Rapid response of vegetation biodiversity and composition to experimental application of historical management and nitrogen deposition **in temperate oak forests**

TECHNICKÁ UNIVERZITA VO ZVOLENE

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Recent changes of temperate oak-forest communities

Factors and drivers affecting recent forest comunities

- global climatic changes
- nitrogen depositions (Bobbink et al. 2010, ...)
- abandonment of historical management (Szabó 2010, Vild et al. 2018, Máliš et al. 2021)

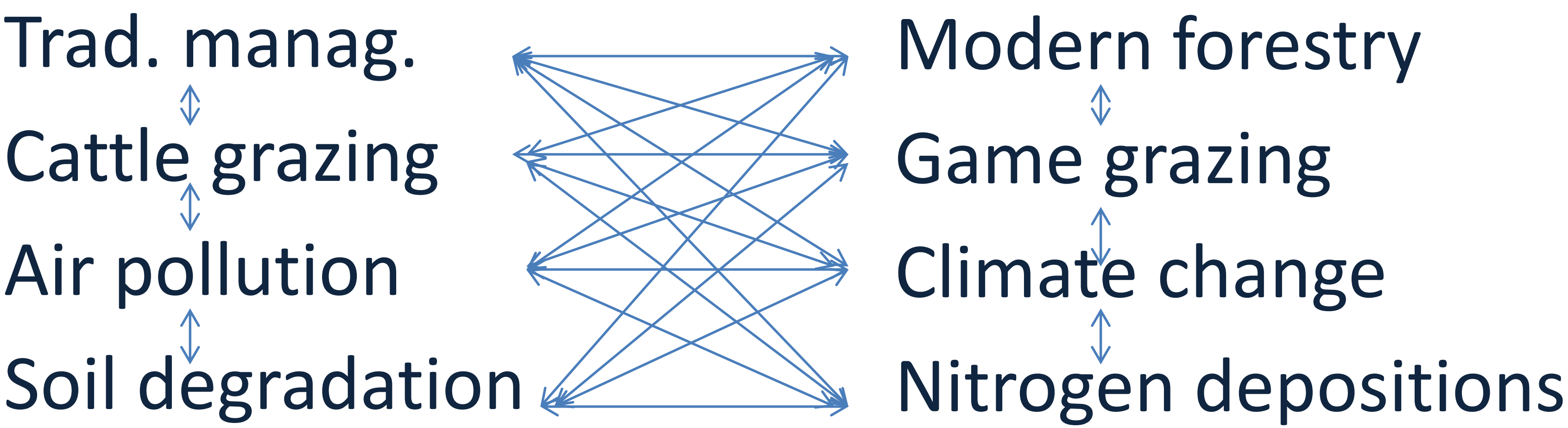
Effects on plant-species composition and diversity

- termophilization (De Frenne et al. 2013, Zellweger et al. 2020, Feeley et al. 2020)
- eutrophication (De Schrijver et al. 2011, Verheyen et al. 2012, Dirnböck et al. 2014)
- biotic homogenization (Velend et al. 2007, Keith et al. 2009, Kopecký et al. 2013, Hermy 2017)

most affected are oak forests of planar and colline zones

Interactions of main drivers in temperate Europe

Historical legacies x Recent factors



Is it possible to disentagle causes and effects?

70 combinations of 4 interacting factors of 8 considered ...☺

Resurvey studies – indirect evidence

- vegetation resampling
  - permanent and semi-permanent plots
  - forestREplot group (Verheyen et al. 2017)
- species richness change depends on historical forest management type (Perring et al. 2018)
- disturbances accelerates thermophilization of understory plant communities (Stevens et al. 2015)
- interactions of past land use and recent forest management influenced composition of forest understorey (Depauw et al. 2019)
- …

Field experiment
– combitation of three treatments

Direct evidence is needed

Field experiment can be a solution!

Aims of our study:

simulation of historical management and recent anthropogenous nitrogen depositions

8 combinations of three treatments:

