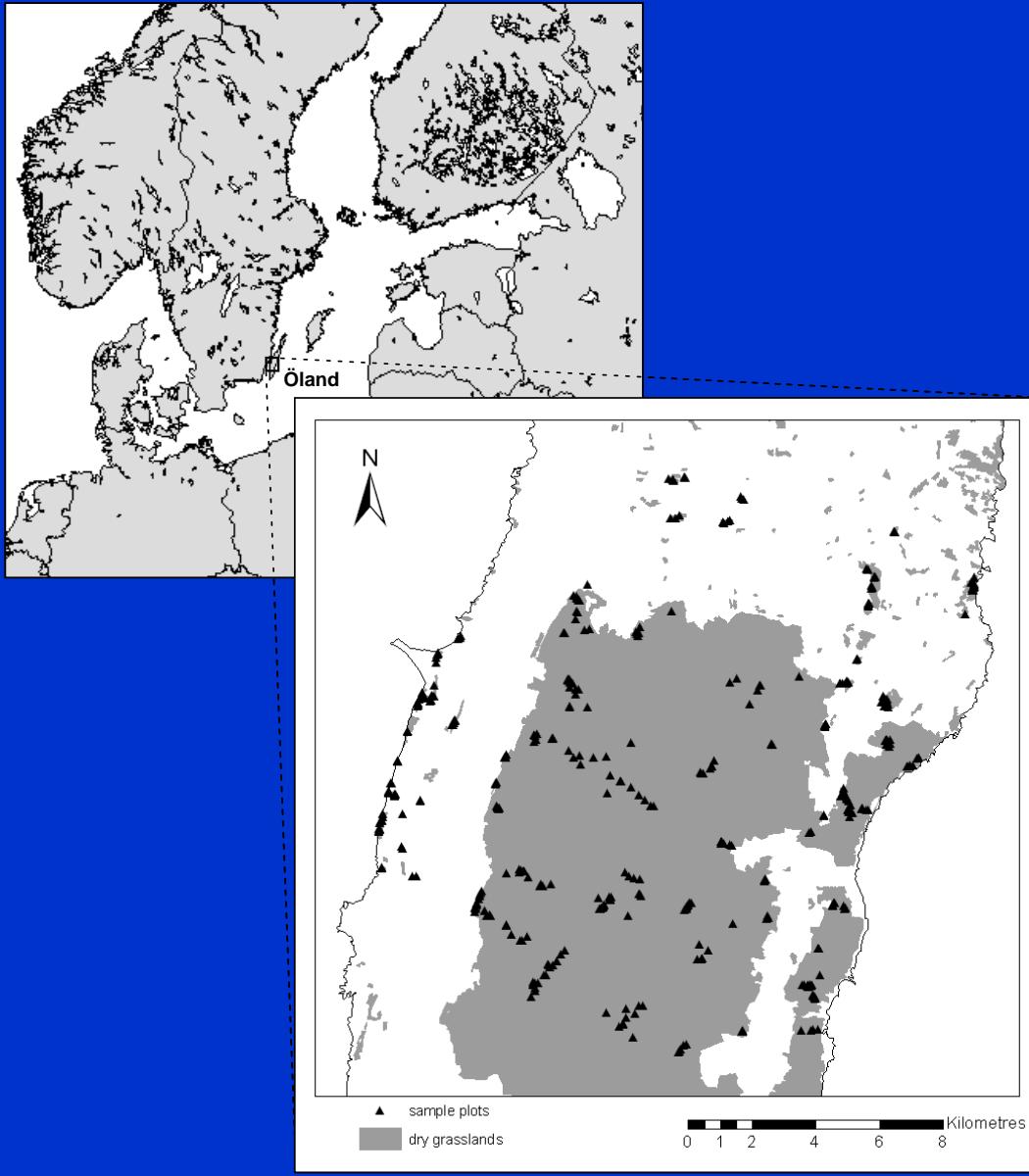
Species-area relationships

(Turtureanu et al. 2015, Agric. Ecosyst. Environ.)



