Drainage effect on peatlands as seen through multiple landscape ecological indicators – the case of Estonia

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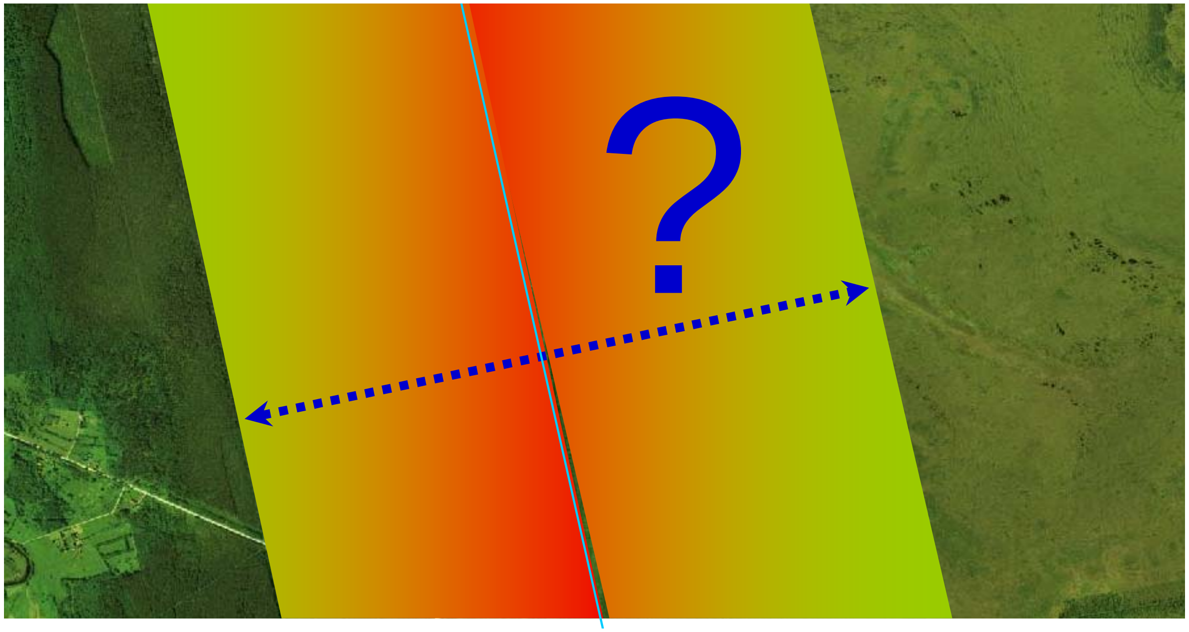
Study period: 2012 - 2016

The main objective of the study was to clarify to what extent the drainage influence mire ecosystem structure and functions.

We aim to quantify long-term drainage effects - what is the spatial extent and intensity of the drainage influence on particular biotic or abiotic components?

*** water level, physical and chemical properties**
*** peat properties**
*** emissions of greenhouse gases**
*** microbiological processes**
*** vegetation pattern and growth increment of trees**
*** diatomeas**
*** invertebrates composition and distribution**

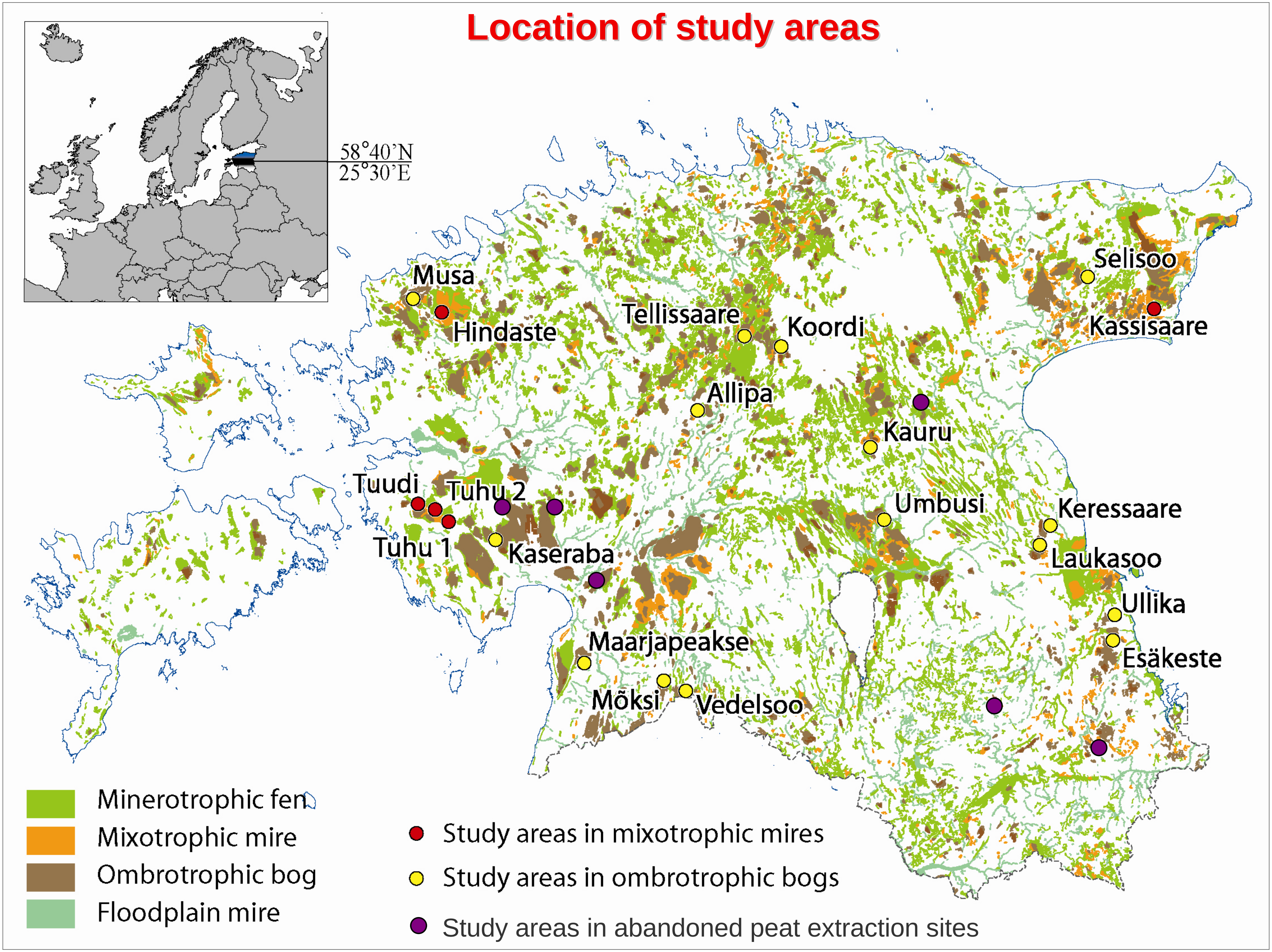


Selection of typologically representative study areas and locations of transects

Stratified sampling

- 20 sample areas with different mire types (transitional and rised bogs) were selected all over Estonia
- Geographical coverage (landscape regions)
- Bedrock (limestone, sandstone, varved clay)
- Drainage type
- Surrounding landuse (peat excavation, arable, grassland, forest)

All pre-selected areas were checked during field work in in order to avoid any concurrent influences (grazing, beaver dams, wood harvesting etc.)


Location of study areas
58°40'N
25°30'E
Musa
Hindaste
Tellissaare
Koordi
Selisoo
Kassisaare
Allipa
Kauru
Tuudi
Tuhu 2
Tuhu 1
Kaseraba
Umbusi
Keressaare
Laukasoo
Ullika
Esäkeste
Maarjapeakse
Mõksi
Vedelsoo
Minerotrophic fen
Mixotrophic mire
Ombrotrophic bog
Floodplain mire
Study areas in mixotrophic mires
Study areas in ombrotrophic bogs
Study areas in abandoned peat extraction sites