canopy reduction

litter raking

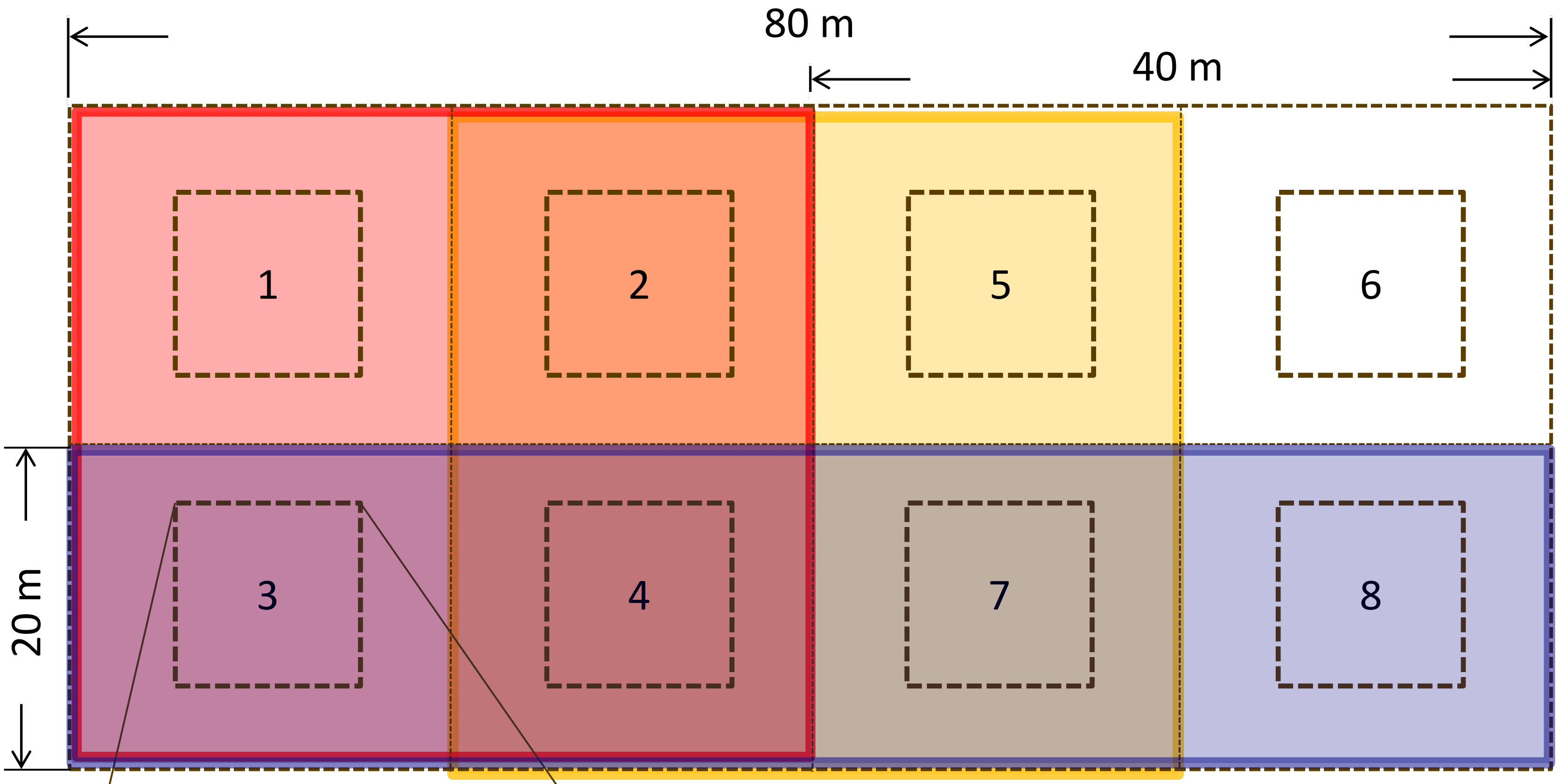
nitrogen fertilisation

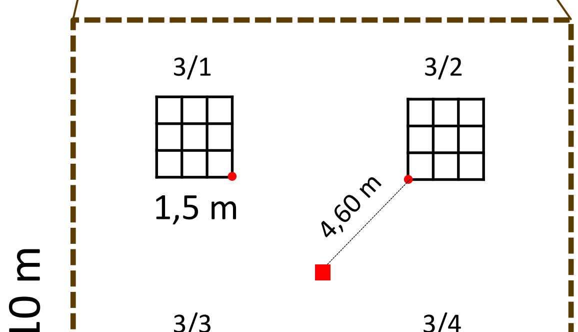
studying response of understorey plants

Field experiment
– combitation of three treatments

- oak-hornbeam forests (*Carpinion* alliance)
- Central Slovakia, Western Carpathians
  - forest enterprise of Technical university in Zvolen
- volcanic bedrock (andesites), moderately acidic cambisols (topsoil pH H_2O 4.3 – 5.8)
- altitudes about 500 m a.s.l., SW-W slopes up to 20°,
- precipitation XXX, annual temperatures XXX

Field experiment
– combitation of three treatments





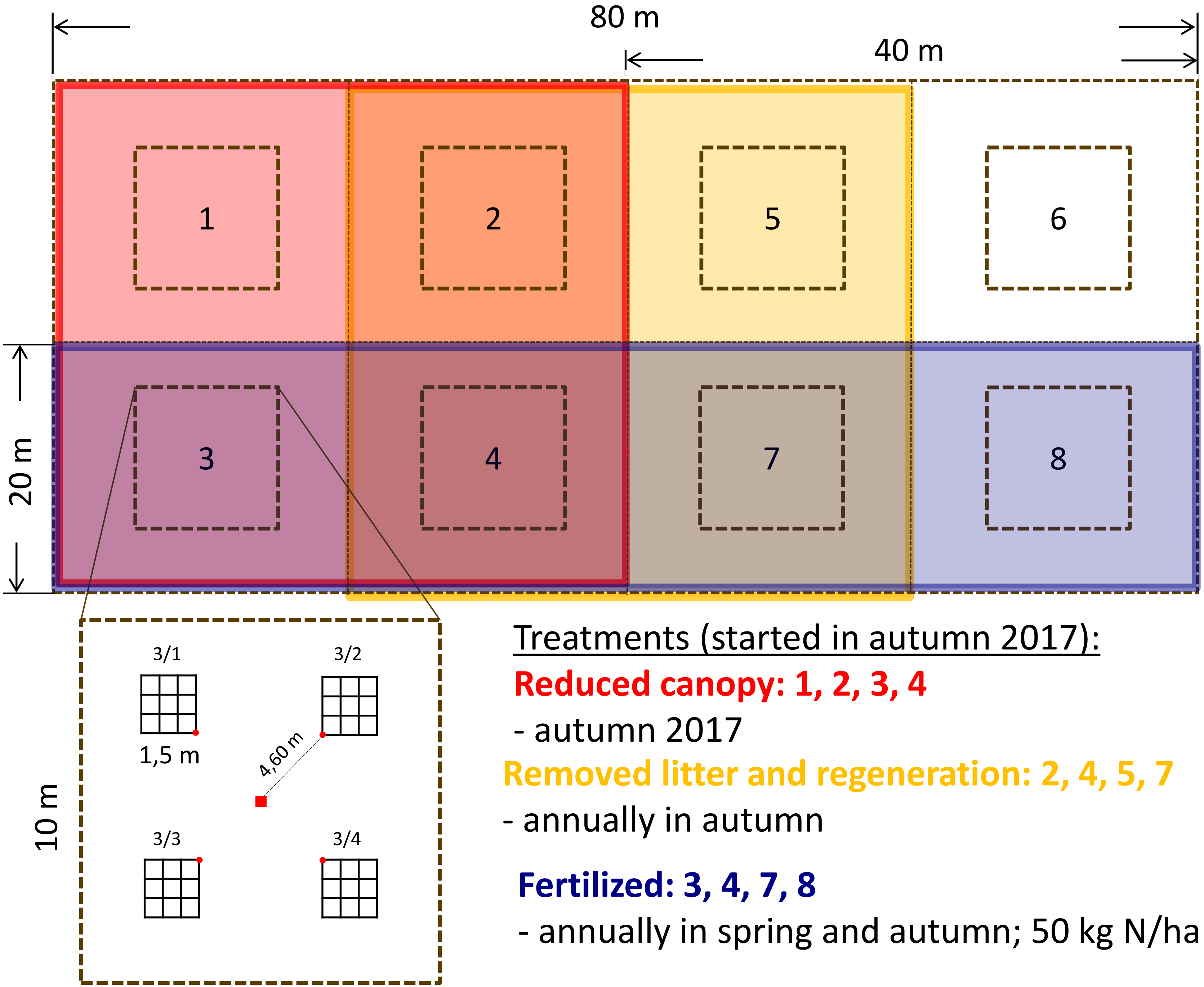
<u>Treatments (started in autumn 2017):</u>