- 3 land-use types have nearly parallel SARs
- Also z-values (β -diversity) are unusually high
- Unexpected and unexplained peak of z-values at 0.01-0.1 m²

Öland (S. Löbel & J. Dengler)



Öland (Sweden)

- Island in the Baltic Sea
- 137 km long, 15 km wide

Climate:

- Precipitation: 450-500 mm/a
- Annual mean temperature: 7 °C
- July temperature: 16-17 °C
- Growing Season: c. 210 days

Geology:

- Great extension of superficial or exposed bedrock
- Ordovician limestone plateau
- Moraine deposits
- Ancient shore ridges

Vegetation and flora:

- Boreo-nemoral zone
- Isolated occurrences of SE European, SW European, Siberian and arctic-alpine taxa
- Some endemics



Festucetum polesicae (Koelerio-Corynephorenea)

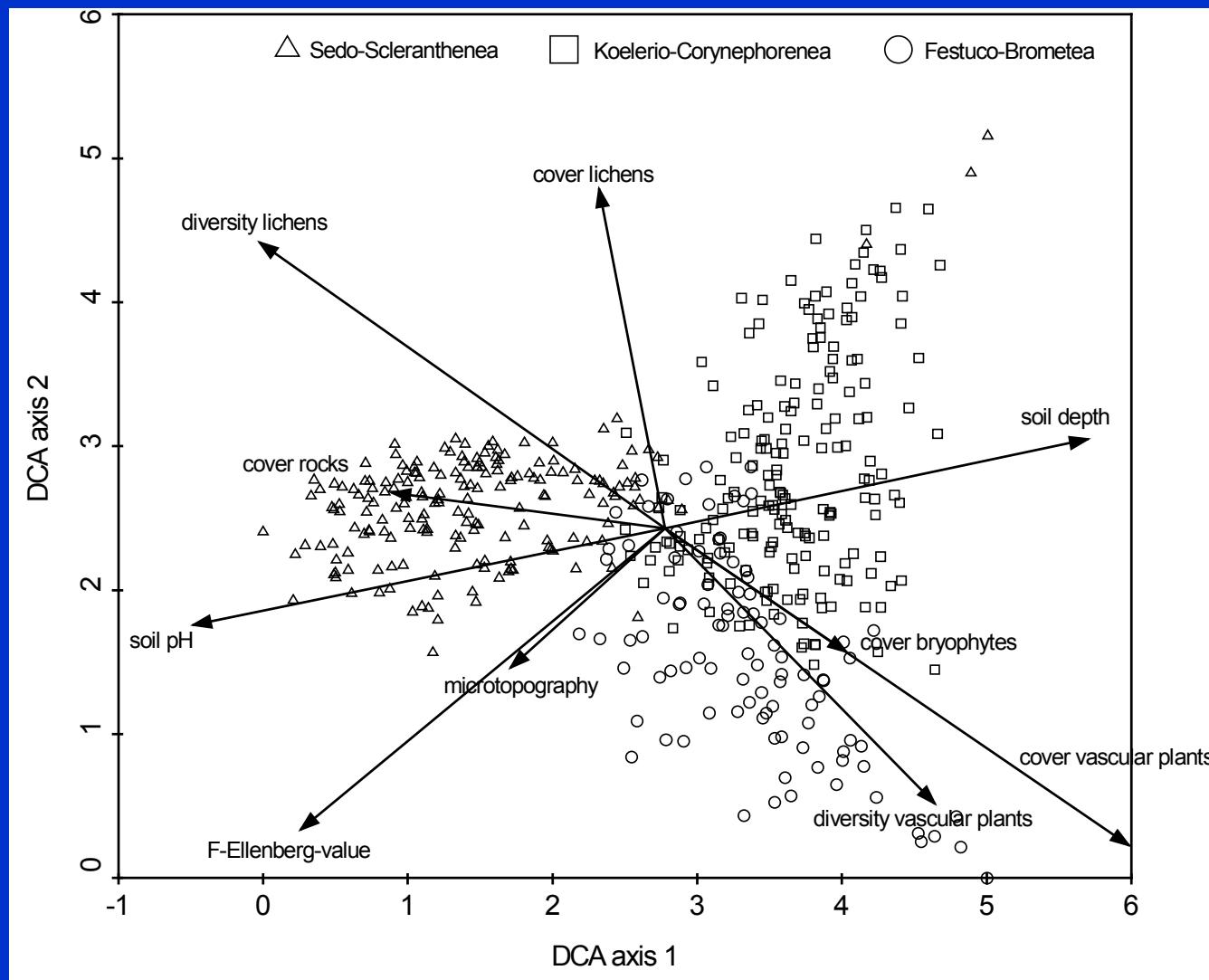


Veronico spicatae-Avenetum (Festuco-Brometea)