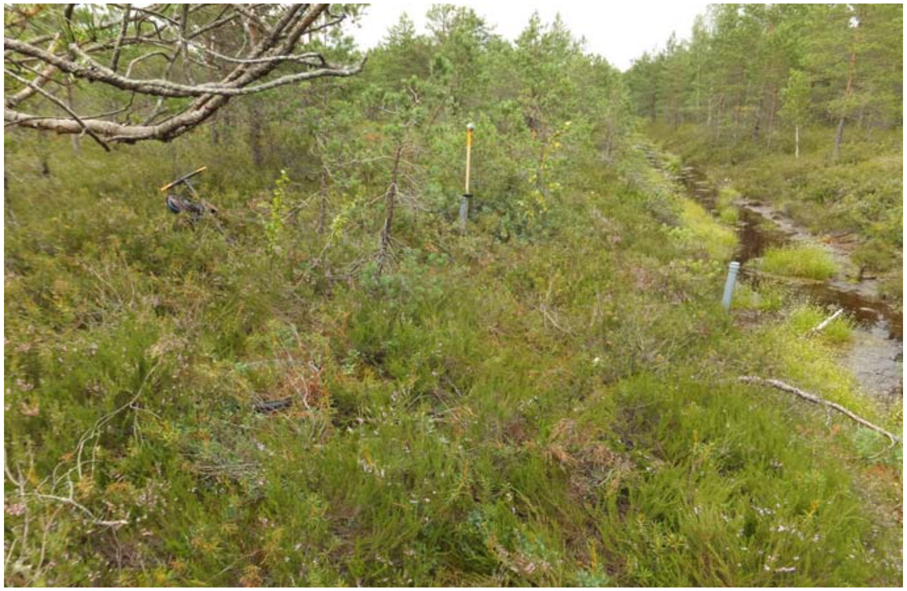
Study areas

Deep intensively draining double ditches neighbouring with peat extraction area

Study areas

- Old overgrown ditch across the bog dug only into peat layer

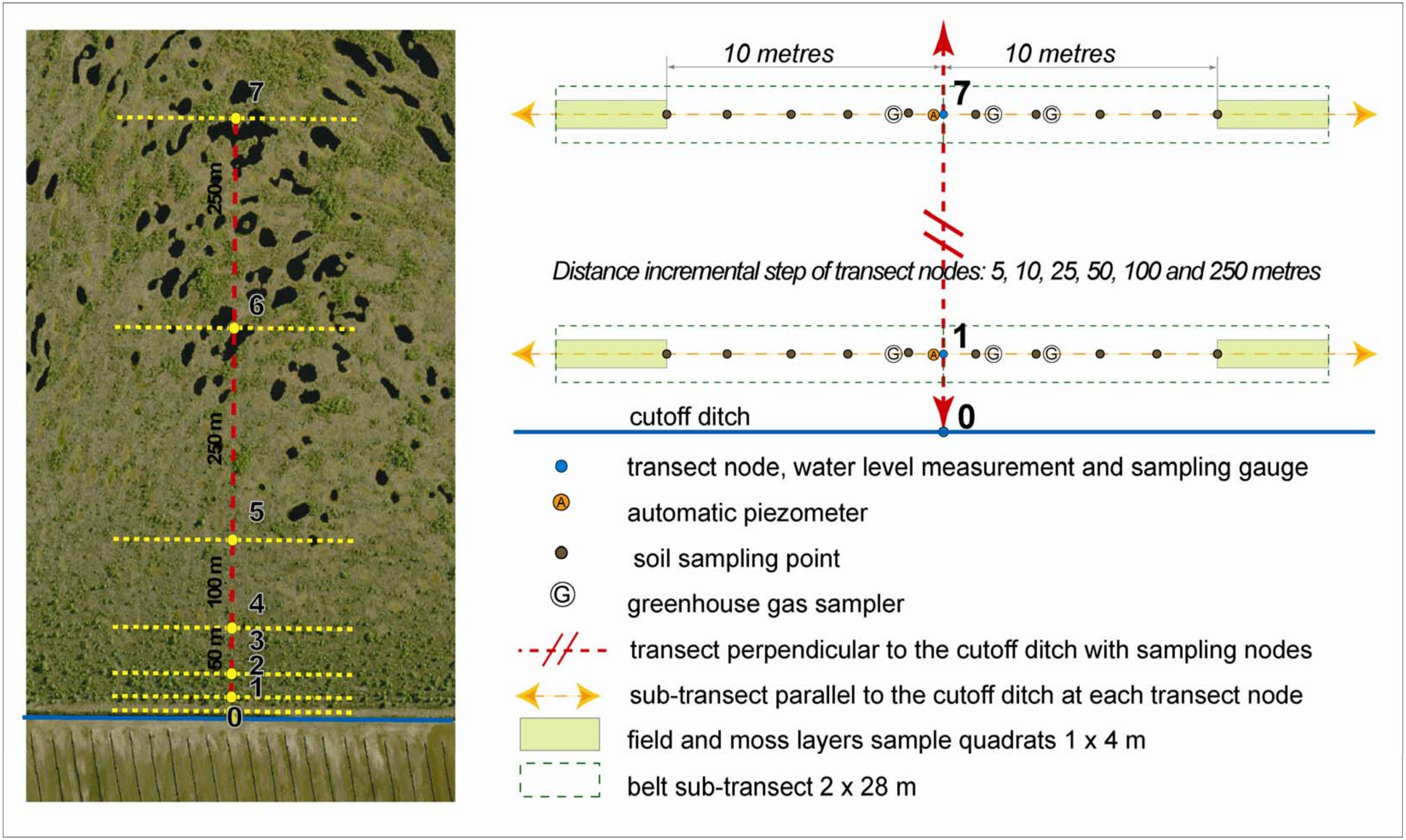

- Silvicultural intensively draining ditch cut through bog peat layer




Study areas

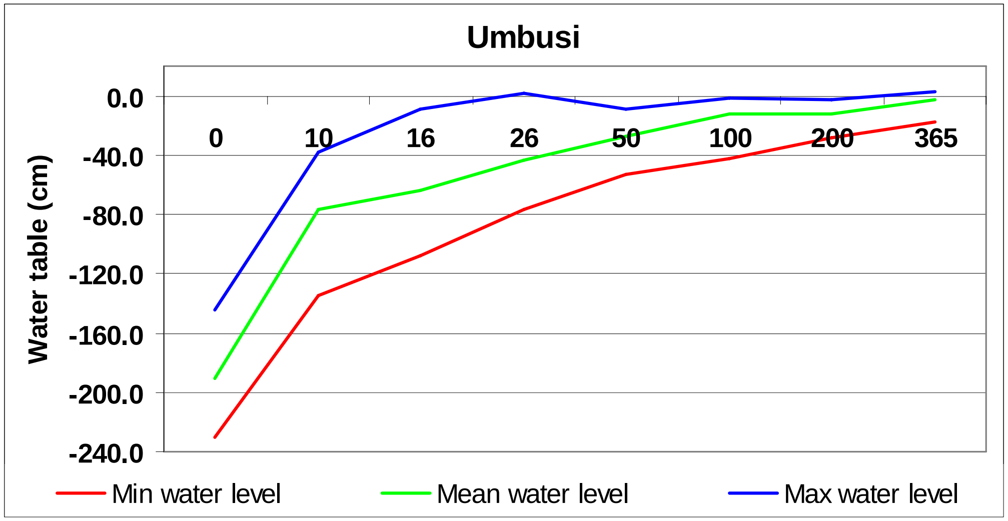
- Transitional bogs (mixotrophic mires)



Study transect and sampling areas layout with nodes and sampling plots along the sub-transects. Distance increment order: 0 – 5 – 10 – 25 – 50 – 100 – 250 – 250 m.

In mires it is all about water ...



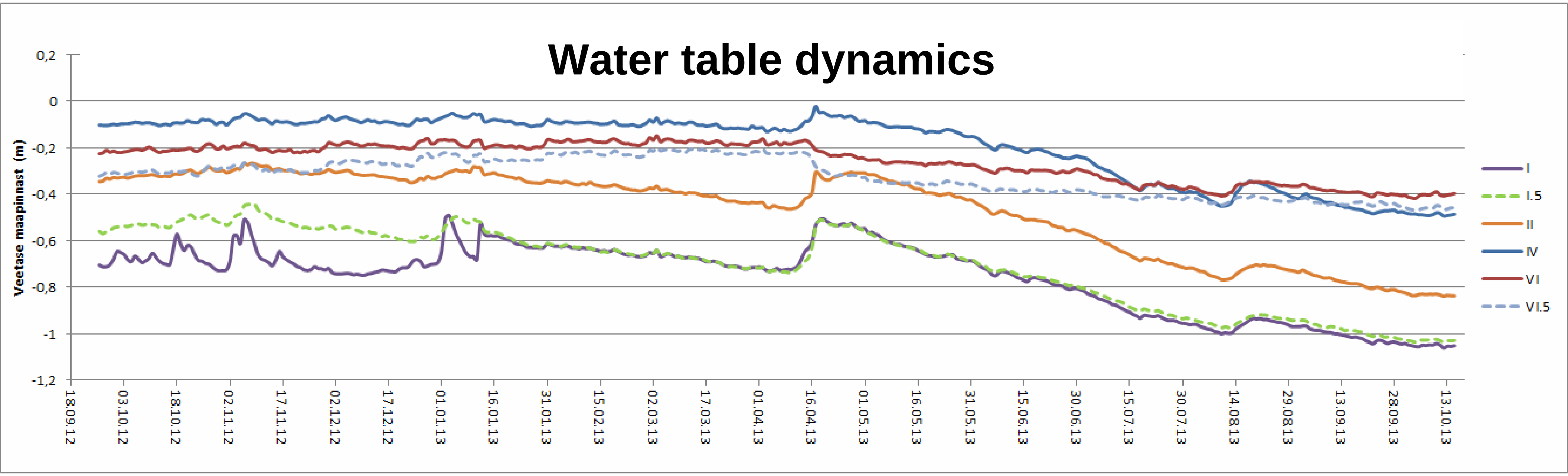
Water sampling

water level:

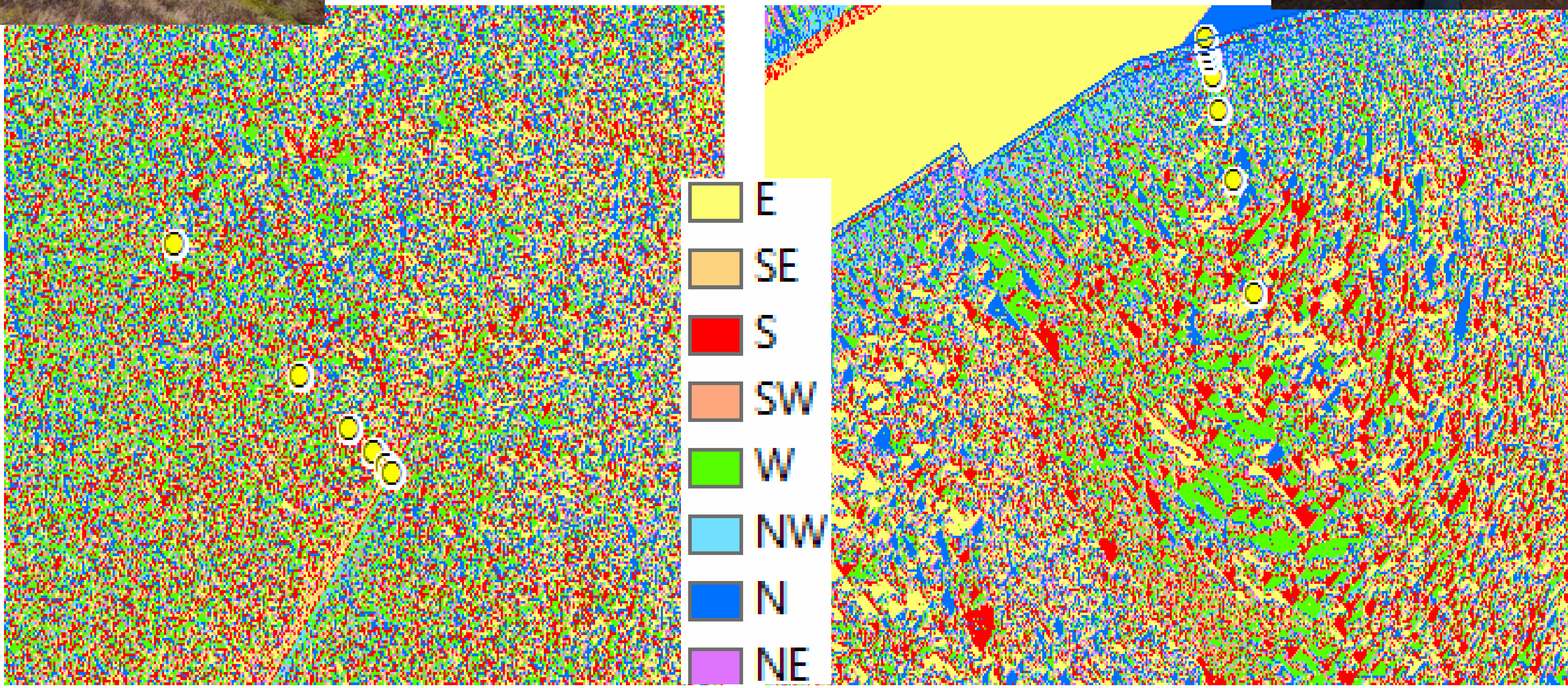
- **manually in water sampling wells (1 per month)**
- **automatic piesometers (24 h: pressure level, temperature)**

water properties: pH, t°, ORP, EC, O_2, soil t°

water chemistry (NH_4, NO_3, NO_2, N_{tot}, PO_4, Ca, K, Mg, DOC, DIC, DC, DN)



Water flow: 2 extreme cases

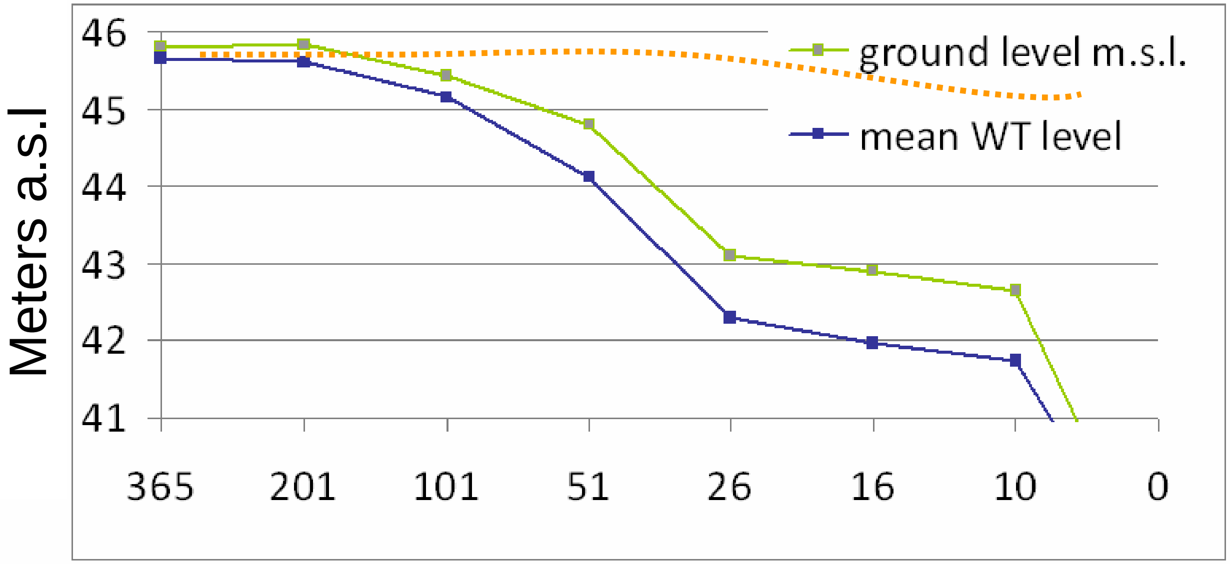


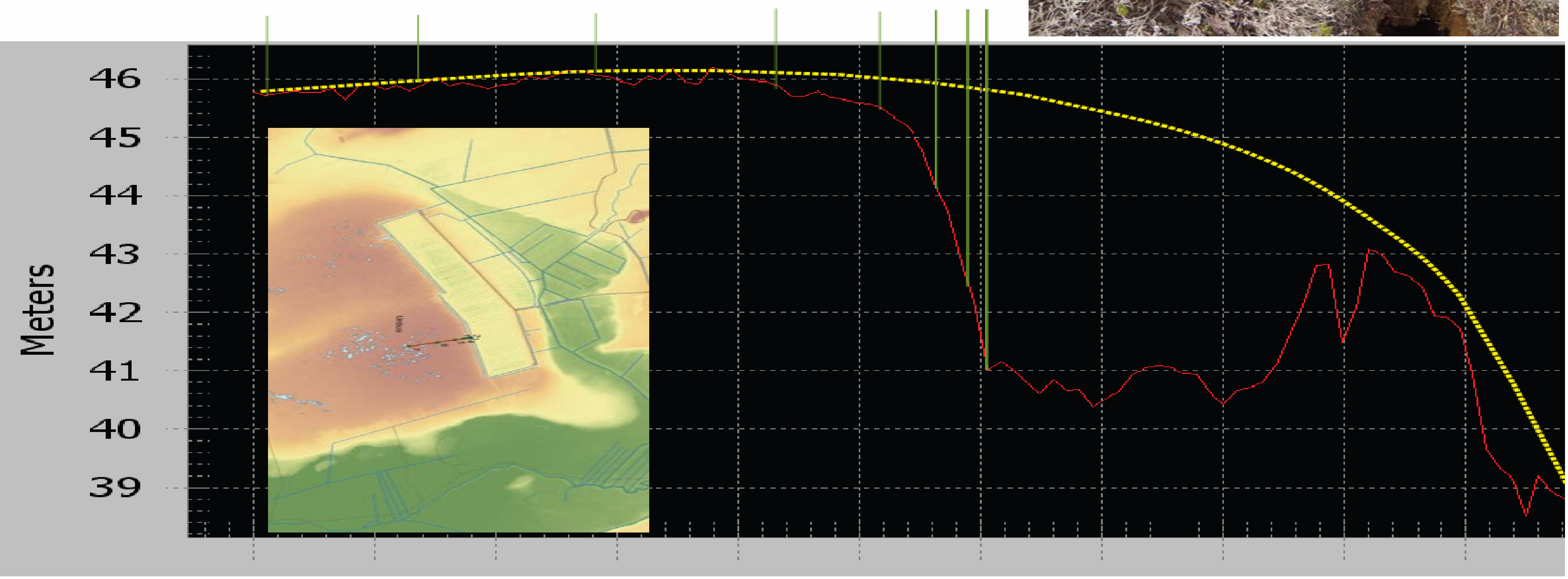
Maarjapeakse, old overgrown ditch

Umbusi, intensively drained peat extraction area

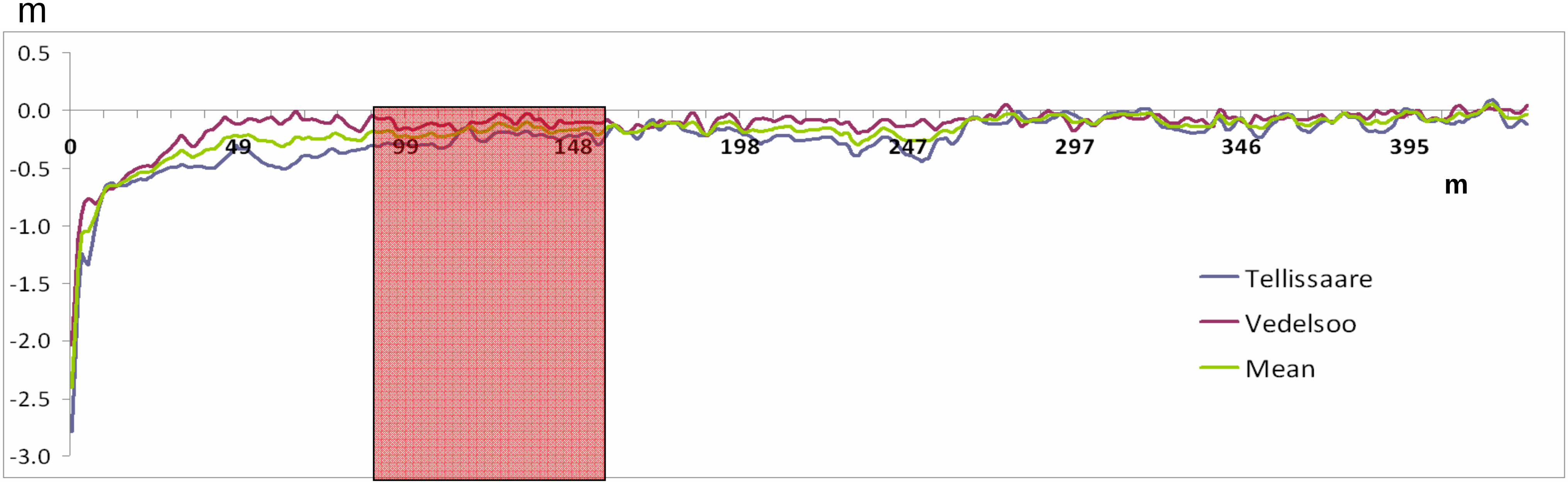
Surface water flow direction determined based on high-resolution LIDAR elevation data by 8 point of the compass

