Transformation of pine monoculture to biodiverse food forest

Baseline study of soil quality, carbon stock and biodiversity in a pine production forest on sandy soil in Overloon, the Netherlands

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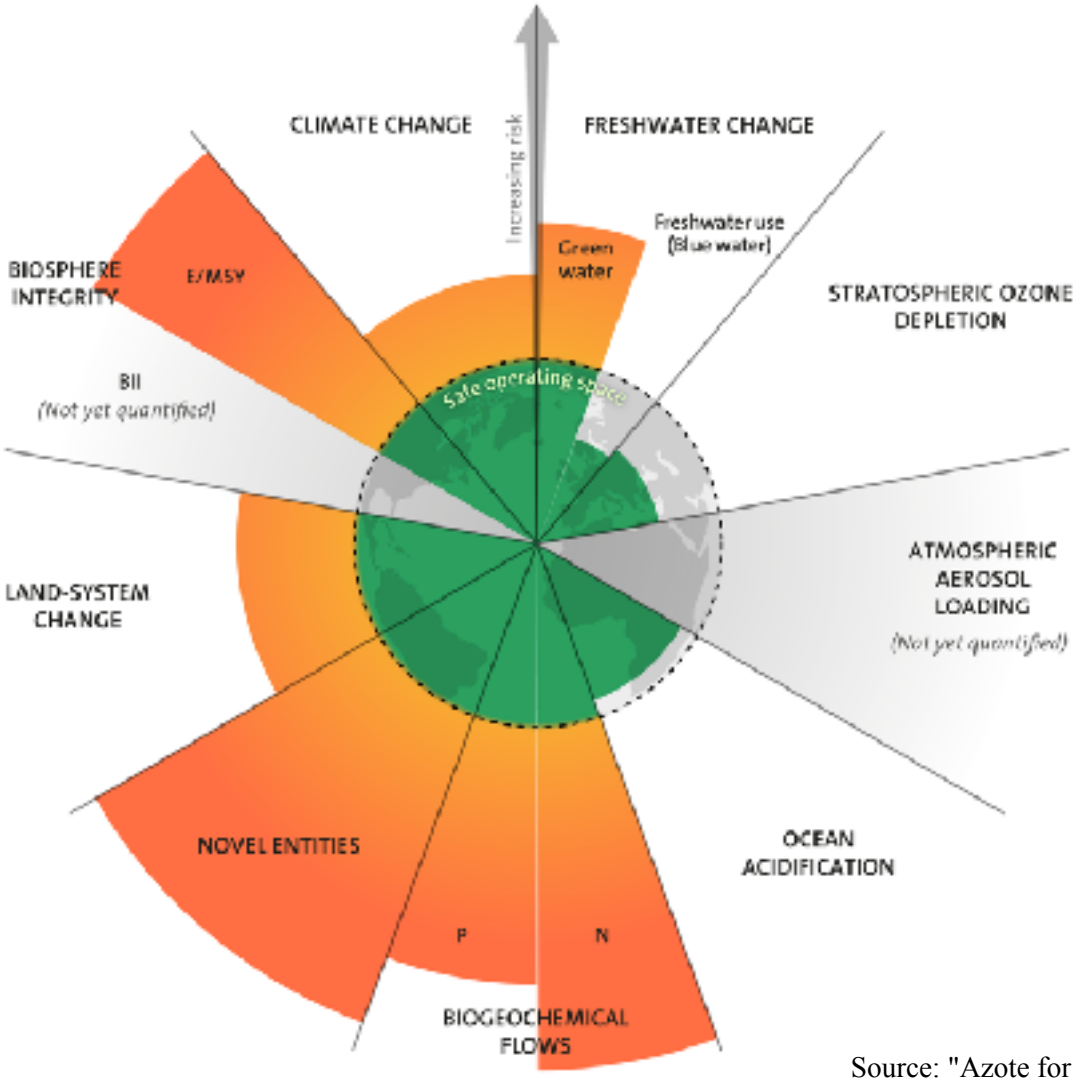
Thanks to:

AGRO PROEFTUIN de Peel

Planetary Boundaries



Source: "Azote for Stockholm Resilience Centre, based on analysis in Wang-Erlandsson et al 2022".

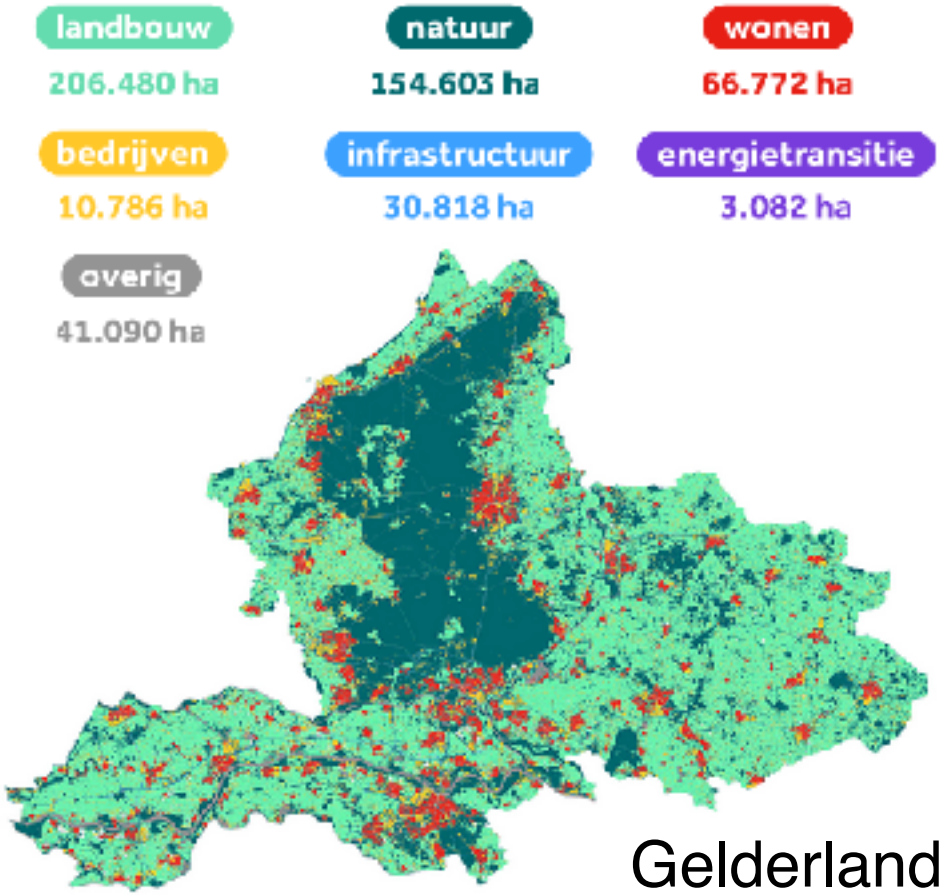
Definition ‘Nature’:

The whole of material reality, considered as independent of human activity and history