Reduced canopy: 1, 2, 3, 4

- autumn 2017

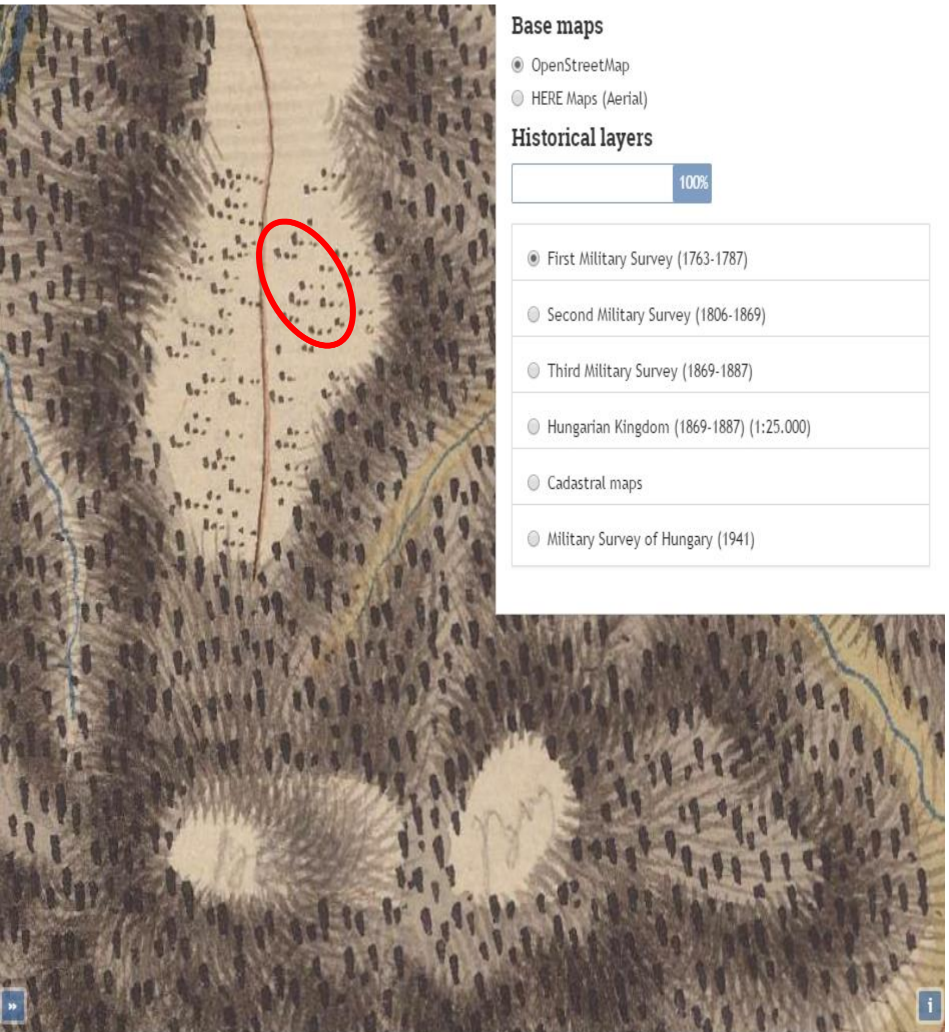
Removed litter and regeneration: 2, 4, 5, 7