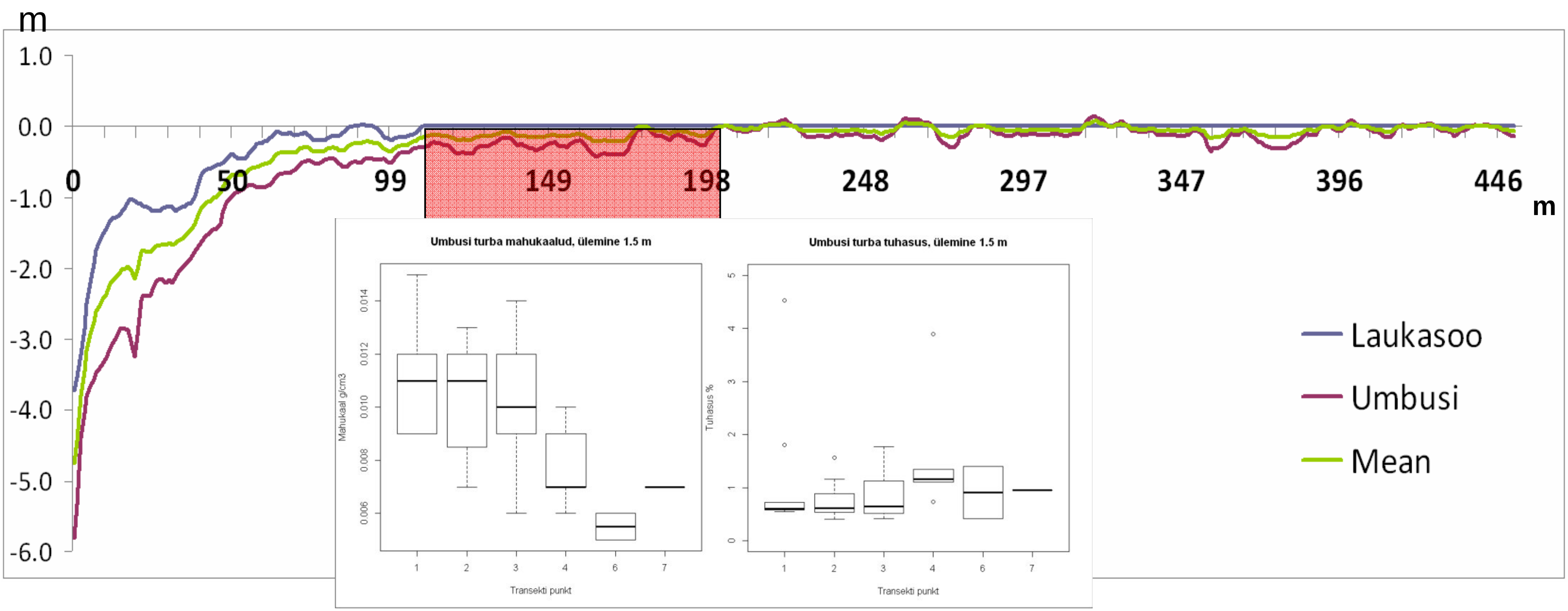
Surface subsidience: mineralization and compaction



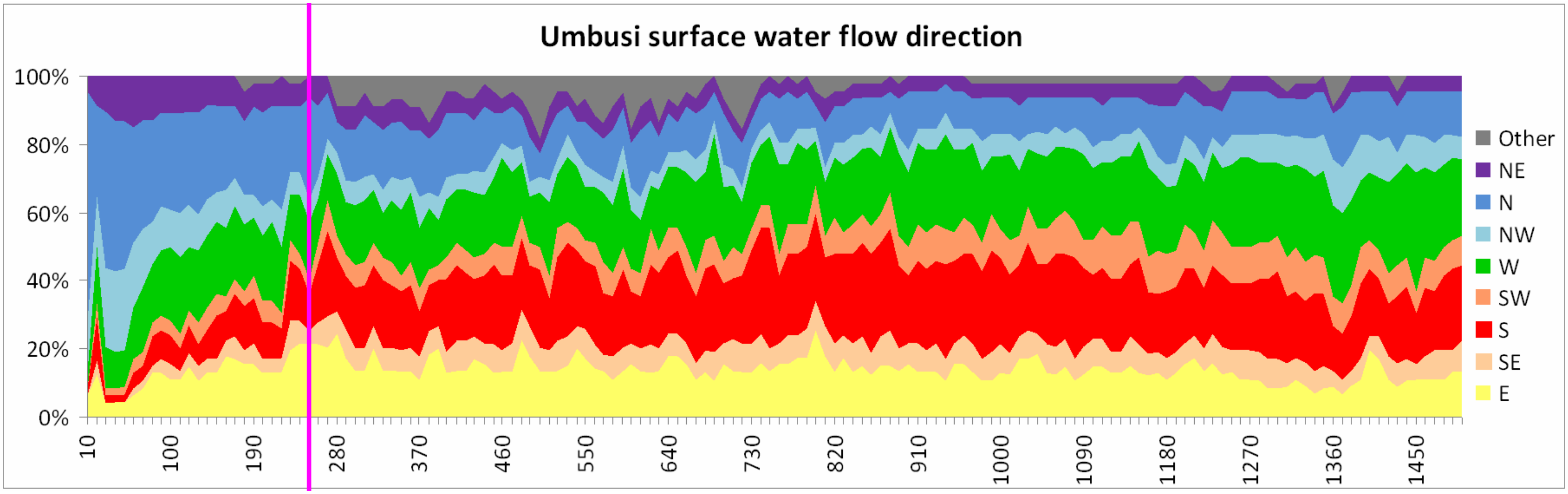


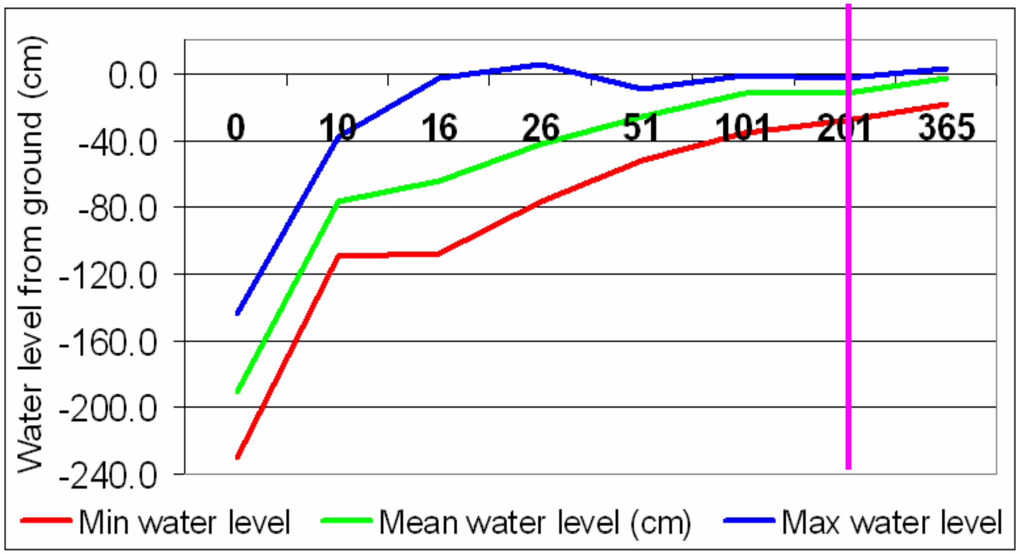
Surface subsidience: mineralization and compaction