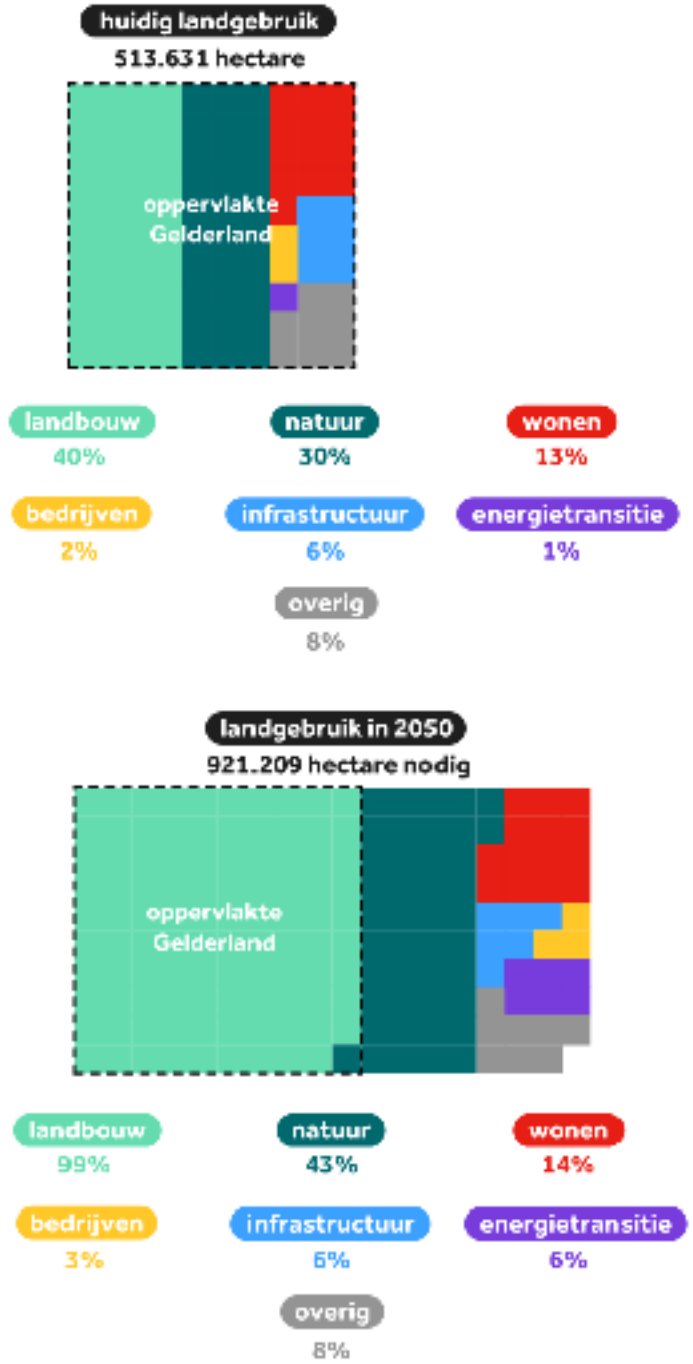
Source: Ducarme, F., & Couvet, D. (2020). What does ‘nature’ mean? *Palgrave Communications* 2020, 6(1), 1-8.

Source: Painting “Tilling” by Morgan Bulkeley

Segmentation of the land



Gelderland

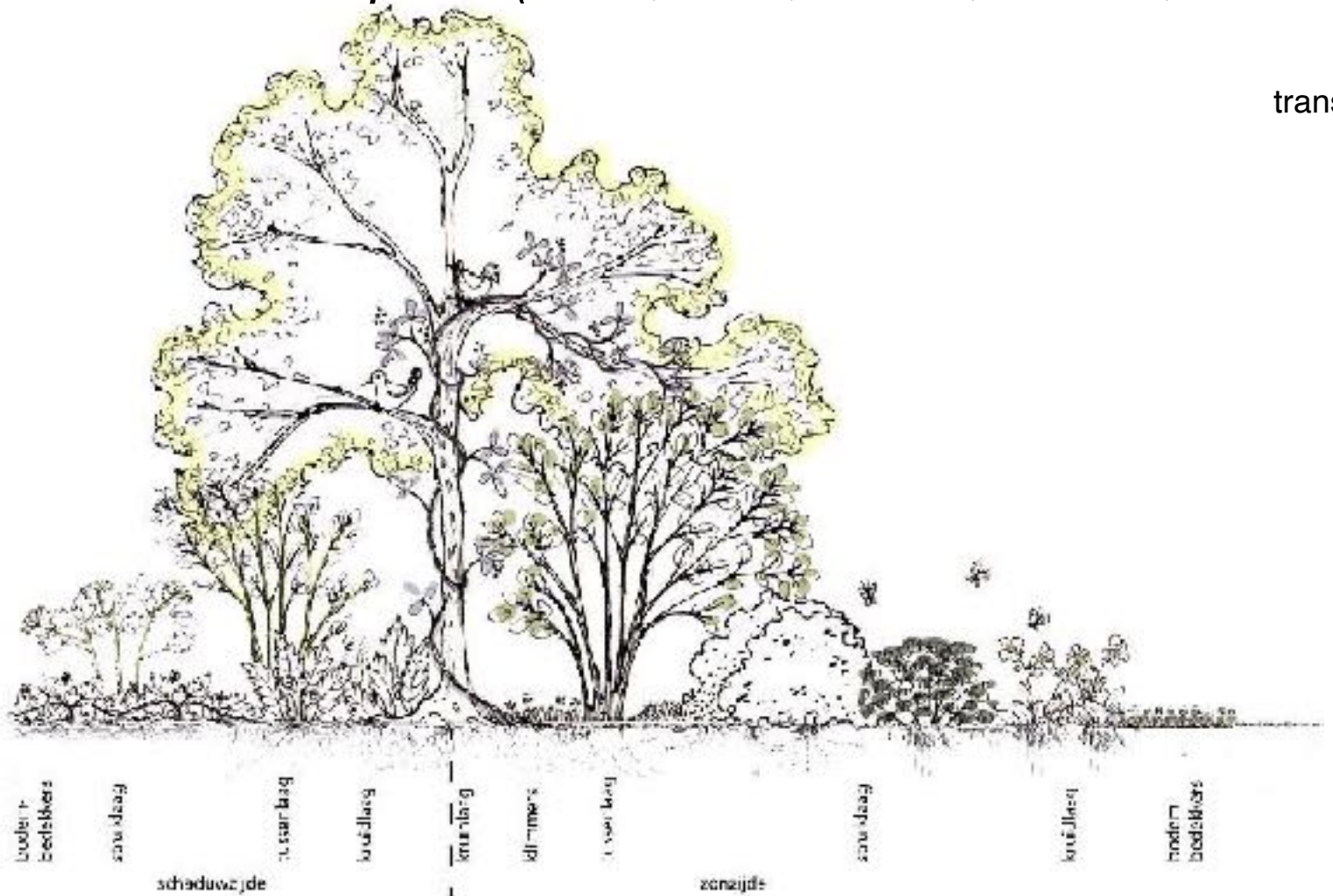


Source: NOS, “Boeren, huizen of natuur”, https://app.nos.nl/op3/gelderland-verdeeld/

Food Forest:

‘Human-designed productive ecosystem, consisting of multiple layers and a rich soil system that mimics a natural forest, with a great diversity of perennial, woody species, of which parts (fruits, nuts, seeds, leaves, branches) serve as human food.’

translated from Green Deal Voedselbossen (2017)



Source: https://www.voedselbos.eu/voedselbos/wat-is-een-voedselbos.html

Pine production forest Overloon

Three goals:

- Increase carbon storage
- Increase biodiversity
- Increase economic return

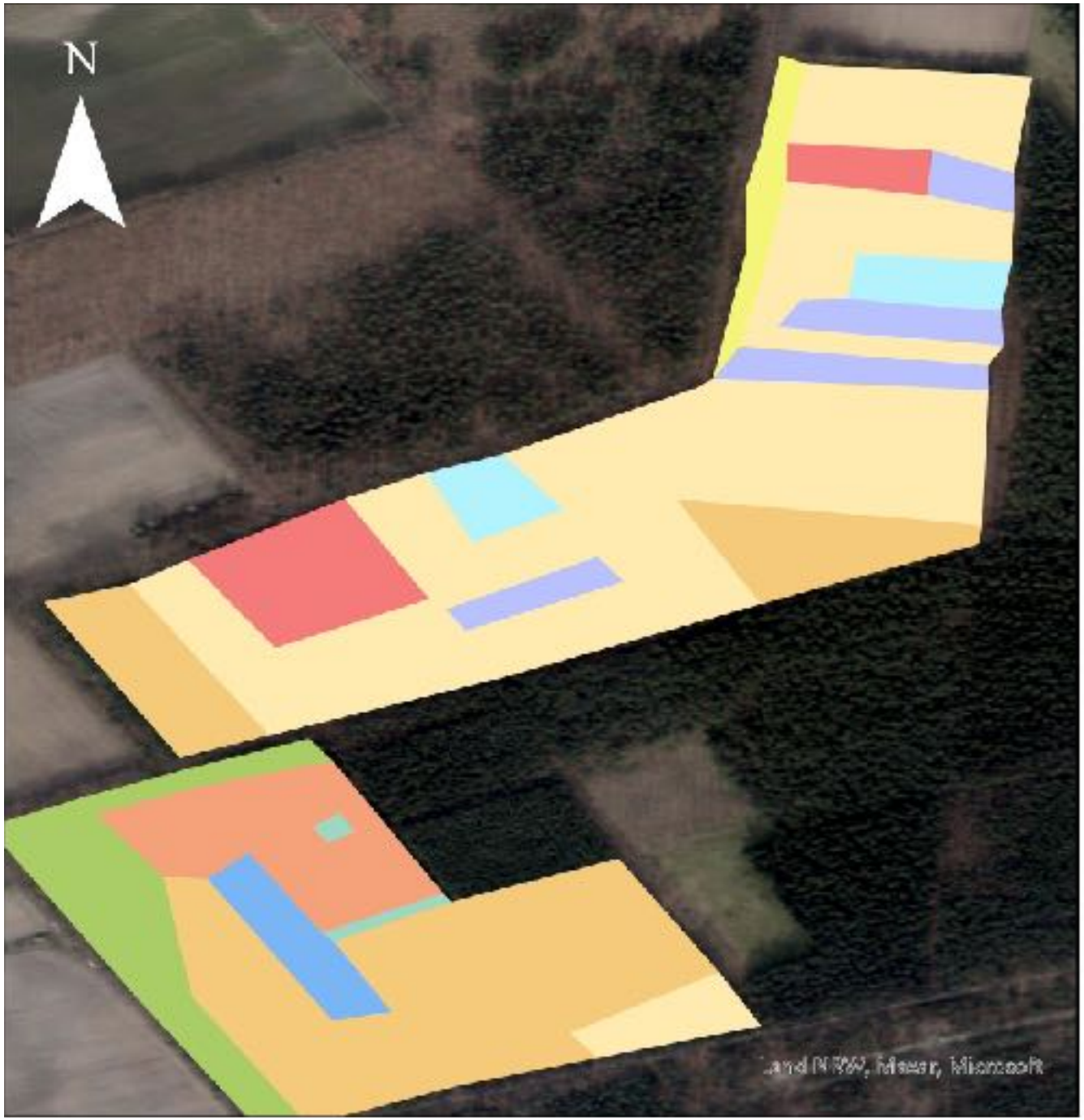
Research Questions:

1. What is the state of the:
    (1) soil according to chemical, physical and biological variables;
    (2) aboveground woody carbon stocks;
    (3) plant and insect diversity?

2. Do these variables differ across forest types?

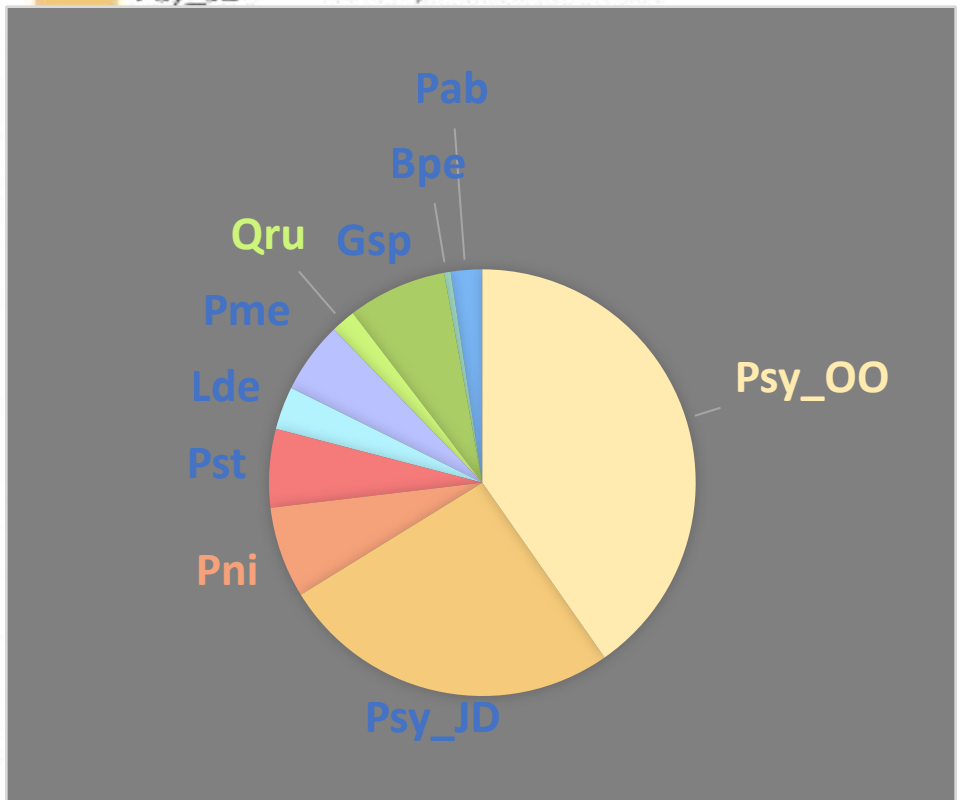
3. Considering these variables, what improvements are expected when turning this production forest into a food forest?

4. What are the short-term effects of adding chalk and rock flour to a forest clearing and could this help to kickstart the nutrient cycle?



Forest types

Code	Dominant tree species
Bpe	*Betula pendula*
Gsp	*Generibus sp.* (mixed)
Lde	*Larix decidua*
Pab	*Picea abies*
Pme	*Pseudotsuga menziesii*
Pni	*Pinus nigra*
Pst	*Pinus strobus*
Psy_JD	*Pinus sylvestris* (young dense)




PsyOO
Pinus sylvestris Old Open
PsyJD
Pinus sylvestris Young Dense

Soil

- **Average soil sample for each forest type**
- **Top layer: 0-25 cm**

Physical soil properties

	UNIT	PST/PME	PSYJD	PSYOO	PNI	PLOTS 1&2 (PSYOO)	PLOTS 3&4 (PSTJD)
Bulkdensity	kg/m³	1365	1389	1419	1320	1429	-
Acidity	pH	3.3	3.4	3.4	3.4	3.5	3.3
C-organic	%	1.7	1.4	1.2	2.1	1	2.2
Organic matter	%	3.1	2.6	2	4.1	1.8	4
C/OM-ratio		0.55	0.54	0.6	0.51	0.56	0.55
Carbonated lime	%	0.7	0.6	0.4	0.2	0.2	0.9
Clay	%	<1	1	1.2	2	<1	2
Silt	%	5	3	2	10	8	5
Sand	%	91	93	92	84	90	88
Cation exchange capacity (CEC)	mmol/kg	15	14	17	17	<11	27
CEC-saturation	%	78	74	72	76	-	60
Ca-saturation	%	50	60	58	56	-	41
Mg-saturation	%	15	<0.1	<0.1	8.2	-	9.6
K-saturation	%	10	11	14	9.4	-	5.9
Na-saturation	%	3.3	2.9	<0.1	2.4	-	3
H-saturation	%	37	31	26	26	-	20
Al-saturation	%	40	40	40	40	-	40