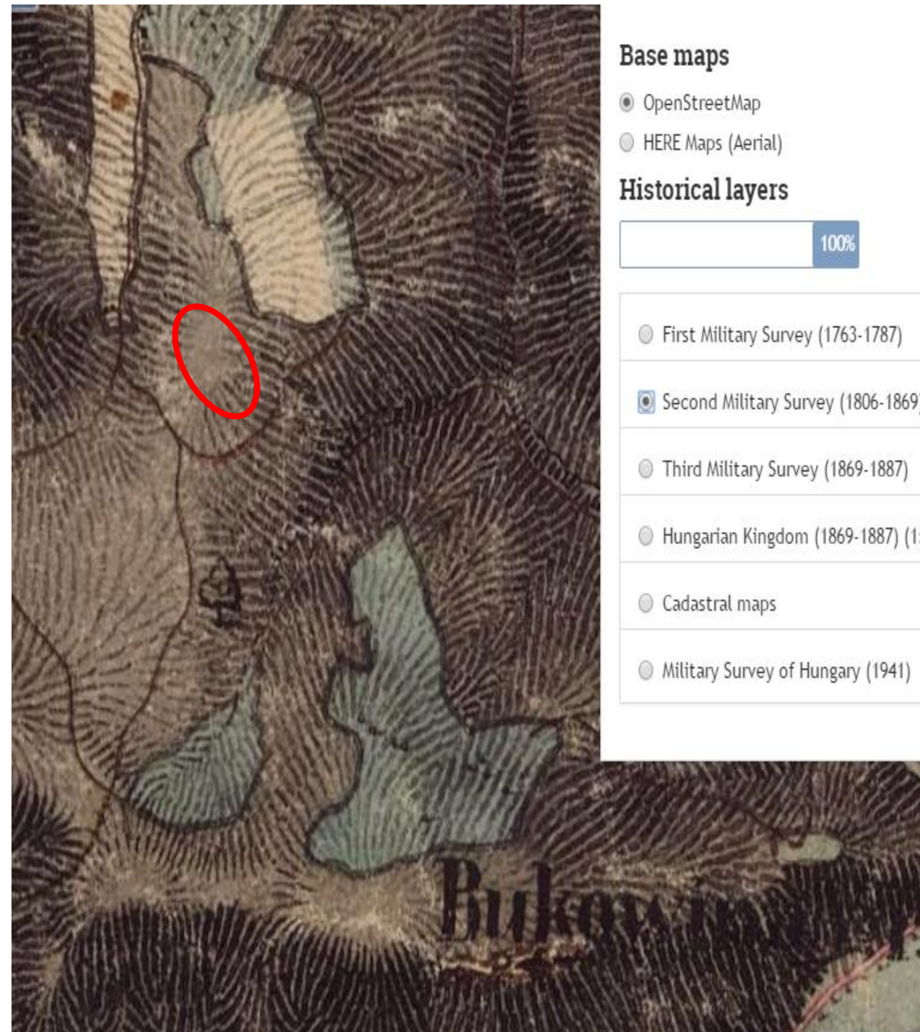
- annually in autumn

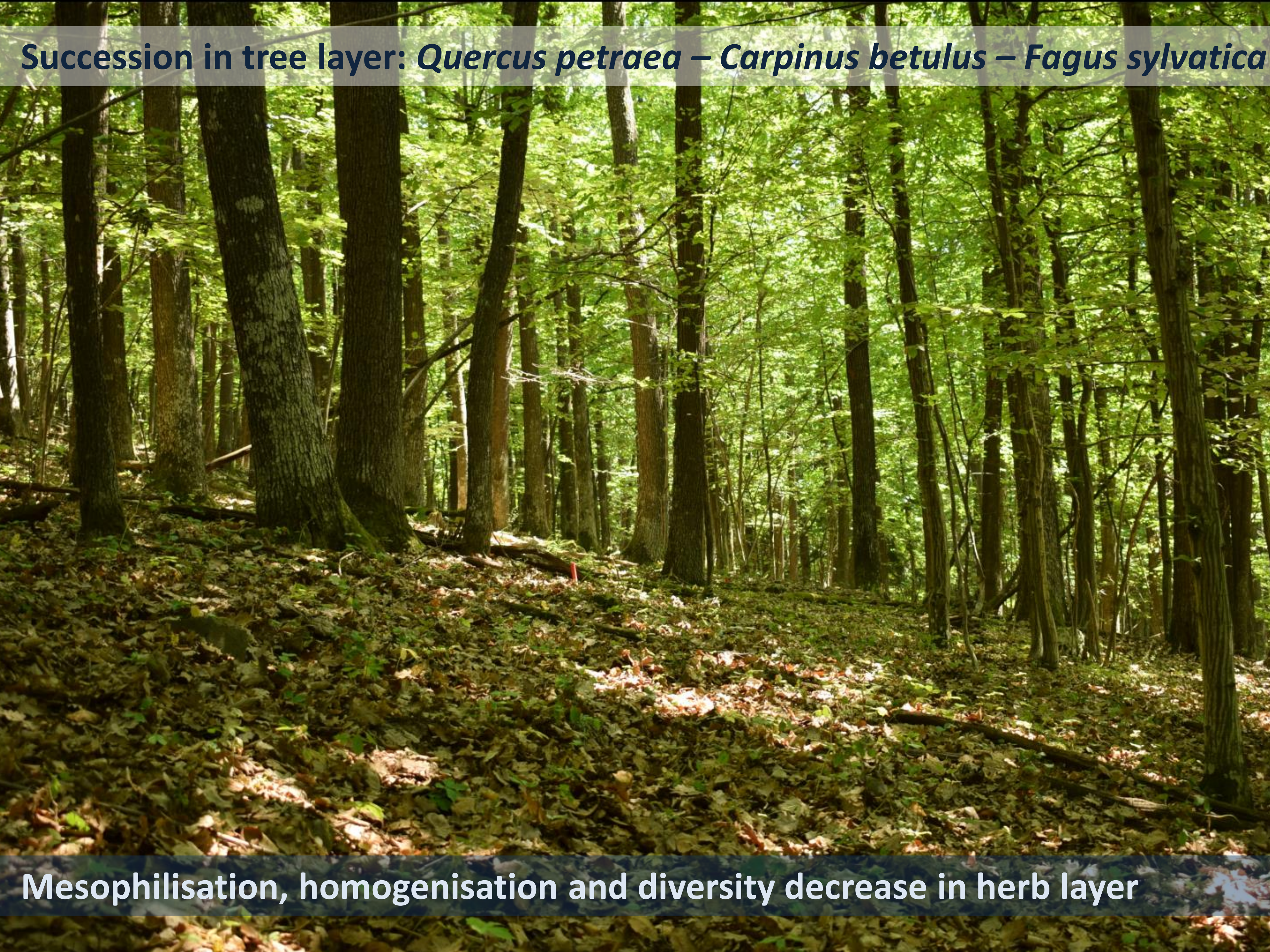

80 m
40 m
1
2
5
6
3
4
7
8
20 m
10 m
3/1
3/2
3/3
3/4
1,5 m
4,60 m
Treatments (started in autumn 2017):
Reduced canopy: 1, 2, 3, 4
- autumn 2017
Removed litter and regeneration: 2, 4, 5, 7
- annually in autumn
Fertilized: 3, 4, 7, 8
- annually in spring and autumn; 50 kg N/ha

Historical management of oak forests in the region

- coppicing, cattle grazing, litter raking






Succession in tree layer: *Quercus petraea – Carpinus betulus – Fagus sylvatica*
Mesophilisation, homogenisation and diversity decrease in herb layer

1st sampling in summer 2017
treatments from autumn 2017

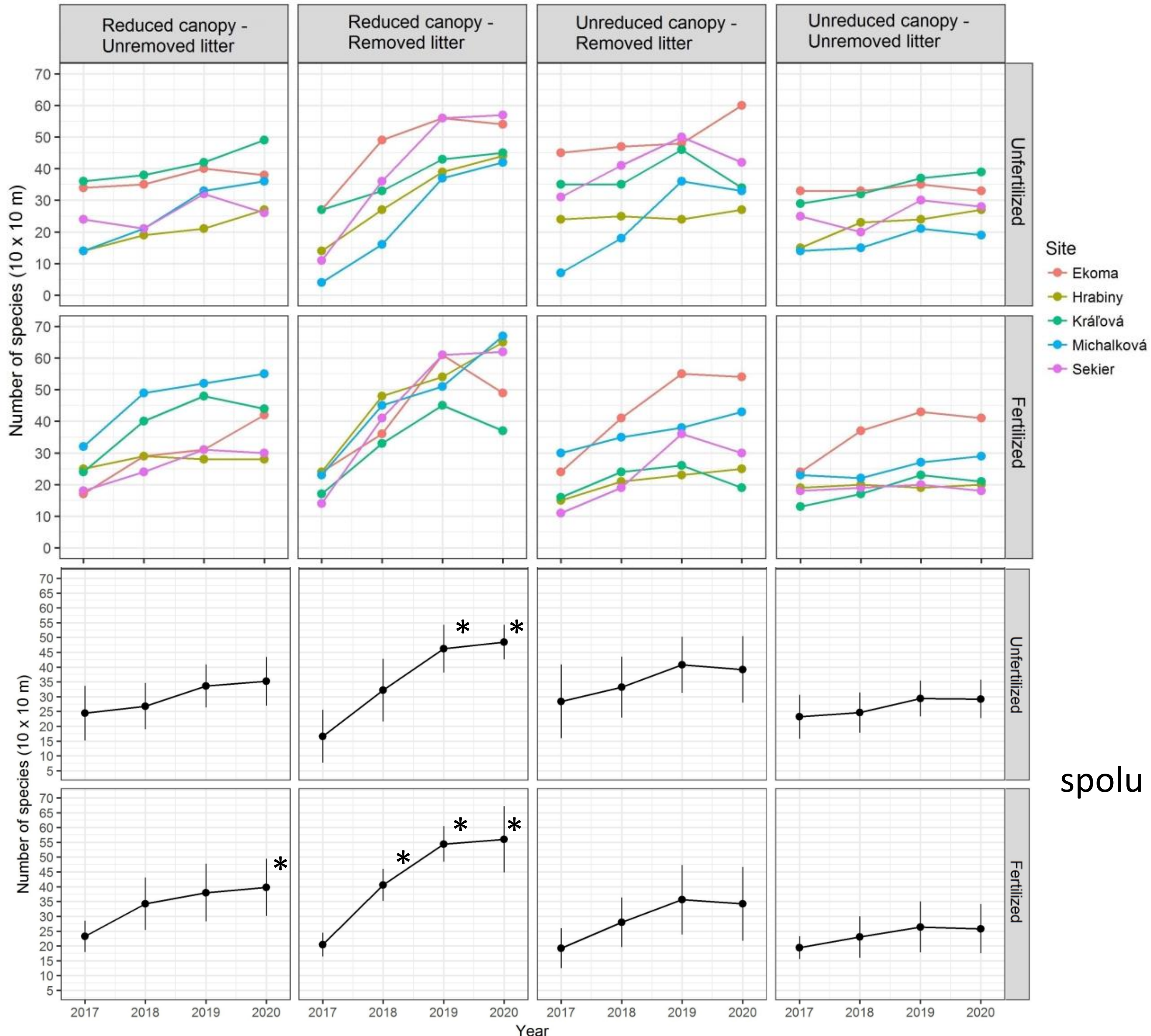
Aims & Hypotheses

Canopy reduction (- 30 %):
reduction of shade-casting trees
Reversing mesophilisation?
Thermophilisation? Come-back of nemoral species?