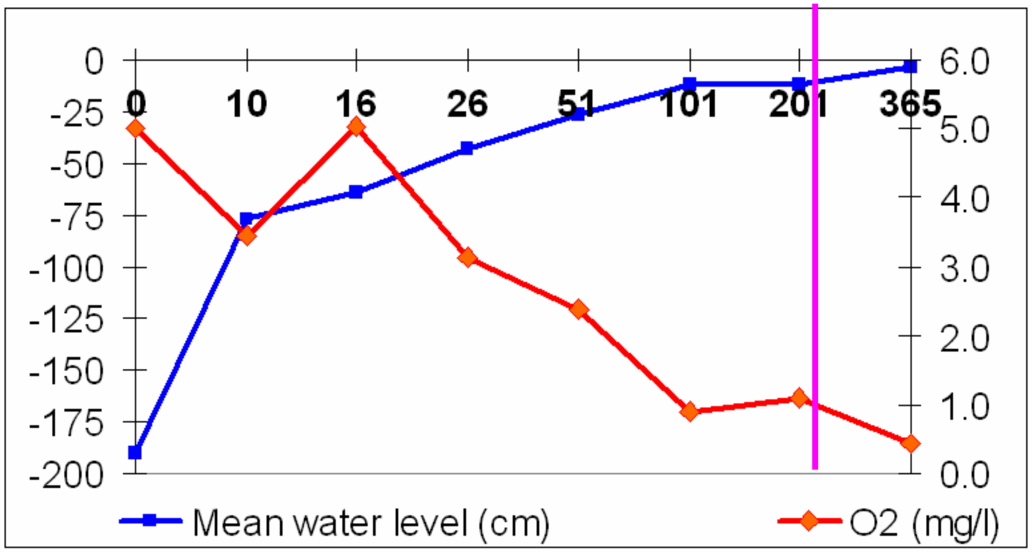




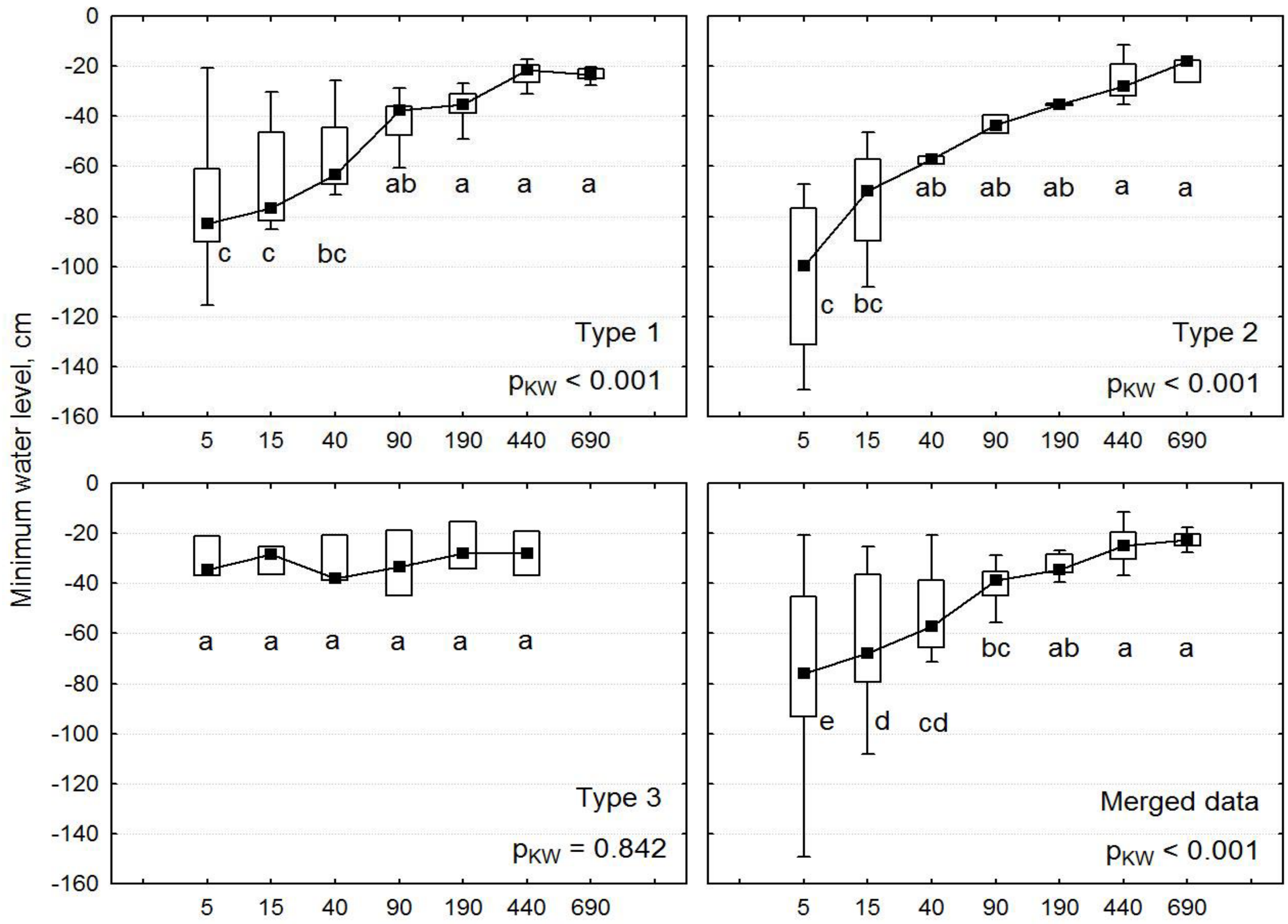
Peat water properties







Drainage effect on minimum water level

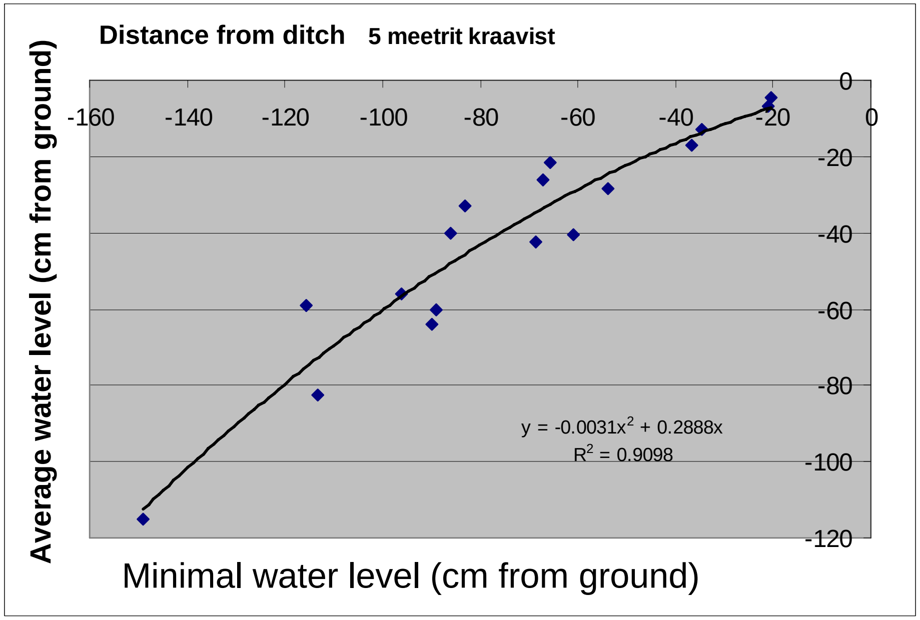


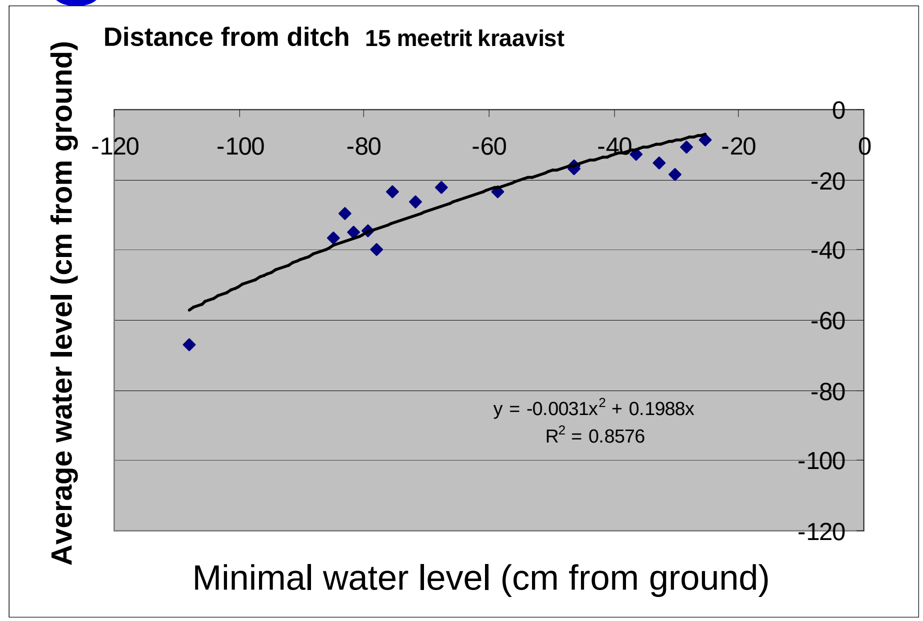
Type 1 – intensively draining marginal cutoff ditch

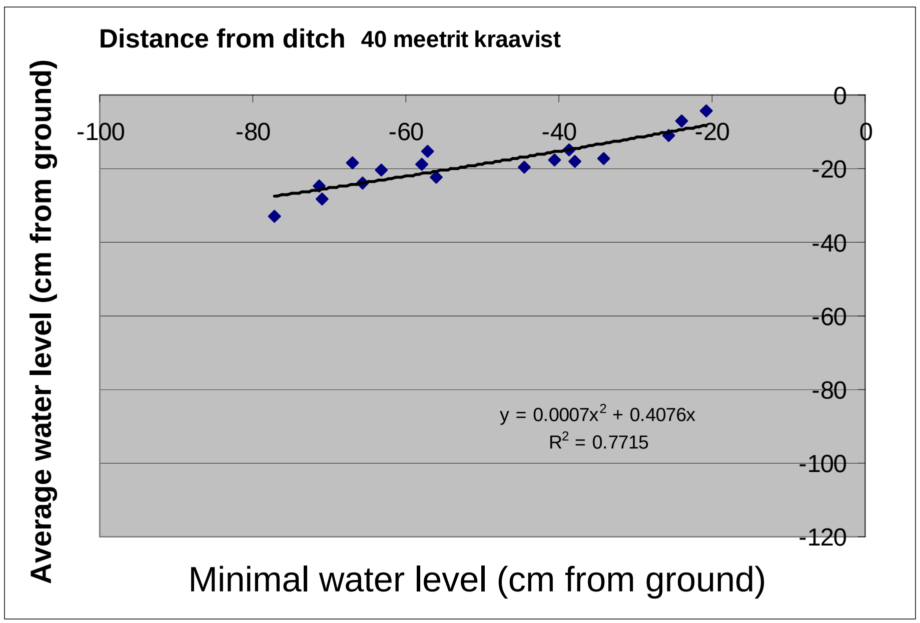
Type 2 – deep dual ditch system neighbouring with peat extraction area

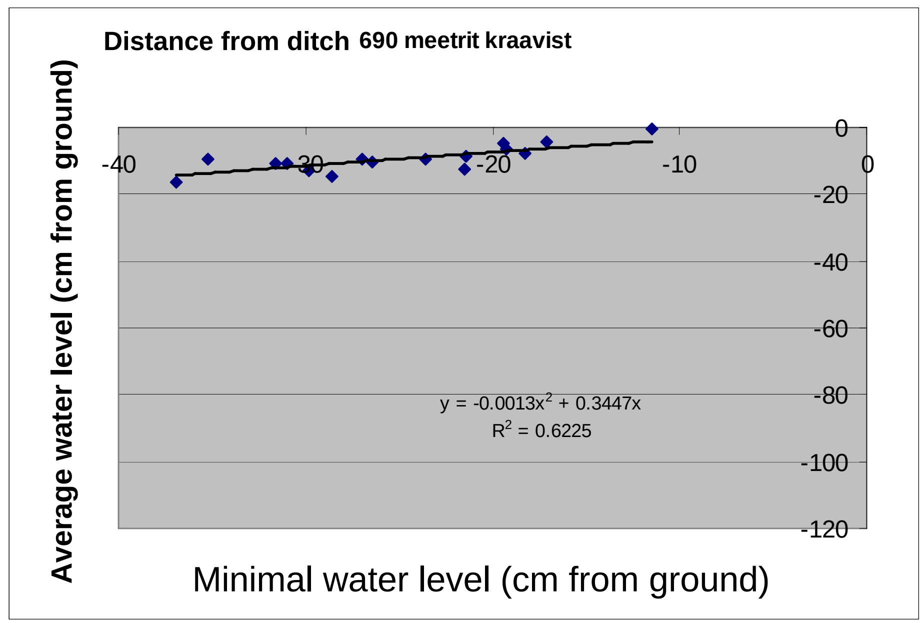
Type 3 - old shallow overgrown ditch across the bog

Minimal or average water level?