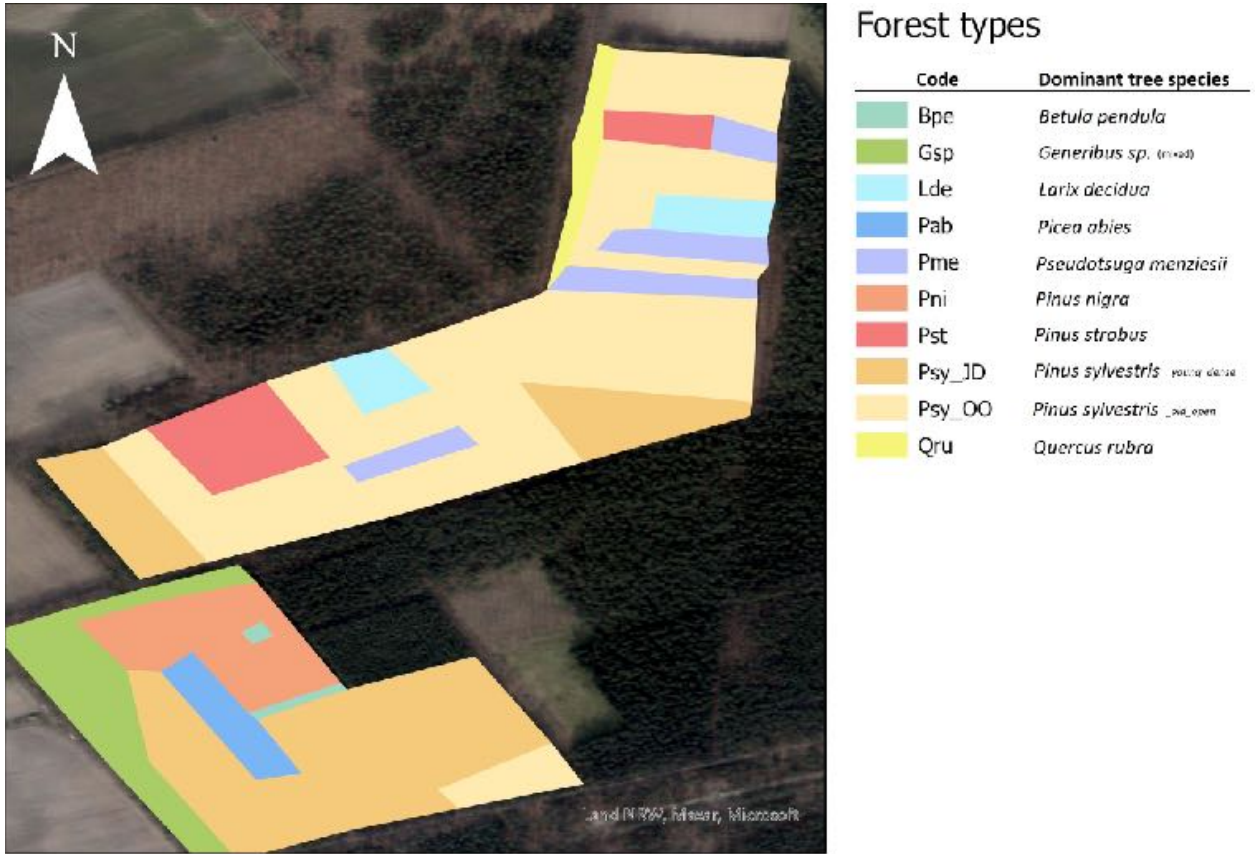
Chemical soil properties

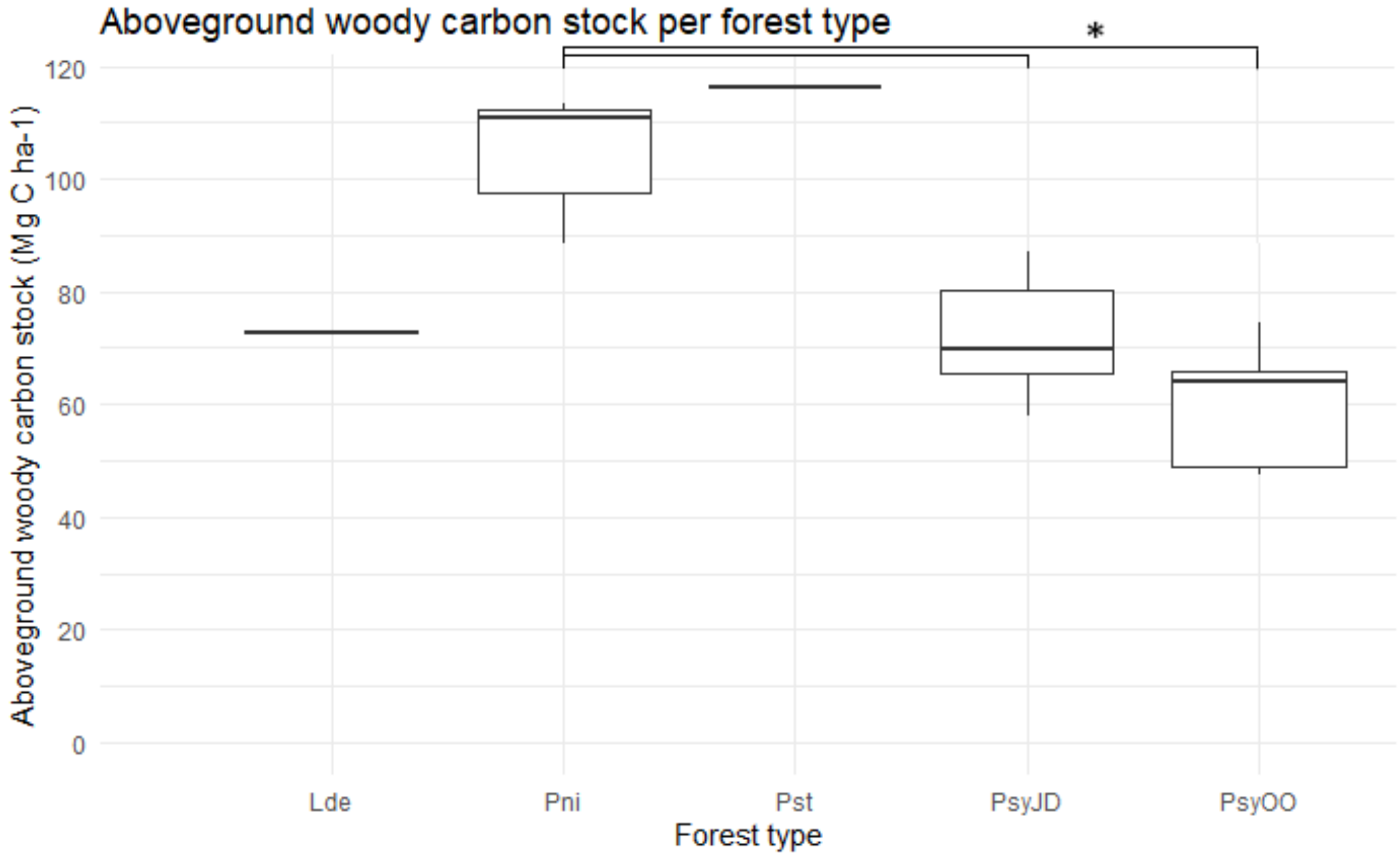
All values given in kg/ha

	PST/PME	PSYJD	PSYOO	PNI	PLOTS 1&2 (PSYOO)	PLOTS 3&4 (PSTJD)
N-stock	2660	1950	2310	3660	1970	2520
C/N ratio	22	25	19	19	18	29
N-releasing power	20	10	25	35	20	0
S-stock	750	625	710	560	680	795
S-available	8	8	7	8	11	19
C/S-ratio	78	78	62	125	53	90
S-releasing power	10	8	11	3	12	9
P-stock	45	45	45	45	45	45
P-available	<1.1	<1.1	<1.1	<1.0	<1.1	4.6
K-stock	200	205	335	205	180	205
K-available	30	35	35	25	30	45
Ca-stock	515	585	695	630	0	745
Ca-available	25	30	55	25	30	25
Mg-stock	95	45	45	55	50	105
Mg-available	<15	<15	20	15	<20	15
Na-stock	40	30	35	30	35	60
Na-available	20	25	20	25	<20	20