Litter raking (annually):
historical management, nutrient export
Increase of diversity?

N – fertilization (50 kg N/ha/year):
anthropogenous N depositions
Eutrophication? Diversity decrease?

Results – changes in species richness

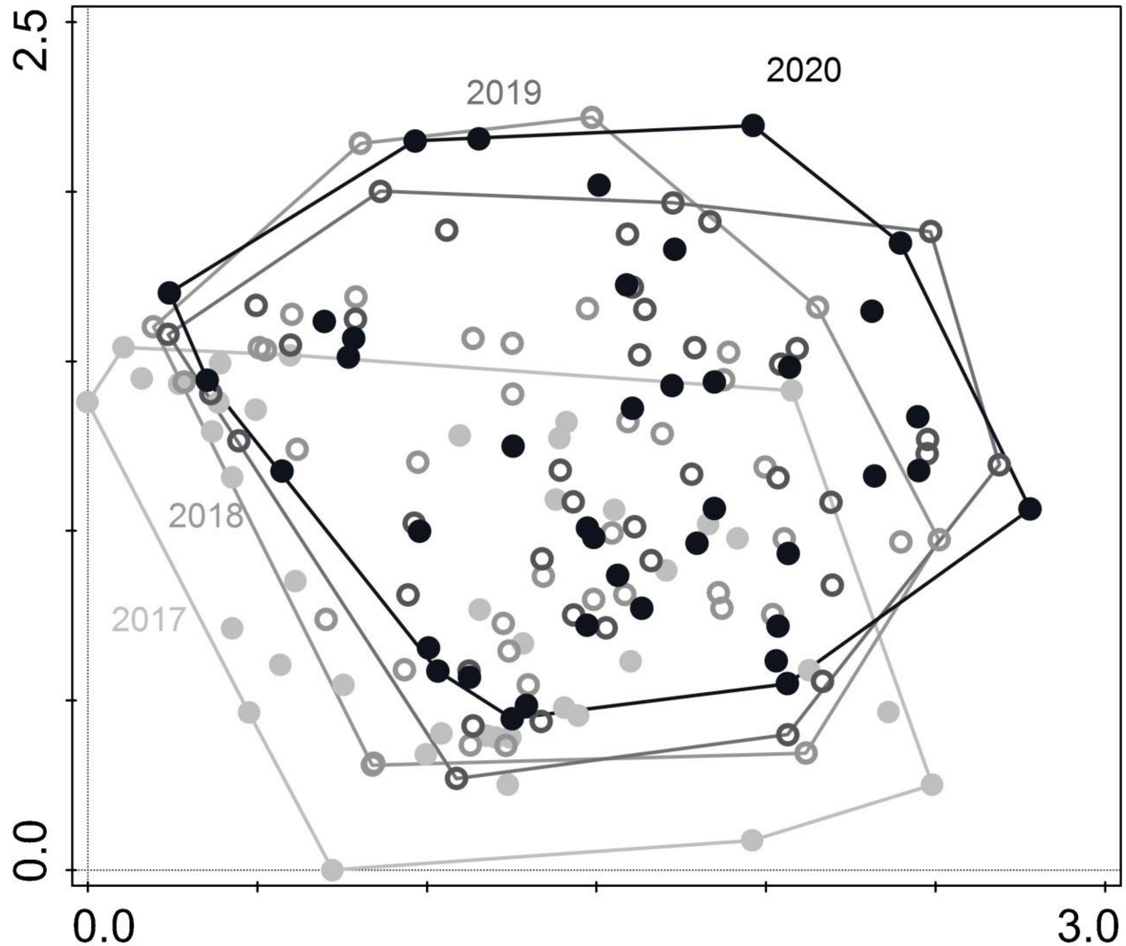


spolu

Changes in species composition

Annual shifts according to DCA ordination

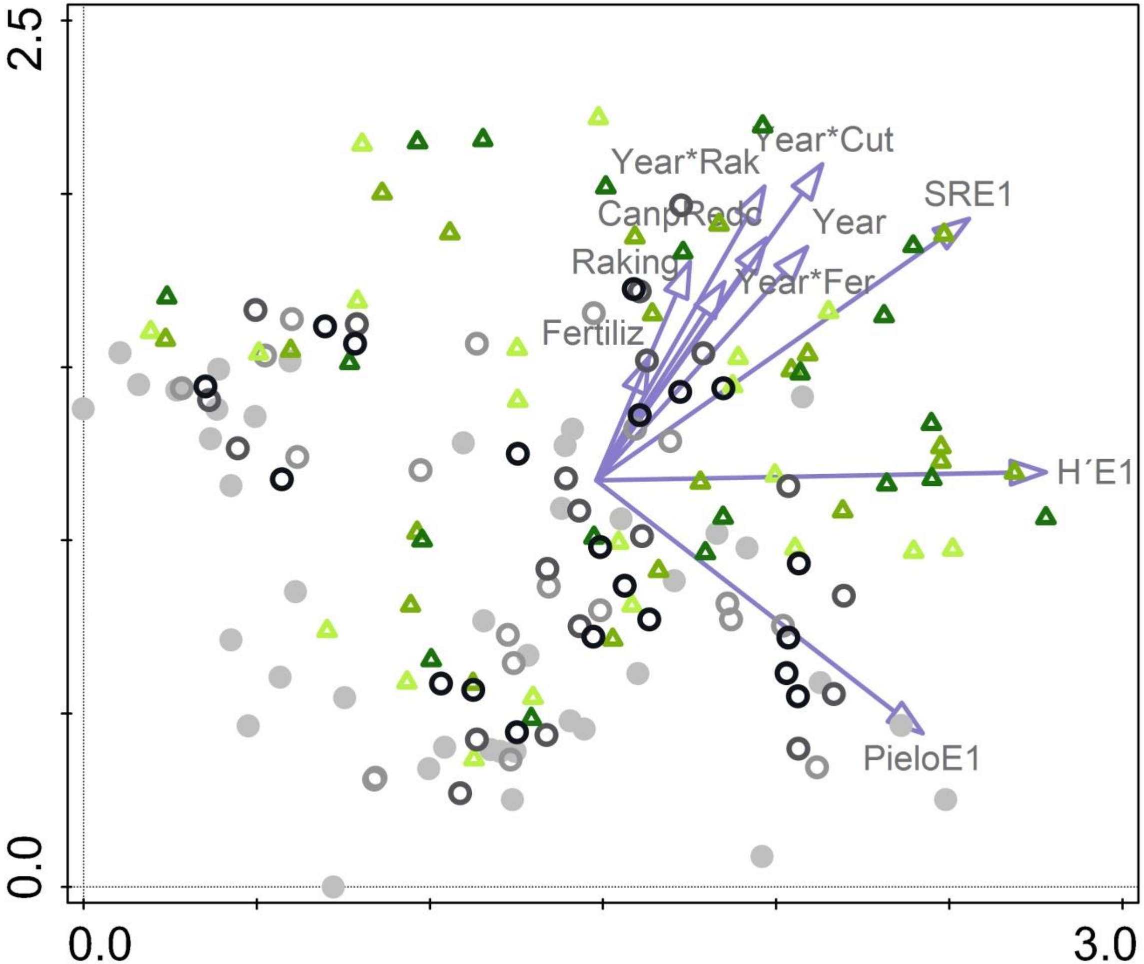
- understorey species
- 100 m2
- log. transformation