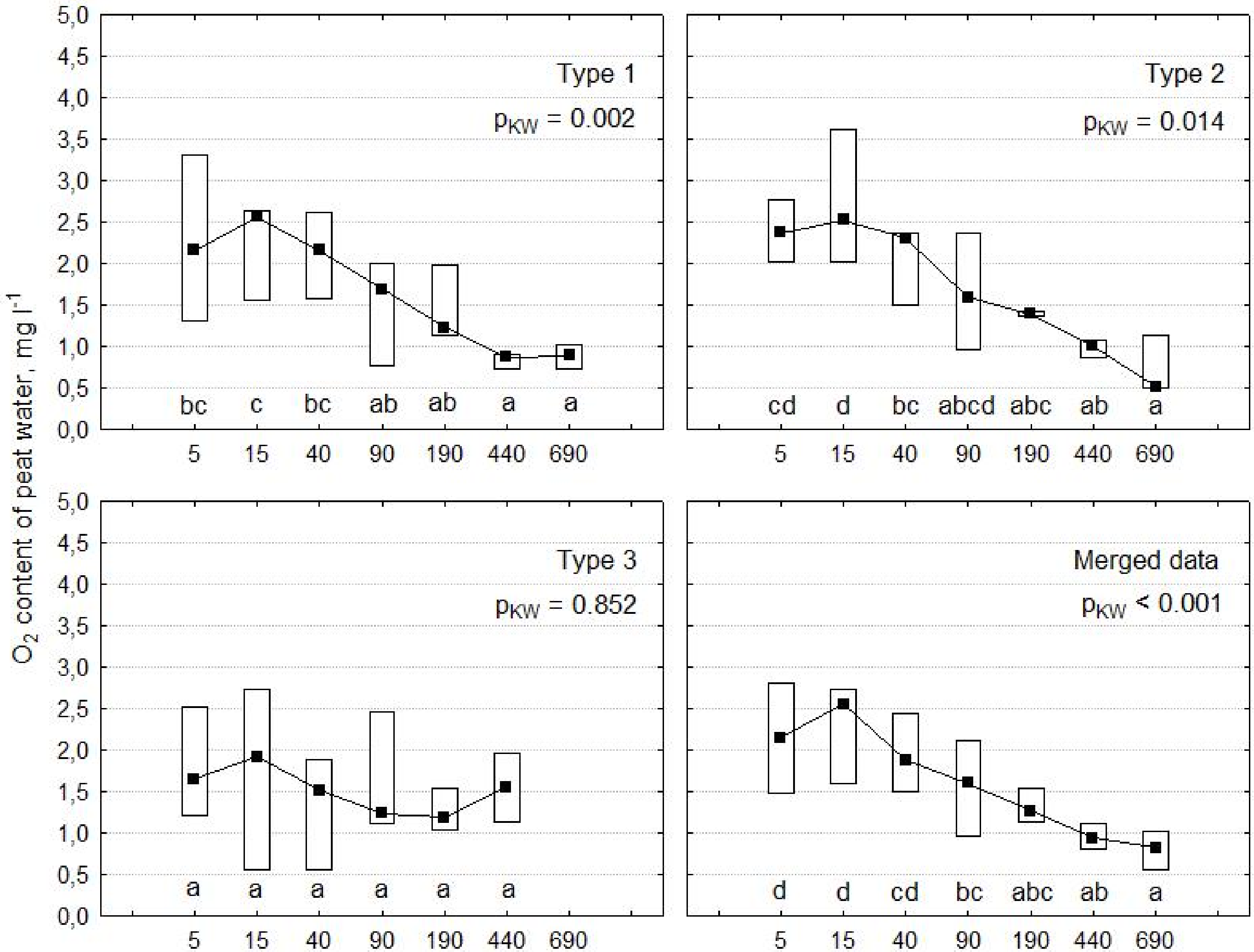






Minimal WL is easier to determine and has statistically slightly stronger descriptive power

Drainage effect on peat water oxygen content



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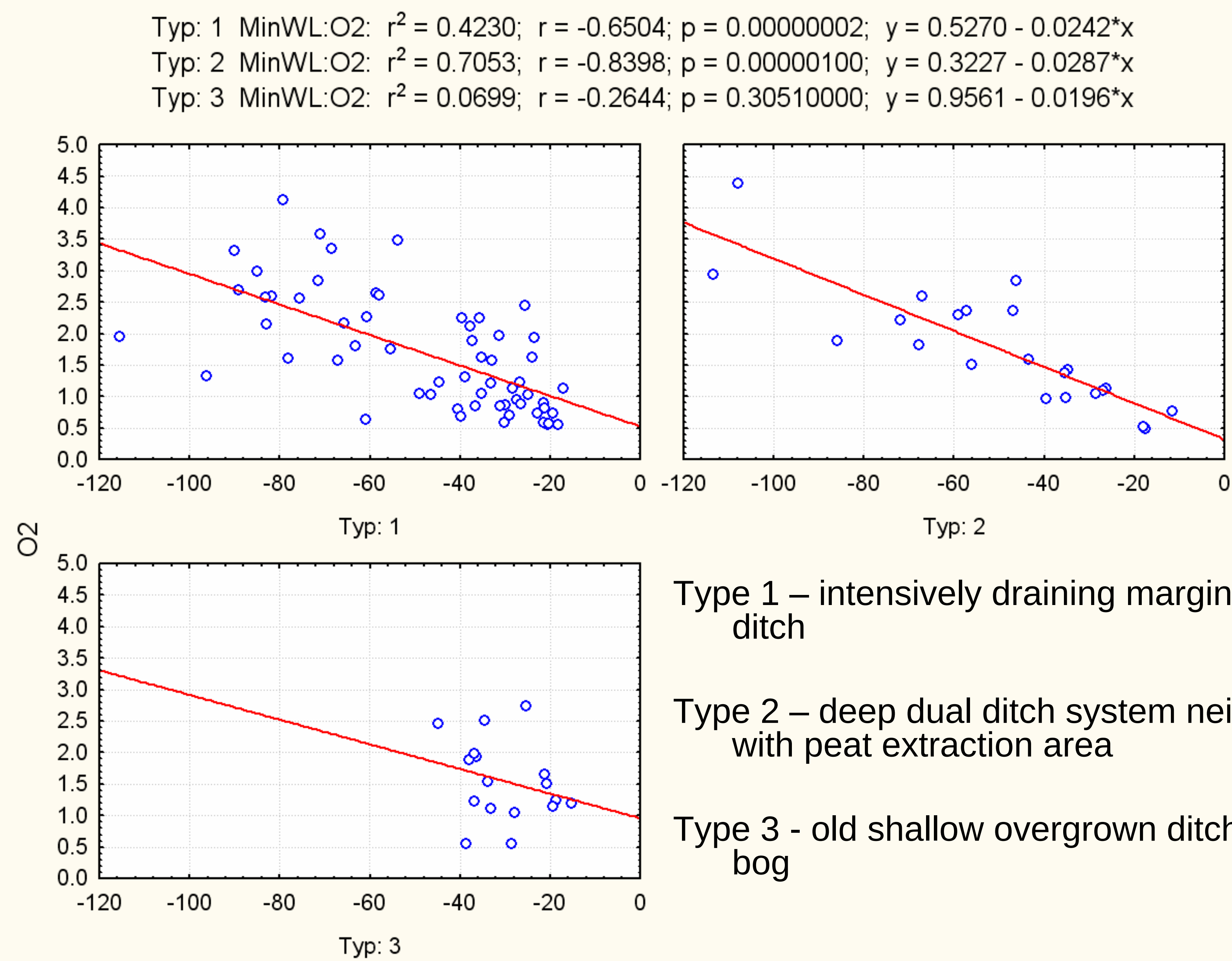
DO (mg/l) vs minimal water level