Carbon storage

- **Five 10 x 10 m plots in PsyOO, PsyJD and Pni**
- **DBH and height**




Aboveground woody carbon stock per forest type
*
Aboveground woody carbon stock (Mg C ha-1)
120
100
80
60
40
20
0
Lde
Pni
Pst
PsyJD
PsyOO
Forest type

Biodiversity

- Plants
- Butterflies & dragonflies
- Moths
- Insects
- Bonus: vertebrates

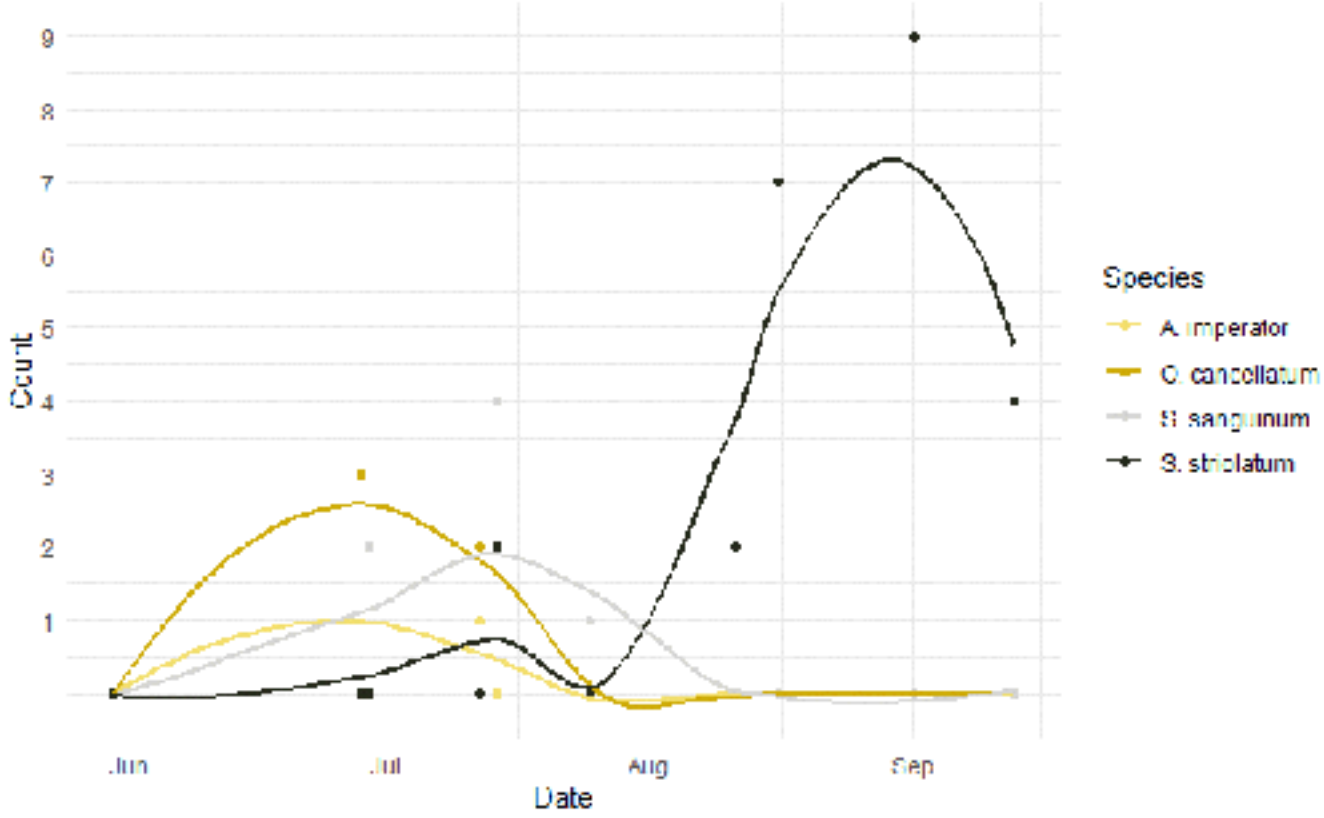
Plant diversity

- **5 x 5 m plots, Braun-Blanquet**
- **Low: 31 species in total**

Forest type	Shannon diversity round 1	Shannon diversity round 2
PsyOO	1.0521933	1.0624930
PsyJD	0.4937526	0.5599122
Pni	0.9088315	0.7549701
Pme	0.8191000	0.9697804
Pst	0.5004024	0.1914441

Butterflies & Dragonflies

- **Butterfly transect**
- **9 species of butterfly, sporadically**
- **Dragonflies more frequent:**