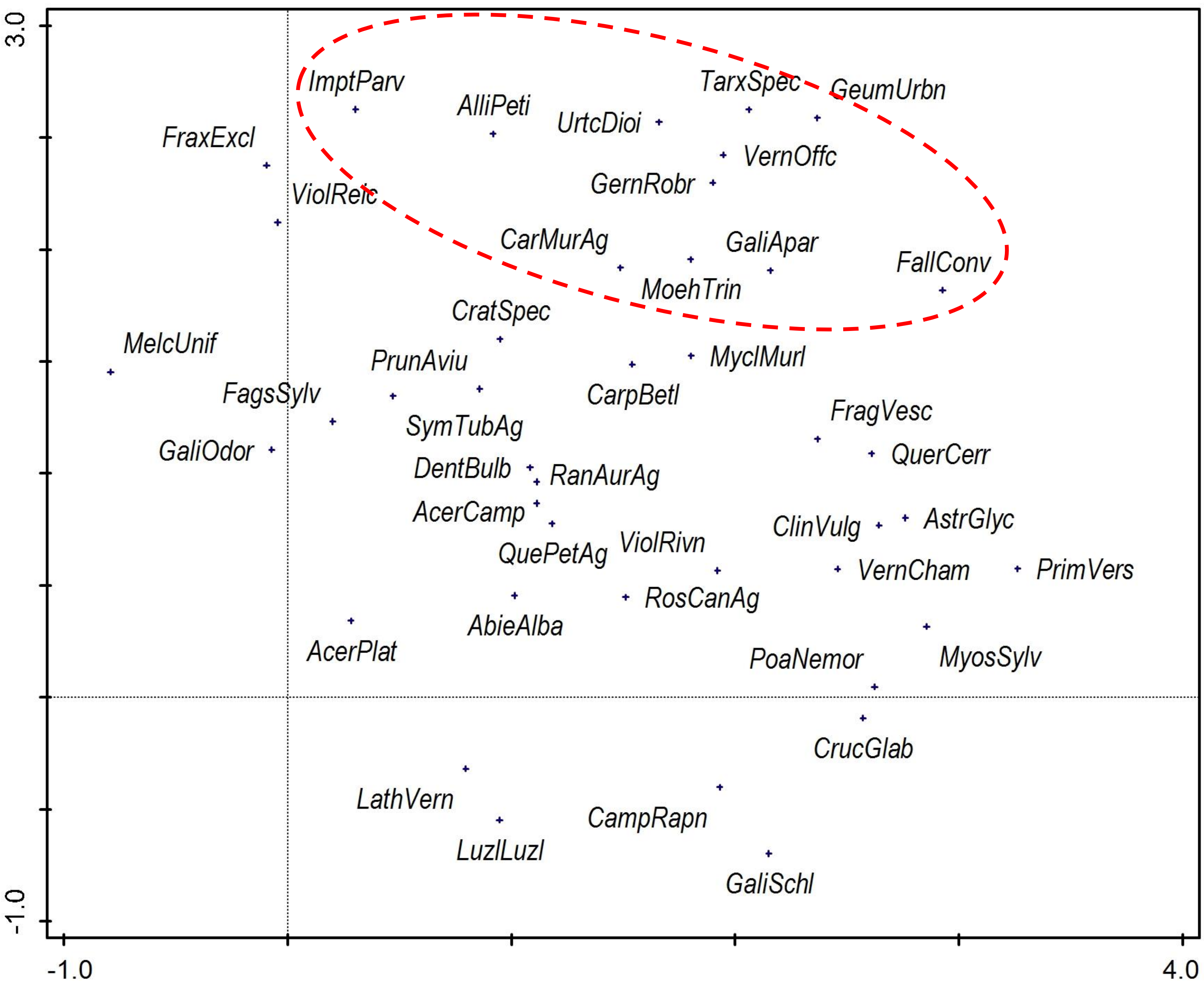


Changes in species composition

Shifts in raked plots

– understorey species
– 100 m2
– log. transformation




3.0
-1.0
-1.0
4.0
ImptParv
AlliPeti
UrtcDioi
TarxSpec
GeumUrbn
FraxExcl
VernOffc
GernRobr
ViolReic
CarMurAg
GaliApar
FallConv
MoehTrin
CratSpec
MelcUnif
PrunAviu
MyclMurl
FagsSylv
CarpBetl
FragVesc
SymTubAg
GaliOdor
QuerCerr
DentBulb
RanAurAg
AcerCamp
ClinVulg
AstrGlyc
ViolRivn
QuePetAg
VernCham
PrimVers
RosCanAg
AbieAlba
AcerPlat
PoaNemor
MyosSylv
CrucGlab
LathVern
CampRapn
LuzlLuzl
GaliSchl

Species colonizing raked plots

Synoptic table with percentage frequency and fidelity (phi coefficient *100) shown for species with significantly higher frequency in year (Fisher´s test, p ≤ 0.01)