Fulgensio-Poetum alpinae (Sedo-Scleranthenea)

Ordination of all relevés according to their floristic composition



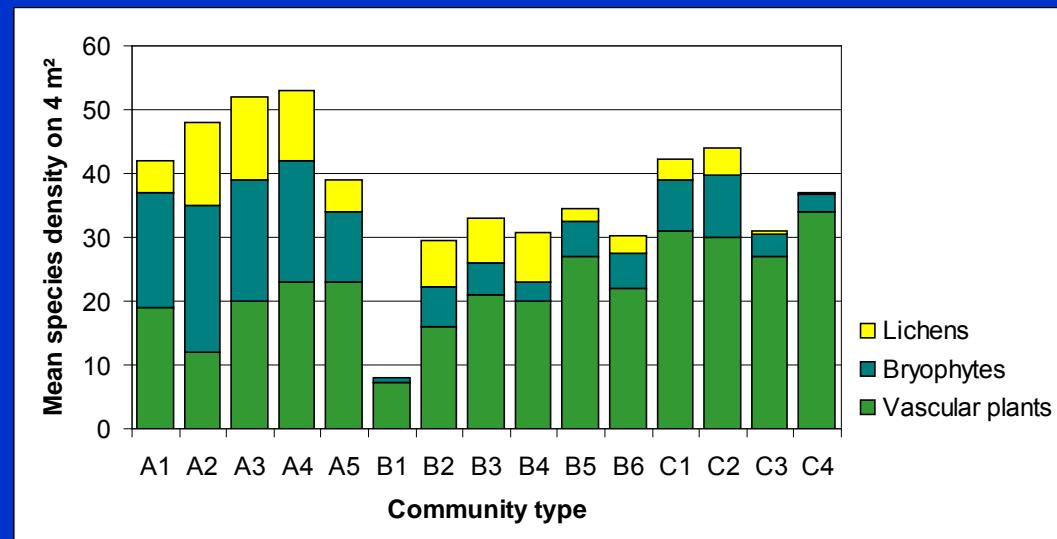
Phytodiversity

Great differences between the 15 communities (mean values: 8-53 species on 4 m²)

Also high variability within the communities

High proportion of cryptogams

Weathered rock and outcrop communities of the Great Alvar belong to the most species rich communities on small areas (up to 80 species on 4 m²)



A = Sedo-Scleranthenea; B = Koelerio-Corynephorenea
C = Festuco-Brometea

Further reading

- Löbel, S., Dengler, J., Hobohm, C. 2004. Beziehungen zwischen der Artenvielfalt von Gefäßpflanzen, Moosen und Flechten in Trockenrasen der Insel Öland (Sweden). – Kiel. Not. Pflanzenkd. Schleswig-Holstein Hamb. 32: 9–13.
- Löbel, S., Dengler, J. & Hobohm, C. 2006. Species richness of vascular plants, bryophytes and lichens in dry grasslands: The effects of environment, landscape structure and competition. *Folia Geobotanica* 41: 377–393.
- Dengler, J. & Löbel, S. 2006. The basiphilous dry grasslands of shallow, skeletal soils (*Alysso-Sedetalia*) on the island of Öland (Sweden), in the context of North and Central Europe. *Phytocoenologia* 36: 343–391.
- Löbel, S., Dengler, J. 2008. Dry grassland communities on southern Öland: phytosociology, ecology, and diversity. *Acta Phytogeogr. Suec.* 88: 13–31.