Moths

- **Skinner trap with UV-light**
- **42 species identified, some very abundant**

Vertebrates

Reptiles

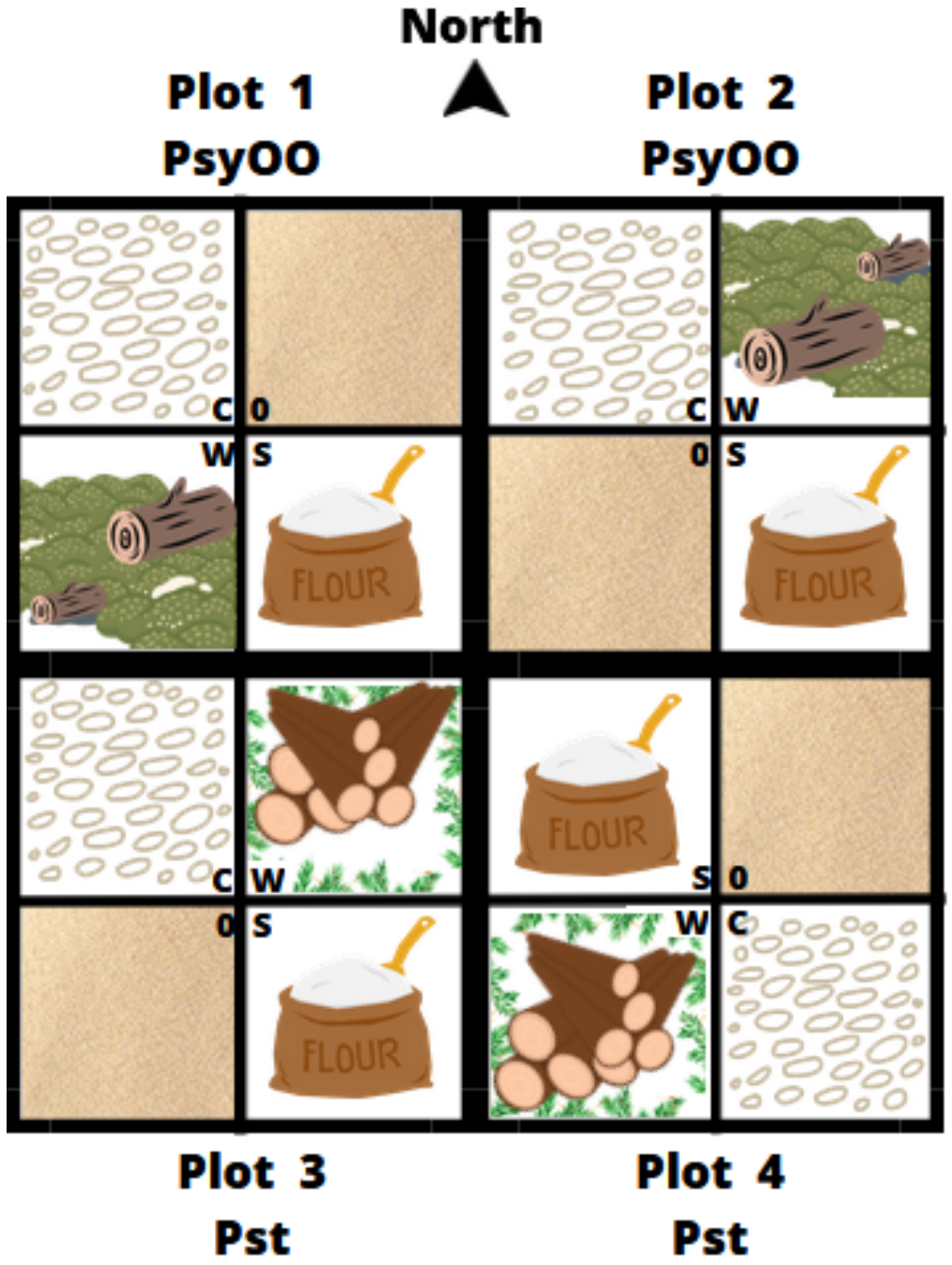
Amphibians

Birds

Mammals

Experimental plots

- Four 10 x 10 m plots
- Two in PsyOO and two in Pst



Before

After

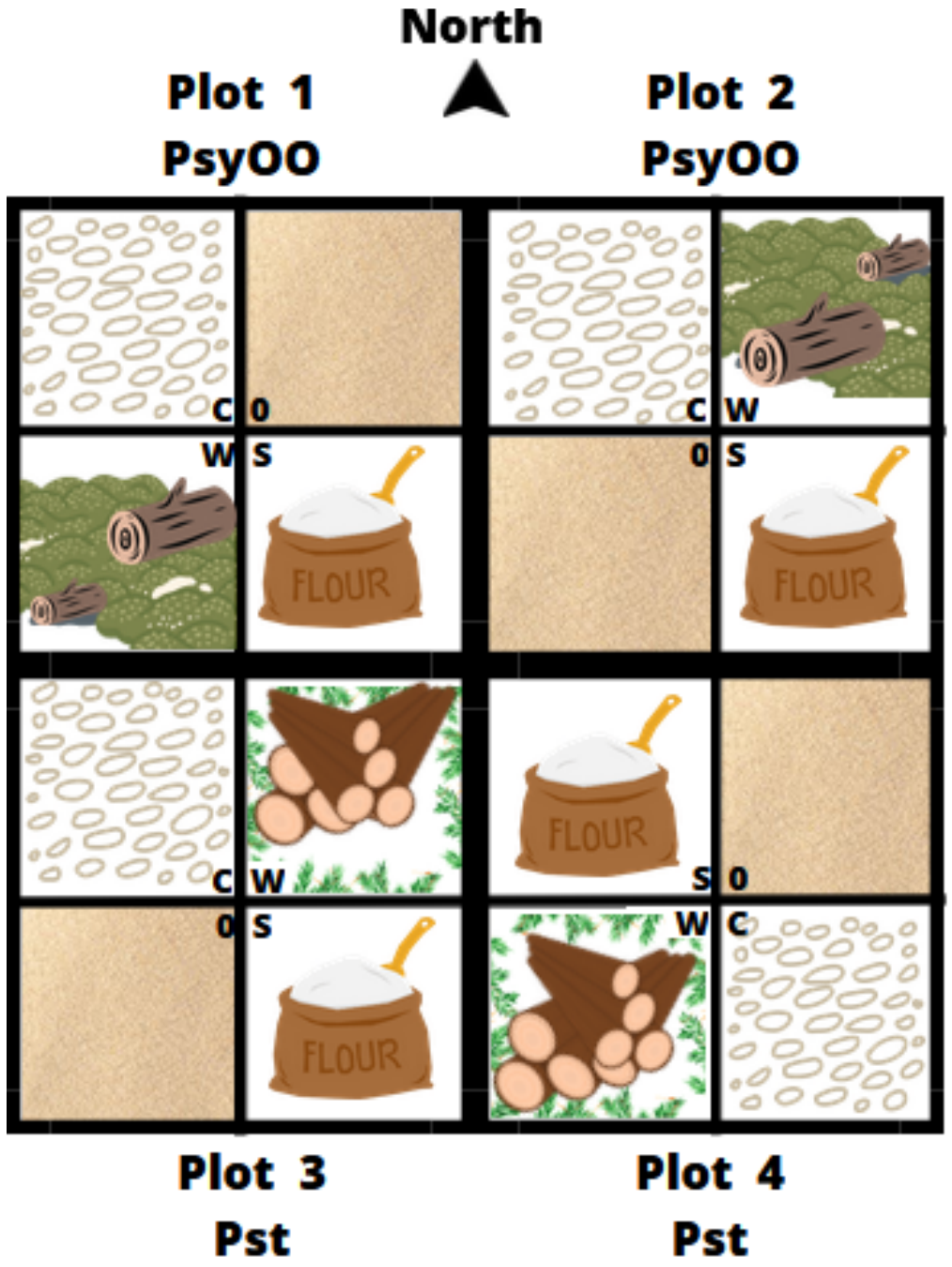
Experimental plots

(W) Wood

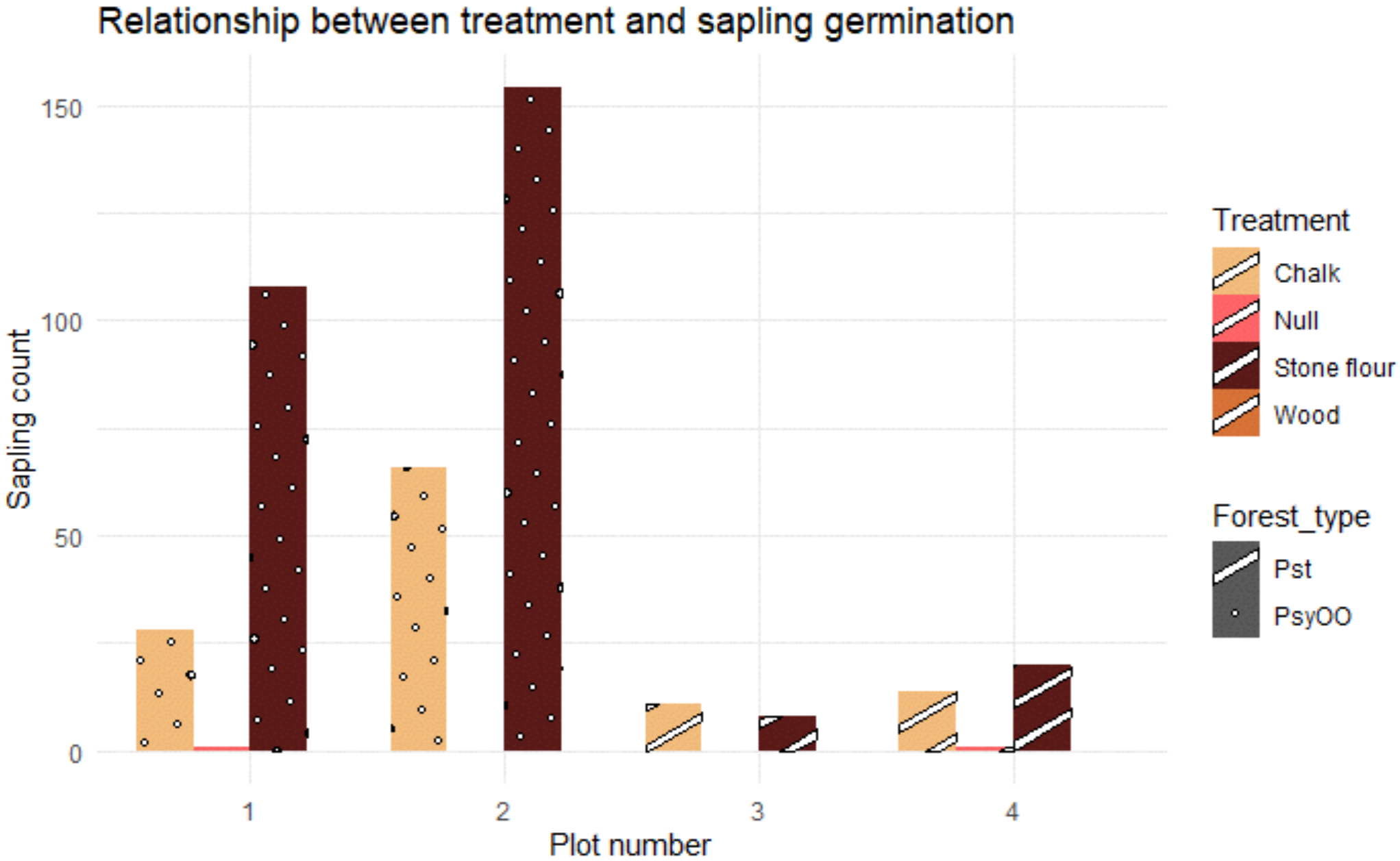
(0) Null

(C) Chalk: 3.75 kg of DCM chalk (15% MgO)

(S) Stone flour: 7.5 kg of Stone flour