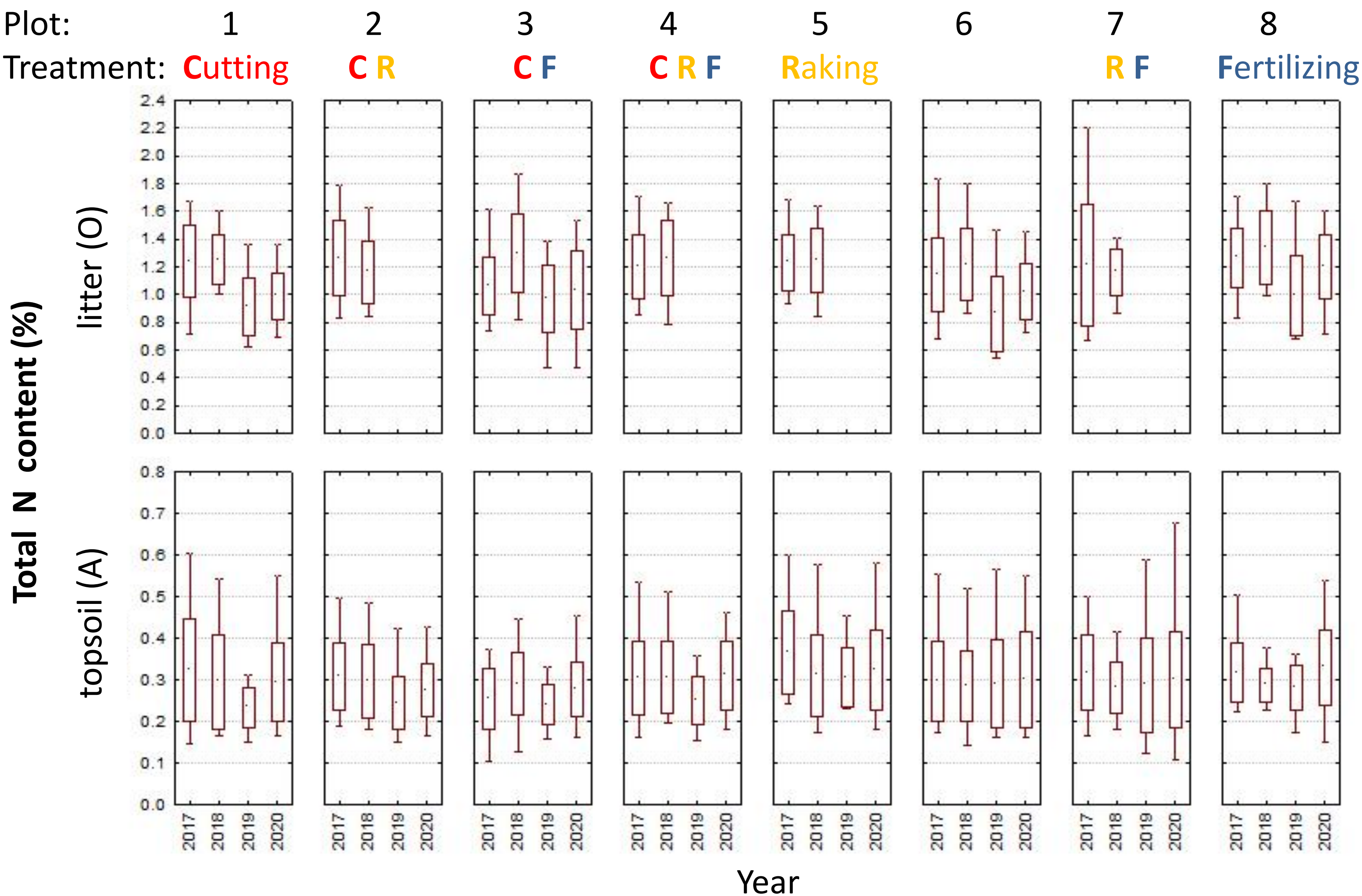
Year	2017		2018		2019		2020		EIV	
No. of relevés	20		20		20		20		*L*	*N*
Rapid colonists										
Sonchus species	.	---	**35**	39.5	15	---	.	---		
Linaria vulgaris	.	---	**15**	36.6	.	---	.	---	*8*	*5*
Erechtites hieraciifolius	.	---	**45**	27.4	35	---	15	---		
Urtica dioica	10	---	**75**	31.1	**80**	35.0	45	---	*x*	*9*
Moehringia trinervia	20	---	**100**	21.1	**100**	21.1	95	---	*4*	*7*
Fallopia convolvulus	15	---	**50**	---	**65**	---	**50**	---	*7*	*6*
Lactuca serriola	.	---	30	---	**40**	34.4	10	---	*9*	*4*
Chenopodium species	.	---	40	---	**50**	31.3	40	---		
Senecio sylvaticus	.	---	30	---	**65**	49.9	30	---	*8*	*8*
Daucus carota	.	---	5	---	**20**	36.7	.	---	*8*	*4*
Epilobium angustifolium	.	---	5	---	**30**	32.3	15	---	*8*	*8*
Sambucus nigra	.	---	5	---	**30**	32.3	10	---	*7*	*9*
Cirsium vulgare	.	---	.	---	**25**	29.3	10	---	*8*	*8*
Geranium robertianum	15	---	40	---	**75**	28.7	55	---	*5*	*7*
Geum urbanum	15	---	30	---	**55**	23.3	50	---	*4*	*7*
Taraxacum species	.	---	55	---	**80**	39.0	**70**	30.9	*7*	*8*
Gradual colonists										
Veronica officinalis	10	---	25	---	**80**	31.4	**90**	39.2	*6*	*4*
Myosotis sylvatica	20	---	40	---	**60**	21.6	**65**	25.6	*6*	*7*
Erigeron annuus	.	---	10	---	30	---	**45**	40.4	*7*	*8*
Calamagrostis epigejos	.	---	.	---	20	---	**25**	29.3	*7*	*6*
Torilis japonica	5	---	15	---	50	---	**65**	34.1	*6*	*8*
Mycelis muralis	40	---	55	---	70	---	**80**	26.6	*4*	*6*
Hypericum perforatum	.	---	5	---	35	---	**55**	36.2	*7*	*4*
Lotus corniculatus	.	---	.	---	15	---	**25**	27.1	*7*	*3*
Ajuga genevensis	.	---	.	---	15	---	**35**	27.0	*8*	*2*
Carex muricata agg.	10	---	25	---	40	---	**60**	26.1	*7*	*6*
Astragalus glycyphyllos	15	---	55	---	60	---	**75**	25.4	*6*	*3*
Lathyrus niger	10	---	5	---	20	---	**35**	24.5	*5*	*3*
Veronica chamaedrys	55	---	65	---	85	---	**95**	20.6	*6*	*x*

Constant understorey species poorly affected by raking

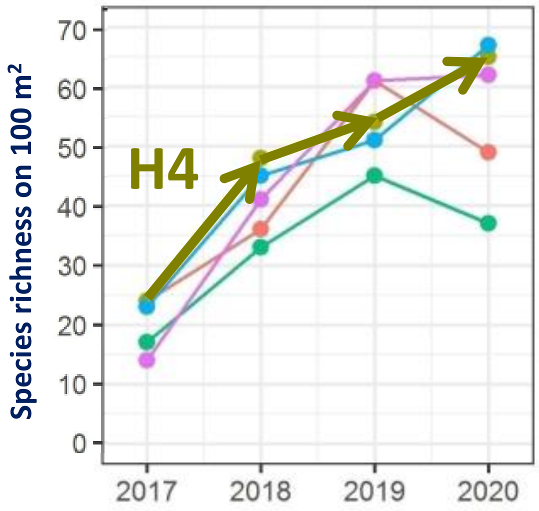
Synoptic table with % frequency (F) and average % non-zero cover (AC) of constant species without significant frequency change in raked plots