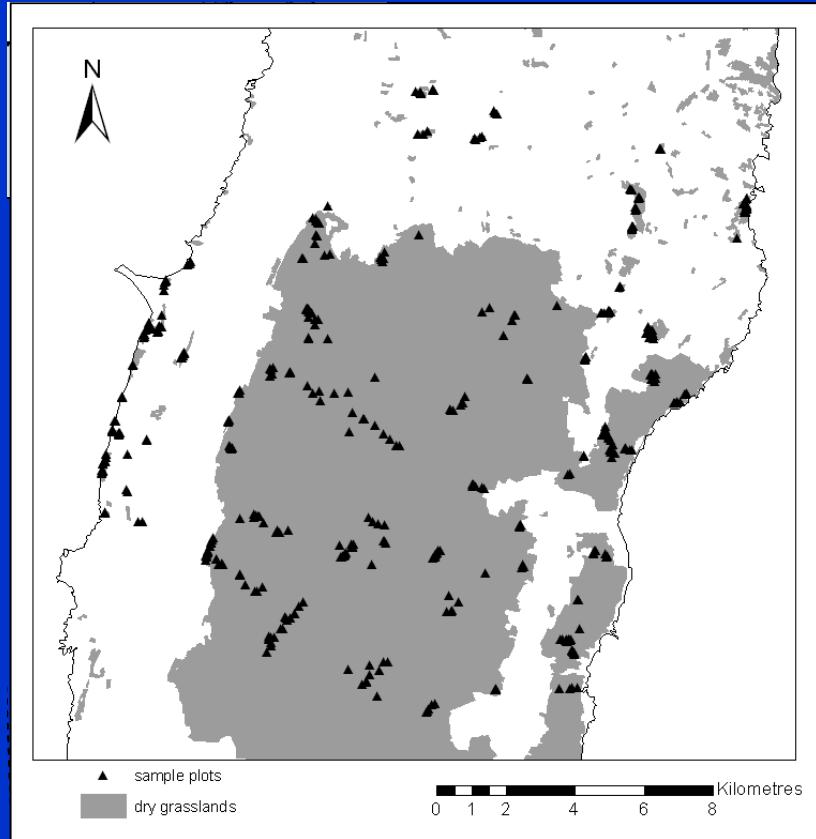
Data collection

452 relevés

- 2 m x 2 m
- all dry grassland types and patches sampled representatively
- all species recorded (except for epilithic crustose lichens)

Data per relevé

- Species numbers (total, vascular plants, bryophytes, lichens)
- Cover (total, vascular plants, bryophytes, lichens)
- Cover bare rocks
- Mean soil depth
- Microtopography
- Soil pH
- Management regime
- Position (GPS)



Vegetation map

- Dry grassland distribution (grey)

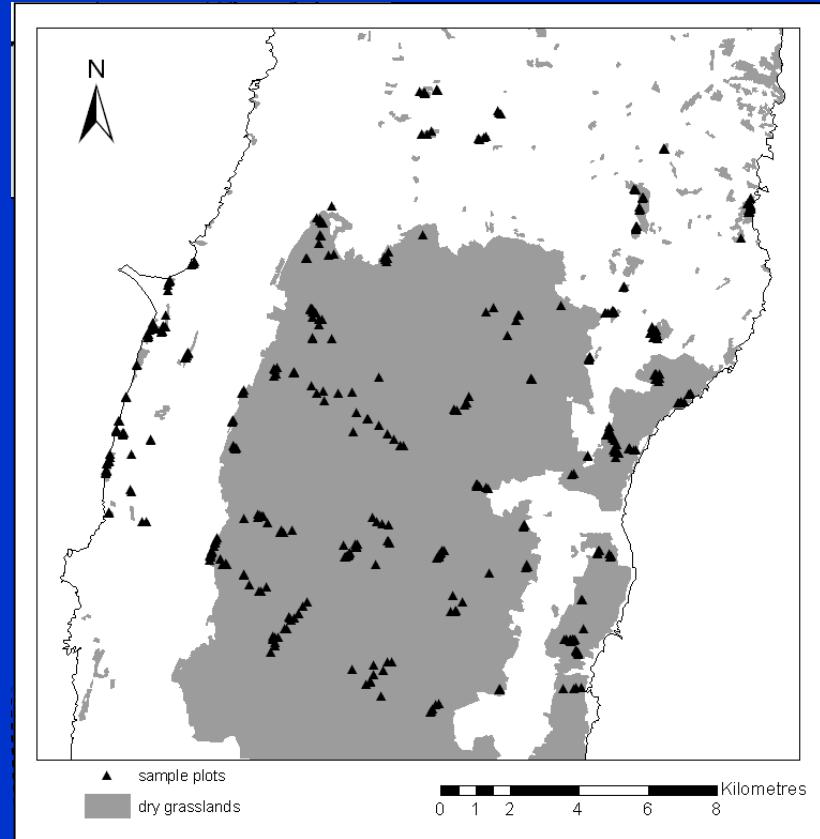
Data analyses

Calculations with GIS

- Distance between plots
- Size of the dry grassland patch
- Proportion of dry grasslands within circles around the plot ($r = 100$ m, 250 m, 500 m, 1 km, 2.5 km)