Relationship between treatment and sapling germination
Sapling count
150
100
50
0
1
2
3
4
Plot number
Treatment
Chalk
Null
Stone flour
Wood
Forest_type
Pst
PsyOO

To Conclude:

1. What is the state of the:
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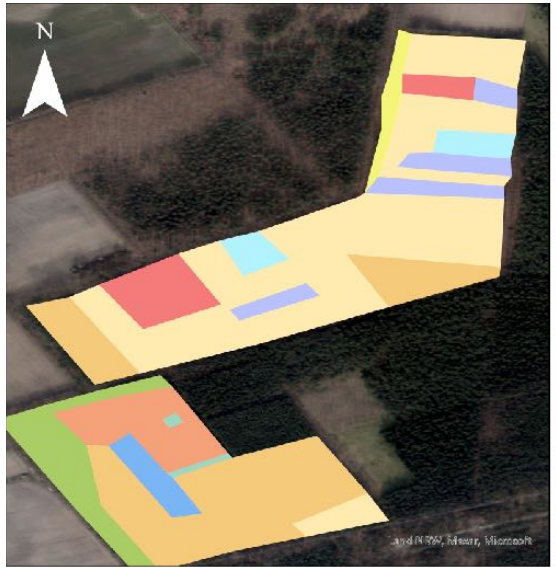
Questions?

Future changes



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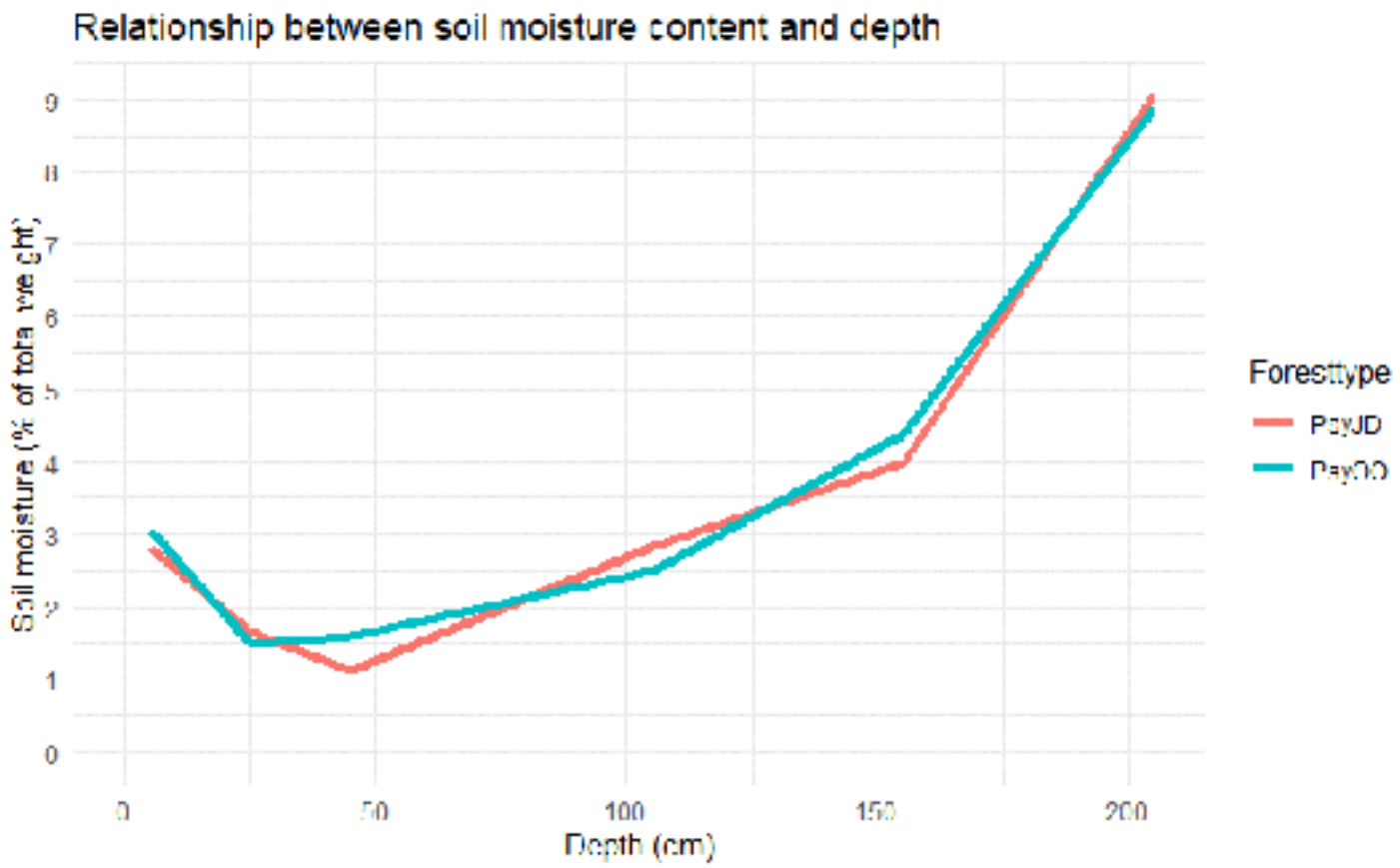
Pst	*Pinus strobus*
Psy_JD	*Pinus sylvestris*
Psy_OO	*Pinus sylvestris*
Qru	*Quercus rubra*