	Year	2017		2018		2019		2020		*EIV*	
	No. of relevés	20		20		20		20		*L*	*N*
		F	AC	F	AC	F	AC	F	AC		
	Constant species										
	Dentaria bulbifera	100	2.8	100	4.0	100	2.8	100	4.5	*3*	*6*
	Quercus petraea agg.	70	2.0	80	1.9	90	1.7	100	1.9	*6*	*x*
+	*Carpinus betulus*	70	1.4	100	4.5	90	2.5	95	2.6	*4*	*x*
−	*Galium odoratum*	85	10.1	90	10.8	95	6.3	85	4.8	*2*	*5*
	Fagus sylvatica	85	2.9	80	2.5	65	2.0	70	2.1	*3*	*x*
+	*Poa nemoralis*	50	3.6	70	3.7	85	4.9	75	6.7	*5*	*4*
	Prunus avium	65	1.5	80	1.4	70	1.3	90	1.5	*4*	*5*
+	*Symphytum tuberosum agg.*	35	1.4	70	1.9	65	2.1	70	2.0	*4*	*5*
	Acer campestre	55	1.6	55	1.5	55	1.3	55	1.5	*5*	*6*
	Cruciata glabra	55	2.4	50	2.4	55	2.4	65	2.6	*7*	*5*
−	*Melica uniflora*	55	10.4	50	8.8	55	7.5	55	6.5	*3*	*6*
	Campanula rapunculoides	40	1.4	40	2.4	50	2.3	45	1.9	*6*	*4*
	Crataegus species	45	1.4	50	1.7	60	1.4	55	1.5	*6*	*5*
	Ranunculus auricomus agg.	35	1.3	55	1.4	60	1.2	55	1.8	*5*	*x*
+	*Clinopodium vulgare*	35	1.4	40	1.9	65	1.8	65	2.2	*7*	*3*
	Fraxinus excelsior	50	1.7	40	1.9	45	1.8	45	1.6	*4*	*7*
+	*Galium aparine*	25	1.4	35	1.6	60	2.2	70	1.8	*7*	*8*
	Viola riviniana	35	1.7	60	1.8	60	1.7	50	2.3	*5*	*x*
	Galium schultesii	40	2.6	35	2.0	45	1.9	50	1.8	*5*	*4*
	Luzula luzuloides	30	1.8	30	2.0	35	2.0	35	2.4	*4*	*4*
	Alliaria petiolata	35	1.9	35	2.3	60	2.5	55	2.0	*5*	*9*
	Viola reichenbachiana	35	1.7	30	2.0	50	2.5	35	2.1	*4*	*6*
	Quercus cerris	25	1.6	45	1.4	40	1.1	40	1.4	*6*	*x*
	Lathyrus vernus	35	2.0	35	2.3	35	1.7	35	1.9	*4*	*4*
+	*Primula veris*	35	1.6	25	1.6	50	1.7	45	2.0	*7*	*3*
	Fragaria vesca	25	1.8	30	1.7	50	1.5	50	1.7	*7*	*6*
	Impatiens parviflora	20	1.8	35	1.9	35	2.7	40	1.8	*4*	*6*

Nitrogen content in soil and litter – no relation to treatments

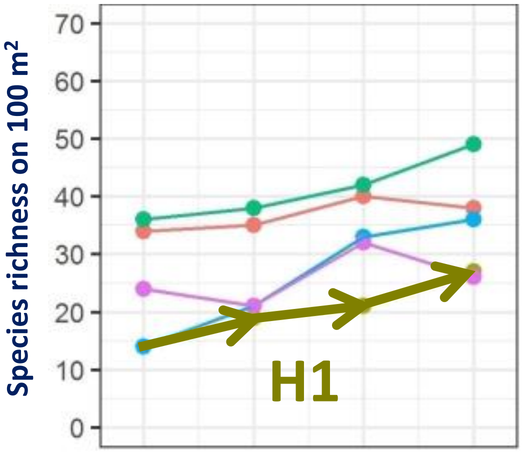


H4 - raked, cutted, fertilized



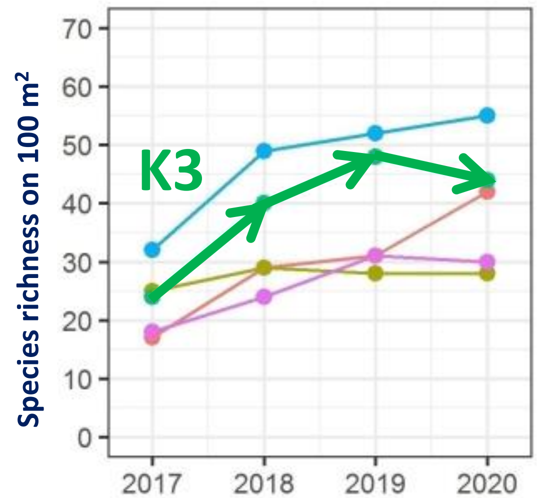
	SR	E3	E1
2017:	24	90 %	70 %
2020:	64	70 %	70 %

H1 - cutted



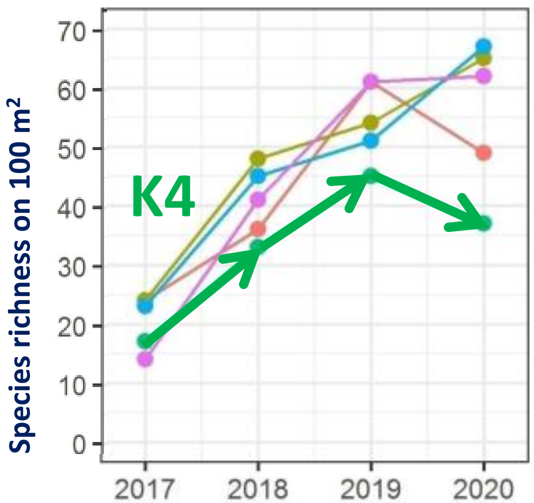
	SR	E3	E1
2017:	15	85 %	15 %
2020:	27	75 %	60 %

K3 - cutted, fertilized



	SR	E3	E1
2017:	24	65 %	30 %
2020:	44	60 %	60 %

K4 - cutted, raked, fertilized



	SR	E3	E1
2017:	17	60 %	17 %
2020:	37	50 %	60 %


2019
K2 – cutted, raked
original tussocks of *Poa nemoralis*


2019
juveniles of *Poa nemoralis*
on raked + cutted plot

dispersal of *Myosotis sylvatica, Veronica chamaedrys*

2019

juveniles of *Fallopia convolvulus*


2020
unfertilized
4th year of fertilization


2020
the strongest understorey changes in plots affected by all treatments


2020

poor understorey response in raked plot without removal of *Carpinus betulus*

Conclusions after the 4th year

- rapid understorey response to treatments – especially to canopy reduction (and removal of shade casting species)
  - fertilizing was the less affecting treatment
    - increases effect of the other treatments
- significant effect on species composition, cover and diversity
  - dispersal of ruderals and annual species in 2018
  - rapid increase of species richness with culminatiion in 2019 in some plots

Conclusions after the 4th year

- target perenial nemoral species show increasing trend especially in raked and cutted plots
  - max. frequency in 2020
  - *Poa nemoralis*, *Veronica chamaedrys*, *Astragalus glyciphyllos*, *Lathyrus niger* etc.
- some nitrophilous and invasive species positively responded as well
  - *Impatiens parviflora*, *Erigeron annuus*, *Fallopia convolvulus*, *Moehringia trinervia*
- among forest shade tolerant generalists *Galium odoratum* was negatively affected
- nitrogen addition was not detected by analyses of totan N content neither in litter nor in topsoil layer

Thank You for attention!