Statistical analyses

- R 1.8.1 with geoR version 1.4-5 and MASS version 7.1-13
- Generalized linear mixed models (GLMM) with Poisson error distribution and a log-link function
- Distance between relevés > 600 m to be treated as independent (because we found a spatial correlation structure up to this scale)
- Manual backward elimination until only significant terms were left



GLMM for total species richness

Variable	Sign	F	p
Soil pH	+	84.9	< 0.001
Soil depth	-	12.9	< 0.001
Soil depth ²	+	9.8	0.002
Cover bare rocks ²	-	9.7	0.002
Microtopography	+	13.9	< 0.001
Soil pH × Microtopography	-	9.5	0.002
Size of grassland patch	+	19.8	< 0.001
Proportion of dry grasslands within 500 m	+	15.7	< 0.001
Size × Proportion of dry grasslands	-	4.4	0.037

number of observations: 452

number of independent groups: 67

exponential spatial correlation structure: $\phi = 54.1$

all variables included with $p < 0.05$

GLMMs for different taxonomic groups

	All species	Vascular plants	Bryophytes	Lichens
Mean species density on 4 m ²	40.7	23.6	11.4	5.4
Spatial autocorrelation up to	160 m	600 m	160 m	300 m
Soil pH	+	+	+	+
Soil pH ²	n. s.	—	n. s.	n. s.
Soil depth	—	n. s.	—	—
Soil depth ²	+	n. s.	+	+
Cover bare rocks	+	—	n. s.	+
Cover bare rocks ²	—	n. s.	—	—
Microtopography	+	+	+	n. s.
Microtopography ²	n. s.	n. s.	n. s.	+
Soil pH x Cover bare rocks	n. s.	+	n. s.	n. s.
Soil pH x Microtopography	—	+	n. s.	n. s.
Size of grassland patch	+	n. s.	+	+
Proportion of dry grasslands within 500 m	+	n. s.	n. s.	+
Area x Proportion of dry grasslands	—	n. s.	n. s.	n. s.

GLMMs for different taxonomic groups

	All species	Vascular plants	Bryophytes	Lichens
Mean species density on 4 m ²	40.7	23.6	11.4	5.4
Spatial autocorrelation up to	160 m	600 m	160 m	300 m
Soil pH	+	+	+	+
Soil pH ²	n. s.	-	n. s.	n. s.
Soil depth	-	n. s.	-	-
Soil depth ²	+	n. s.	+	+
Cover bare rocks	+	-	n. s.	+
Cover bare rocks ²	-	n. s.	-	-
Microtopography	+	+	+	n. s.
Microtopography ²	n. s.	n. s.	n. s.	+
Soil pH x Cover bare rocks	n. s.	+	n. s.	n. s.
Soil pH x Microtopography	-	+	n. s.	n. s.
Size of grassland patch	+	n. s.	+	+
Proportion of dry grasslands within 500 m	+	n. s.	n. s.	+
Area x Proportion of dry grasslands	-	n. s.	n. s.	n. s.