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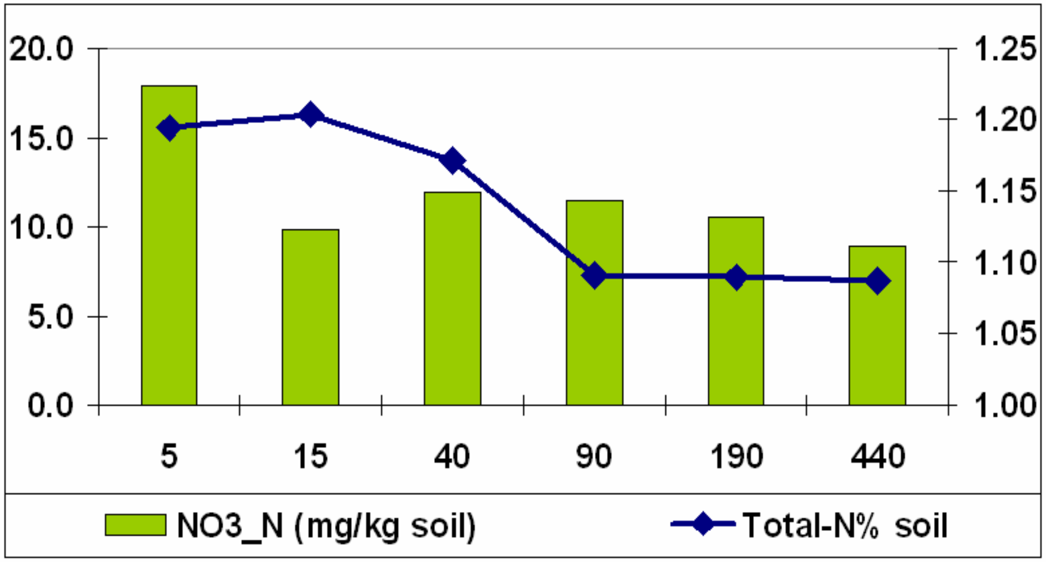
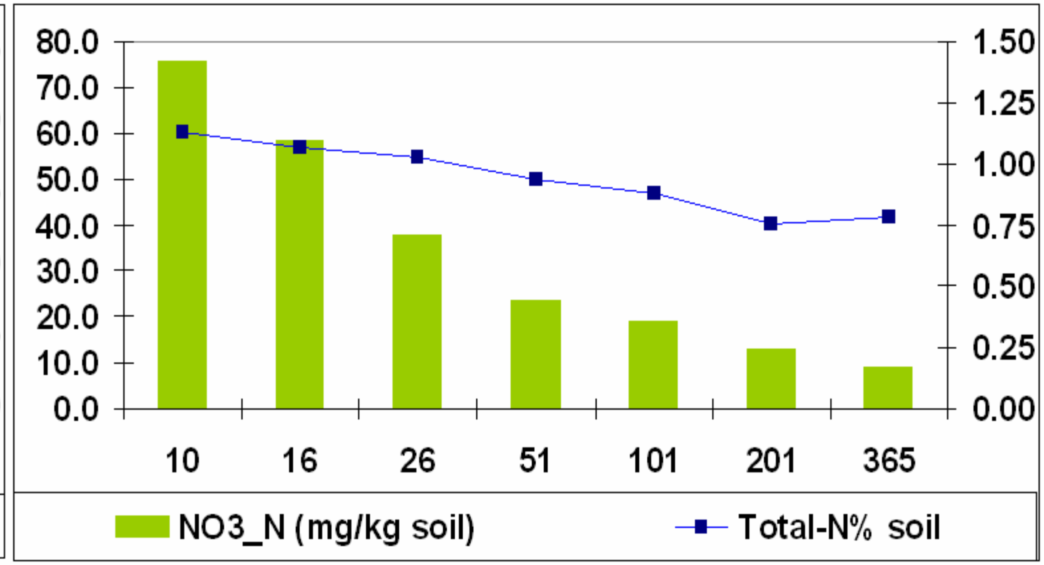
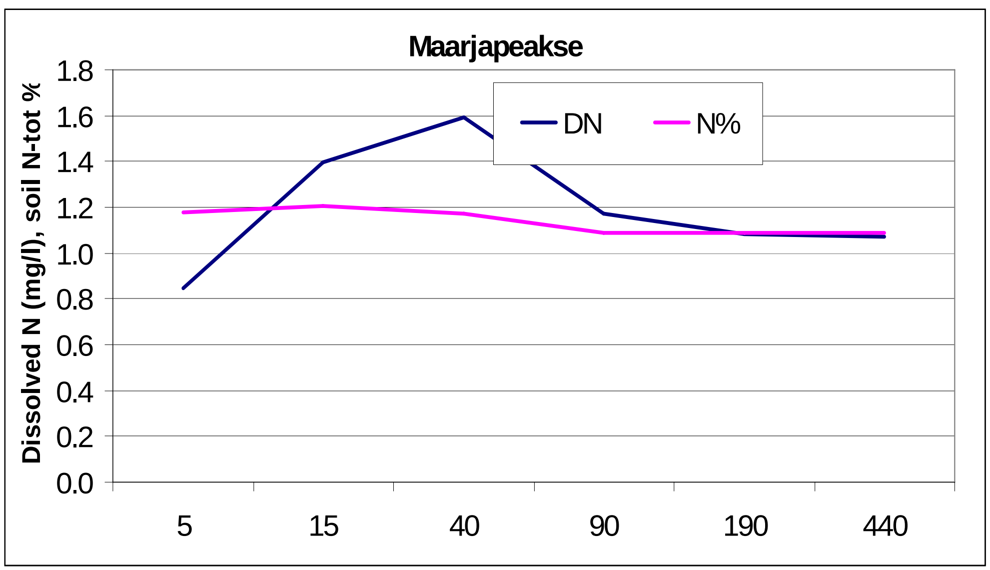
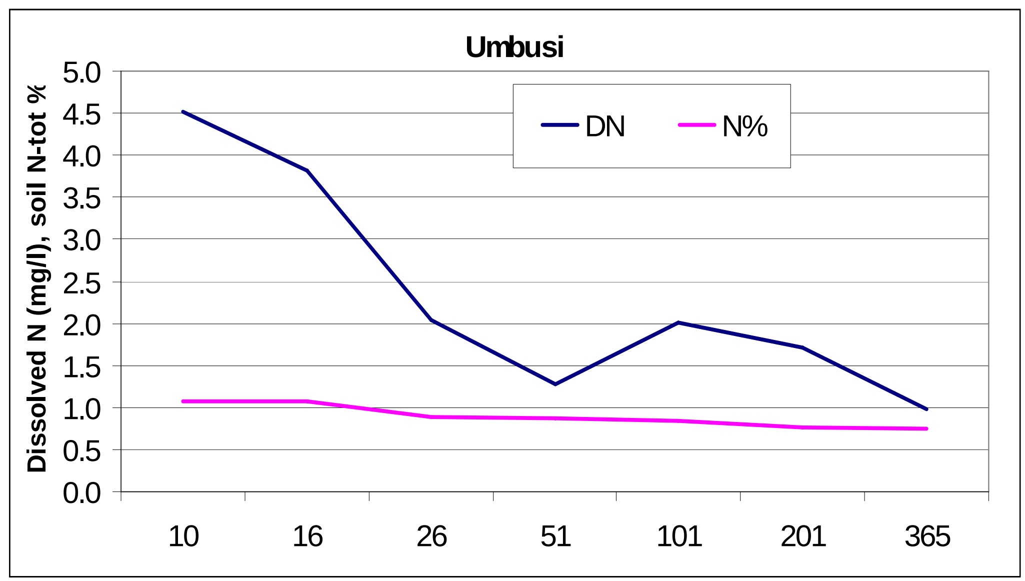
Nitrogen availability