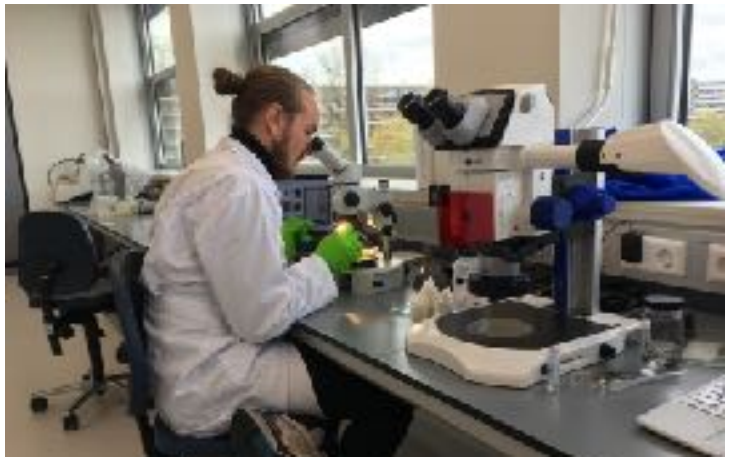
Soil water

- Groundwater tables 1-3 m deep (Brabantwater)
- Gravimetric water content on 01-09-2022



Insects

- 136 pit traps
- 8 malaise traps
- 20 pan traps



Stone Flour

Hoofdelementen:

Element	Verbinding	Gehalte (%)
Silicium	SiO_2	40 - 50
IJzer	Fe_2O_3	9,7 - 10,8
Calcium	CaO	7,5 - 8,4
Magnesium	MgO	5,4 - 7,8
Natrium	Na_2O	3,0 - 3,4
Kalium	K_2O	1,44 - 1,90
Fosfaat	P_2O_5	0,44 - 0,69
Zwavel	SO_3	0,02

Sporenelementen:

Element	Gehalte (mg/kg)	Element	Gehalte (mg/kg)
Cerium	66	**Molybdeen**	2
Cesium	0,2	Neodymium	33
Dysprosium	5	Praseodymium	7,8
Europium	2,2	Rubidium	32
Erbium	2,3	**Selenium**	0,03
Gadolinium	6,3	Scandium	18
Gallium	21	Tantaal	2,7
Germanium	1,3	Terbium	0,9
Hafnium	4	Thulium	0,3
Holmium	0,9	Tin	2
Kobalt	38	Ytterbium	1,8
Koper	**41**	Yttrium	23,5
Lanthaan	33,5	**Zink**	**97**
Lutetium	0,25	Zirkonium	169
Mangaan	**1300**		

Mineralogie:

XRD-analyse

Naam	Verbinding	%
Plagioklaas	$(Ca,Na)AlSi_2O_8$	47
Clinopyroxenen	$(Mg,Ca,Na,Fe)Si_2O_6$	19
Anorthoklaas	$(Na,K)AlSi_3O_8$	18
Forsteriet	Mg_2SiO_4	7
Overige aluminosilicaten		6
Hydroxides		3

Plant species

Group	Species	Dutch name	English name
Conifer trees	*Pinus sylvestris*	Grove Den	Scotts pine
	Pinus strobus	Weymout den	Weymout pine / White pine
	Pinus nigra subsp. laricio	Corsicaanse den	Black pine
	Picea abies	Fijnspar	Norway spruce
	Pseudotsuga menziesii	Douglasspar	Douglas fir
	Larix decidua	Europese lork	European larch
Decidious trees	*Quercus robur*	Zomereik	Common oak
	Quercus rubra	Amerikaanse eik	Northern red oak
	Betula pendula	Ruwe berk	Silver Birch
	Sorbus aucuparia	Wilde lijsterbes	Rowan / mountain-ash
	Amelanchier lamarckii	Amerikaanse krentenboompje	Juneberry
	Prunus serotina	Amerikaanse vogelkers	Black cherry
Herbs & shrubs	*Rubus fruticosus*	Gewone Braam	Blackberry
	Frangula alnus	Sporkehout	Alder buckthorn
	Vaccinium corymbosum	Blauwbes	Northern highbush blueberry
	Calluna vulgaris	Struikhei	Common heather
	Sambucus nigra	Gewone vlier	Elderberry
	Ceratocapnos claviculata	Rankende helmbloem	Climbing corydalis
	Alliaria petiolata	look zonder look	Garlic mustard
	Digitalis purpurea	Vingerhoedskruid	foxglove
	Cardamine flexuosa	Bosveldkers	wavy bittercress
	Stellaria media	Vogelmuur	Chickweed
	Rumex acetosella	Schapenzuring	Sheep's sorrel
Ferns & mosses	*Hypnum cupressiforme*	Gesnaveld klauwtjesmos	Cypress-leaved plaitmoss
	Dicranum scoparium	Gewoon gaffeltandmos	Broom forkmoss
	Polytrichum commune	Gewoon haarmos	Common haircap
	Camylopus introflexus	Grijs kronkelsteeltje	Heath star moss
	Pseudoscleropodium purum	Groot laddermos	Neat feather-moss
	Eurhynchium praelongum	Fijn laddermos	Common feather-moss

Mammal species list

Scientific name	common name	Dutch common name
Pipistrellus pipistrellus	Common pipistrelle	Gewone dwergvleermuis
Myotis nattereri	Natterer's bat	Franjestaart
Nyctalus noctula	Common noctule	Rosse vleermuis
Capreolus capreolus	Roe deer	Ree
Meles meles	Badger	Das
Vulpes vulpes	Fox	Vos
Lepus europeanus	Hare	Haas
Myodes glareolus	Bank vole	Rosse woelmuis
Apodemus sylvaticus	Wood mouse	Bosmuis
Sorex minutus	Eurasian pygmy shrew	Dwergspitsmuis

Reptile & amphibian species list

Scientific name	common name	Dutch common name
Podarcis muralis	Common wall lizard	Muurhagedis
Zootoca vivipara	Viviparous lizard	Levendbarende hagedis
Bufo bufo	Common toad	Gewone pad
Rana temporaria	Common frog	Bruine Kikker
Pelophylax sp.	Water frog	Groene kikker
Ichthyosaura alpestris	Alpine newt	Alpenwatersalamander
Lissotriton vulgaris	Smooth newt	Kleine watersalamander

Bird species list

Scientific name	Common name	Dutch name
Buteo buteo	Common Buzzard	Buizerd
Falco subbuteo	Eurasian Hobby	Boomvalk
Accipiter gentilis	Northern Goshawk	Havik
Accipiter nisus	Eurasian sparrowhawk	Sperwer
Strix aluco	Tawny Owl	Bosuil
Corvus corone	Carrion Crow	Zwarte kraai
Garrulus glandarius	Eurasian Jay	Gaai
Pica pica	Eurasian Magpie	Ekster
Dendrocopos major	Great spotted woodpecker	Grote bonte specht
Dryocopus martius	Black Woodpecker	Zwarte specht
Columba palumbus	Common wood pigeon	Houtduif
Turdus merula	Common Blackbird	Merel
Fringilla coelebs	Common Chaffinch	Vink
Turdus philomelos	Song thrush	Zanglijster
Sylvia curruca	Lesser Whitethroat	Braamsluiper
Certhia brachydactyla	Short-toed Treecreeper	Boomkruiper
Parus major	Great tit	Koolmees
Cyanistes caeruleus	Eurasian blue tit	Pimpelmees
Aegithalos caudatus	Long-tailed tit	Staartmees
Poecile palustris	Marsh tit	Glanskop
Phylloscopus collybita	Common Chiffchaff	Tjiftjaf
Erithacus rubecula	European Robin	Roodborst
Anthus trivialis	Tree pipit	Boompieper