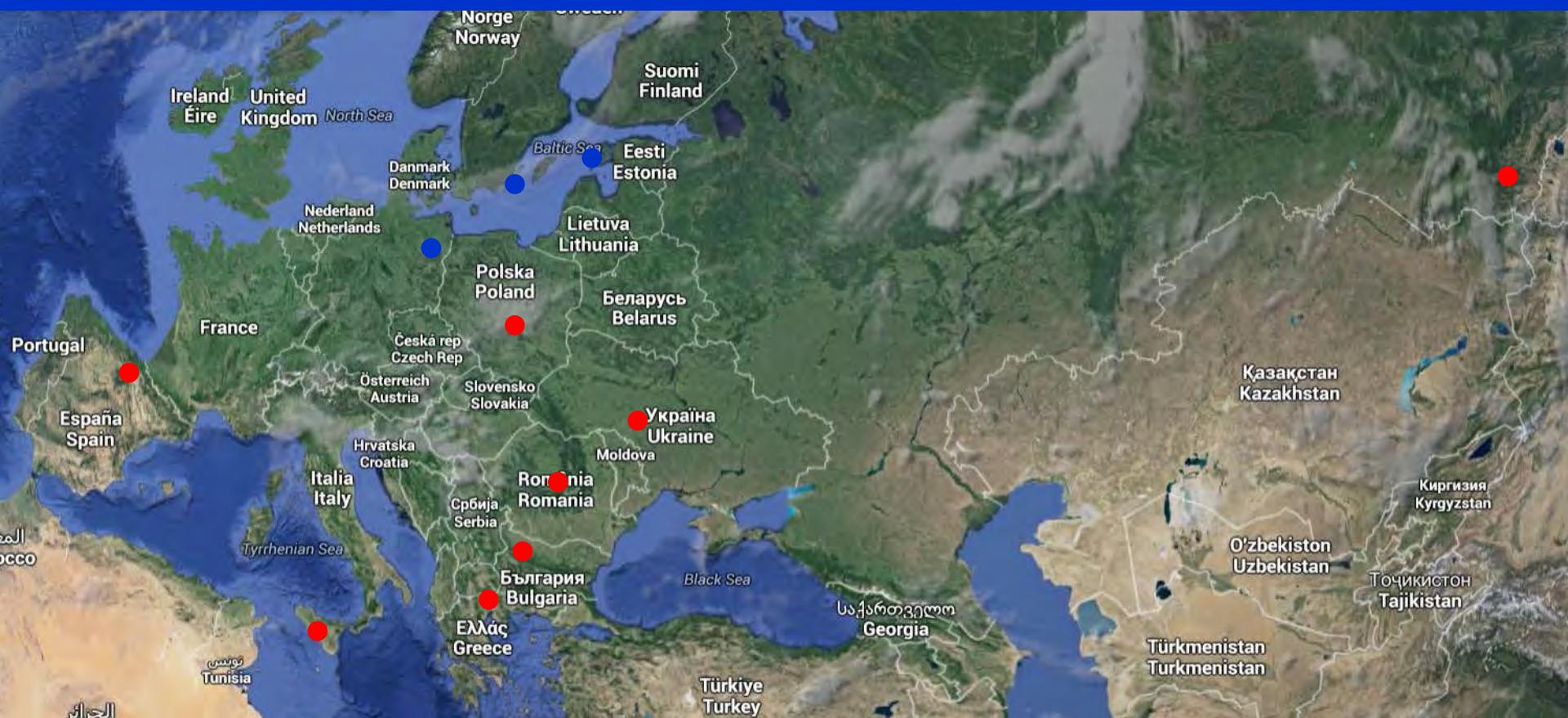
green: most important variable, bold: variable with $p < 0.001$

Management regime (grazed, mown, not used, road verge) never was significant

Conclusions

- Soil pH is the most important factor influencing species richness in all taxonomic groups studied.
- Dispersal limitation seems to be more relevant for bryophytes and lichens than for vascular plants.
- Species densities of vascular plants showed a significant spatial structure which may have historical reasons since it could neither be explained by the present extension of the dry grassland patches nor by the proportion of dry grasslands in the surroundings.

Outlook on all datasets combined



Data from the expeditions

No.	Period	Research area	Altitude (m a.s.l.)	Participants	Countries	Nested- plot series	10-m ² plots
1	14-26 July 2009	Transylvania (Romania)	321-670	6	3	20	63
2	10-25 July 2010	Central Podolia (Ukraine)	73-251	18	8	21	226
3	14-24 August 2011	NW Bulgarian mountains	633-1460	9	5	15	98
4	29 March - 5 April 2012	Sicily (Italy)	4-1200	14	5	21	67
5	15-23 May 2012	N Greece	1-1465	16	6	14	31
6	22 July - 1 August 2013	Khakassia (Russia)	300-700	14	7	39	133
7	15-24 June 2014	Navarre (Spain)	295-1970	16	10	35	119

Diversity data in comparison (total richness)

Region	0.01 m ²		1 m ²		100 m ²	
	mean	max.	mean	max.	mean	max.
Sweden (Öland)	12.6	26	40.4	63	NA	NA
Estonia (Saaremaa)*	10.7	19	29.1	49	80.0	140
Germany (NE)*	6.5	11	17.9	24	50.2	69
Romania (Transylvania)	10.2	20	40.0	82	88.2	134
Bulgaria (NW)	8.5	15	25.5	41	65.3	89
Ukraine (Podolia)	7.3	13	24.4	42	66.8	86
Russia (Siberia)	9.6	31	33.0	54	70.9	99
Spain (Navarre)	11.5	26	32.6	64	79.9	125
Italy (Sicily)	7.6	22	25.1	50	67.2	124

* values include non-terricolous taxa

Publications from Expeditions/Field Workshops

Published

- **Transylvania No. 1: phytosociology/classification**

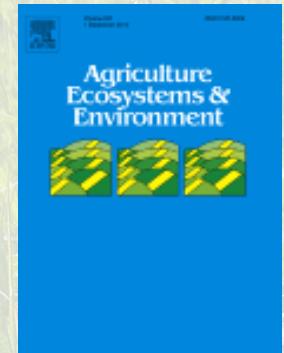
Dengler, J., Becker, T., Ruprecht, E., Szabó, A., Becker, U., Beldean, M., Bita-Nicolae, C., Dolnik, C., Goia, I., Peyrat, J., Sutcliffe, L.M.E., Turtureanu, P.D. & Ügurlu, E. 2012. ***Festuco-Brometea* communities of the Transylvanian Plateau (Romania) – a preliminary overview on syntaxonomy, ecology, and biodiversity.** *Tuexenia* 32: 319–359.

- **Bulgaria No. 1: phytosociology/classification**

Pedashenko, H., Apostolova, I., Boch, S., Ganeva, A., Janisová, M., Sopotlieva, D., Todorova, S., Ünal, A., Vassilev, K., Velev, N. & Dengler, J. 2013. **Dry grasslands of NW Bulgarian mountains: first insights into diversity, ecology and syntaxonomy.** *Tuexenia* 33: 309–346.

- **Transylvania No. 2: biodiversity patterns**

Turtureanu, P.D., Palpurina, S., Becker, T., Dolnik, C., Ruprecht, E., Sutcliffe, L.M.E., Szabó, A., Dengler, J. (2014): **Scale- and taxon-dependent biodiversity patterns of dry grassland vegetation in Transylvania (Romania).** *Agric. Ecosyst. Environ.* 182: 15–24.



- **Ukraine No. 1: phytosociology/classification**

Kuzemko, A.A., Becker, T., Didukh, Y.P., Ardelean, I.A., Becker, U., Beldean, M., Dolnik, C., Jeschke, M., Naqinezhad, A., Ügurlu, E., Ünal, A., Vassilev, K., Vorona, E.I., Yavorska, O.H., Dengler, J. (2014): **Dry grassland vegetation of Central Podolia (Ukraine) – a preliminary overview of its syntaxonomy, ecology and biodiversity.** – *Tuexenia* 34: 391–430.

Publications from Expeditions/Field Workshops

In preparation

- Transylvania No. 3: species-area relationships:
Turtureanu et al.
- Ukraine No. 2: biodiversity patterns
Kuzemko et al., invited for *Biodiv. Conserv.* S.I.
- Sicily No. 1: community description & phytosociology
Guarino et al., invited for *Phytocoenologia* S.I.
- Sicily No. 2: biodiversity patterns
Dembicz et al., planned for *J. Veg. Sci.*
- Spain No. 1: community description & phytosociology
Guarino et al., invited for *Phytocoenologia* S.I.
- Siberia No. 1: biodiversity patterns
Polyakova et al., invited to *Biodivers. Conserv.* S.I.
- [...]

Opportunities of the combined dataset

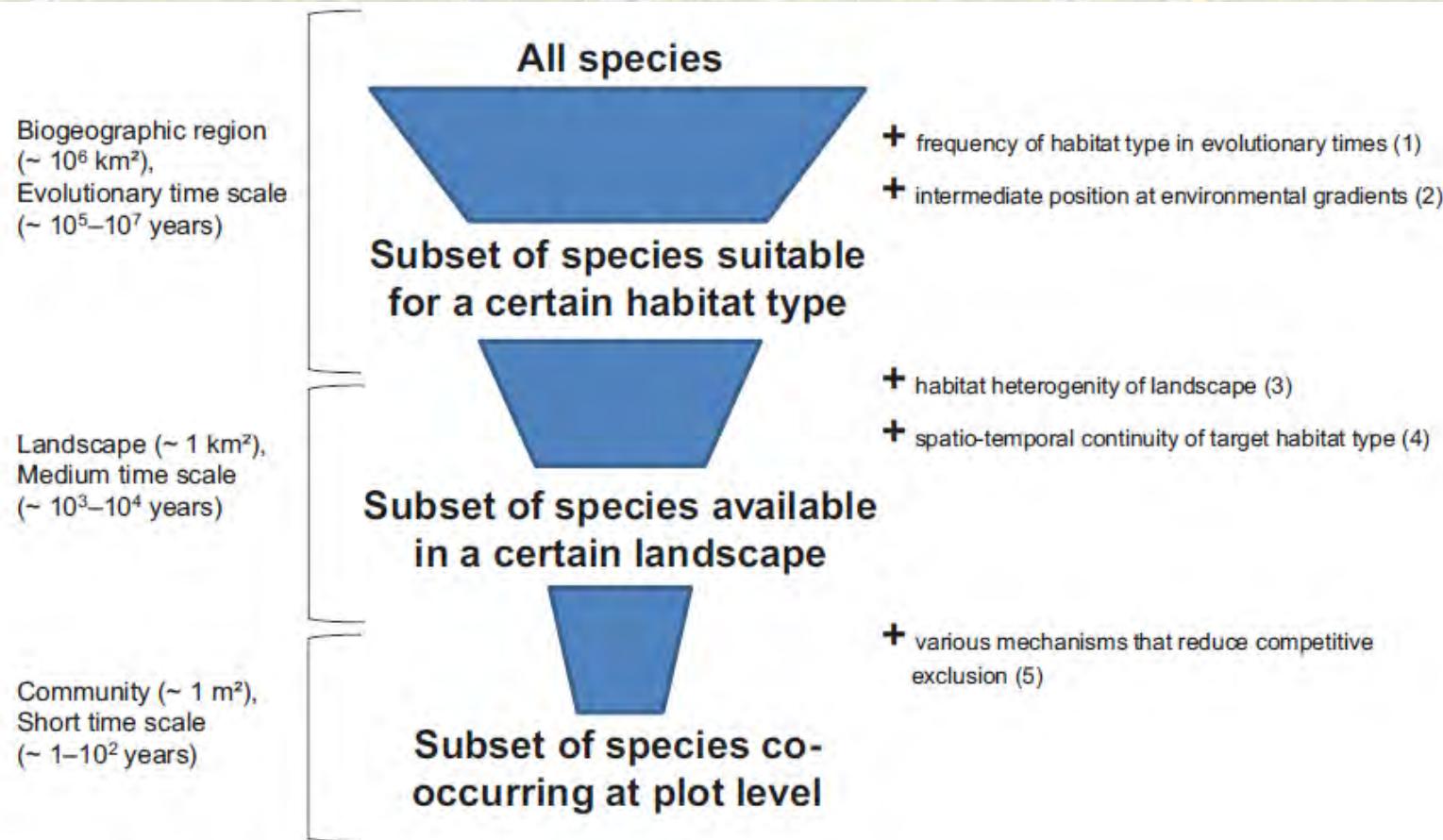
Unique qualities

- Highly standardised sampling
- Huge biogeographic gradient between regions, extensive ecological gradient within each region
- 3 taxonomic groups x 7 grain sizes
- Comprehensive environmental data

Overarching papers planned

- General diversity model (taxon- and scale-dependent)
- Functional composition dependend on climate, soil and land-use data
- Species-area relationships (SARs)
- Functional/phylogenetic diversity across biogeographic gradients and grain sizes (over- vs. underdispersion)
- [...]

Towards a general model...



Dengler, J., Janišová, M., Török, P., Wellstein, C. (2014): Biodiversity of Palaearctic grasslands: a synthesis. *Agric. Ecosyst. Environ.* 182: 1–14.

Field Workshops 2016 et seq.?





Thank you for your attention!



Impressions from the 1st EDGG Research Expedition 2009 in Transylvania