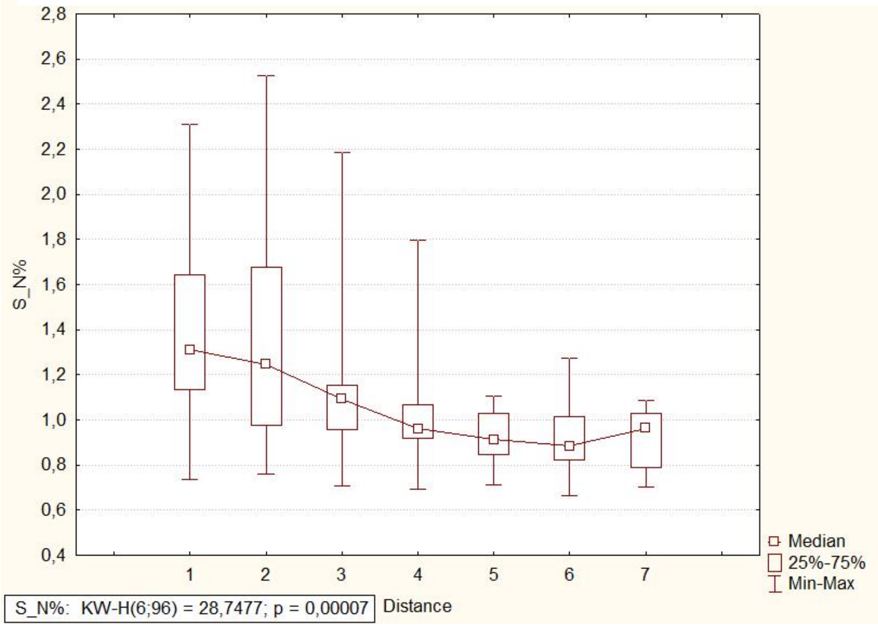


Maarjapeakse, old overgrown ditch

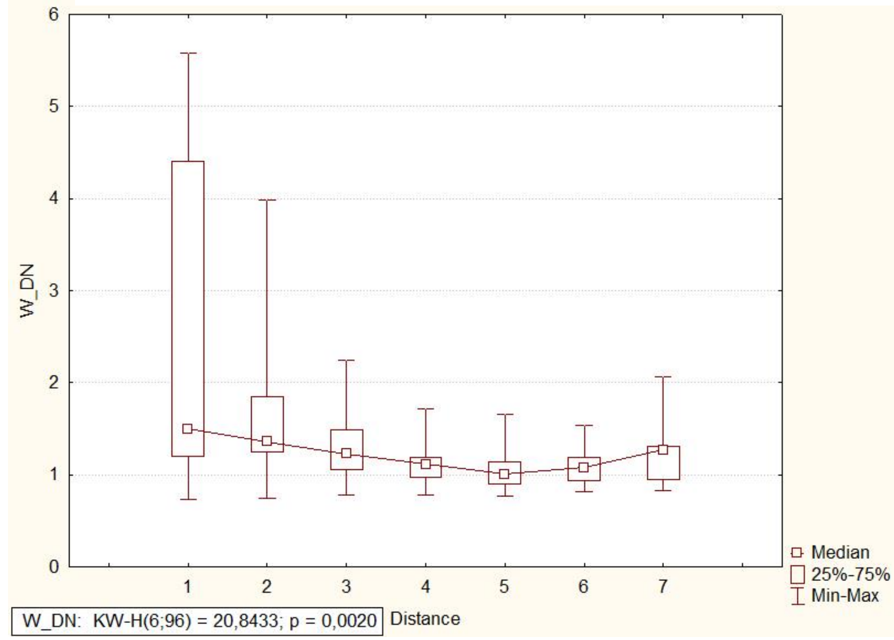
Umbusi, intensive drainage

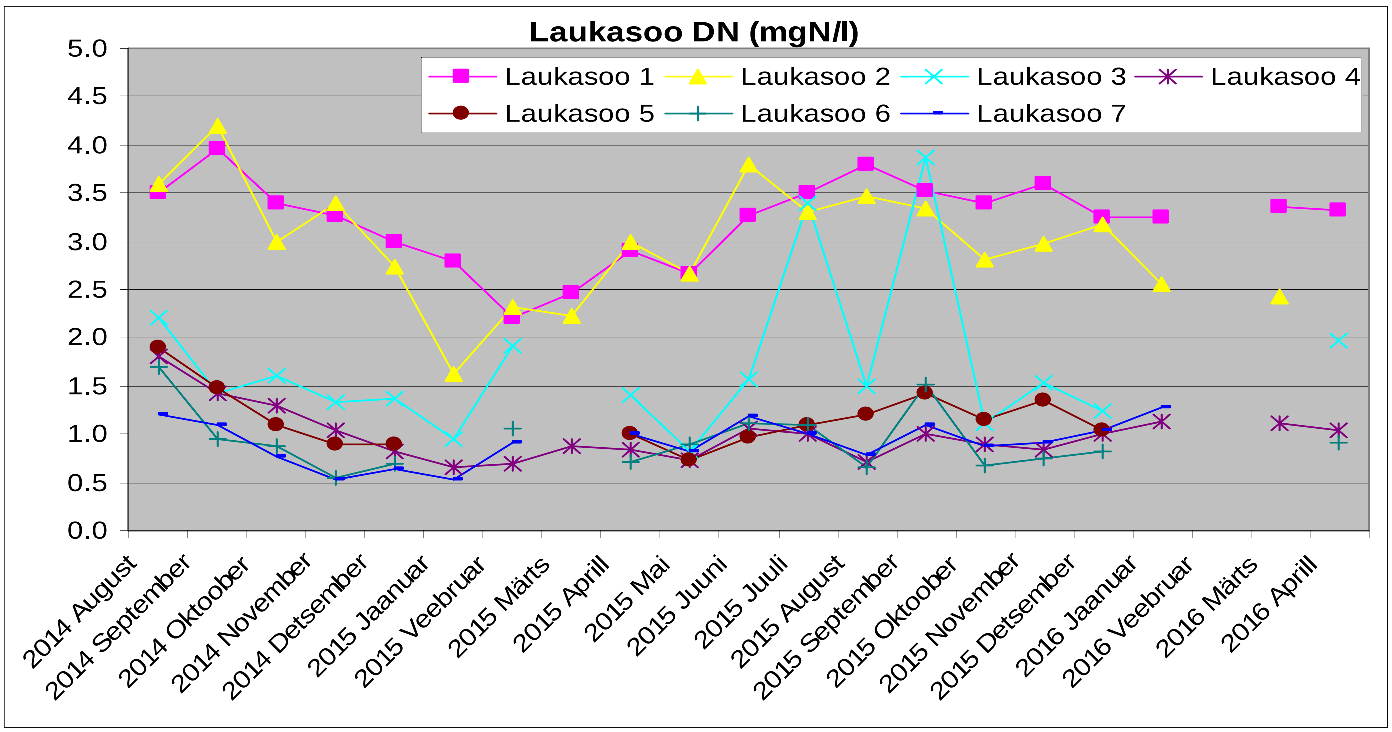
Nitrogen availability

Soil N-total, % (all bogs)

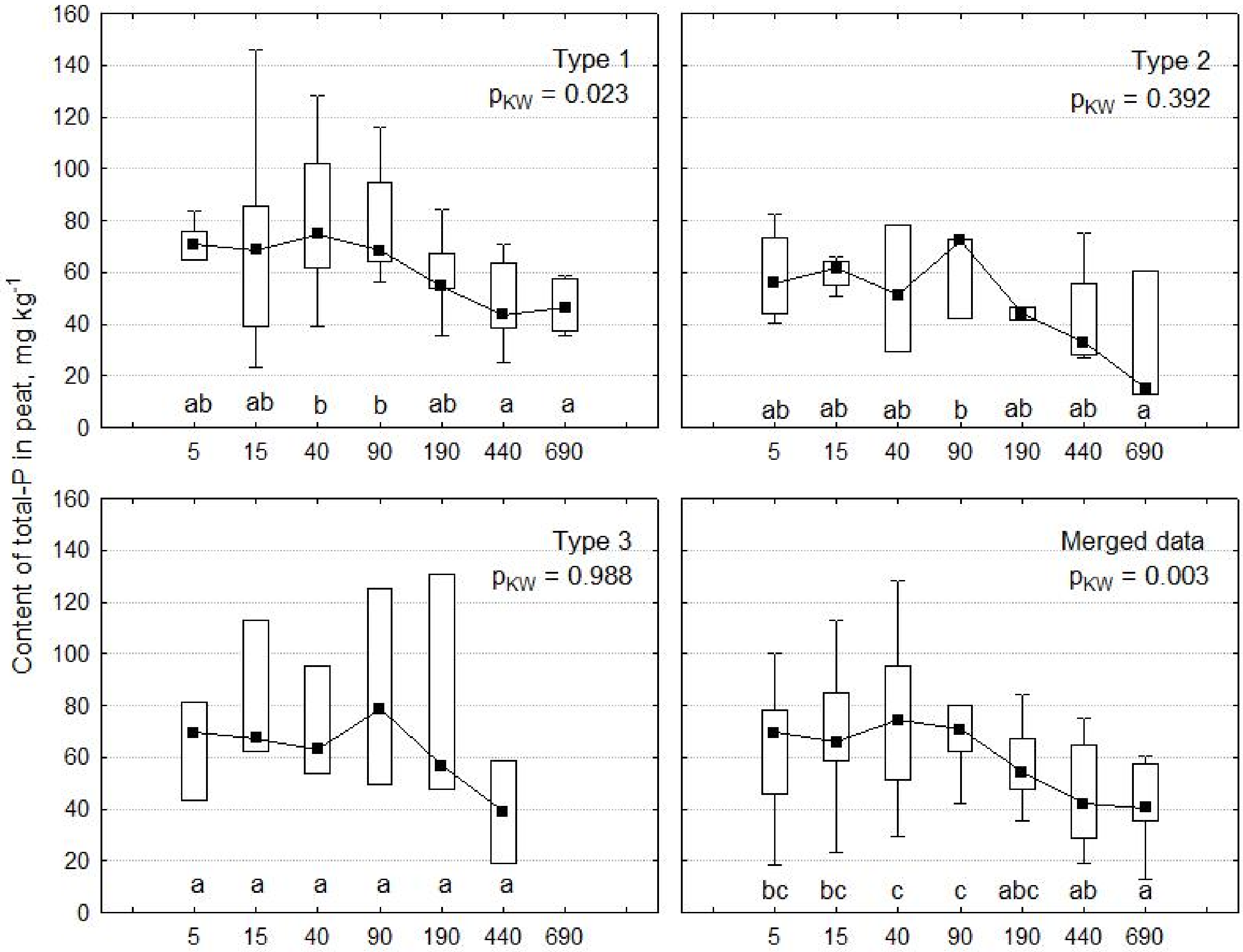


Peat water DN, mg/l (all bogs)





Soil total-P content



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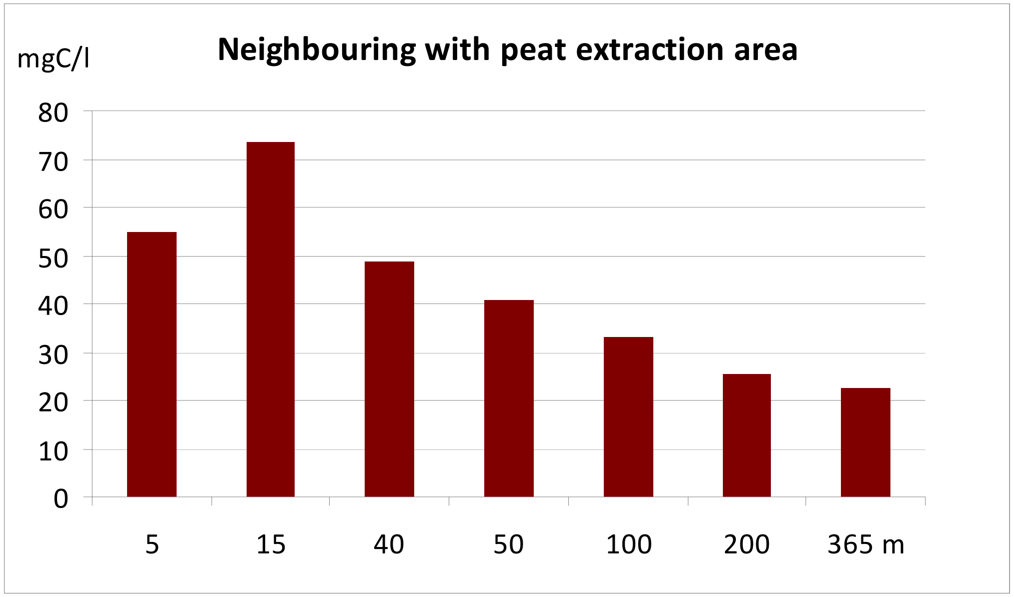
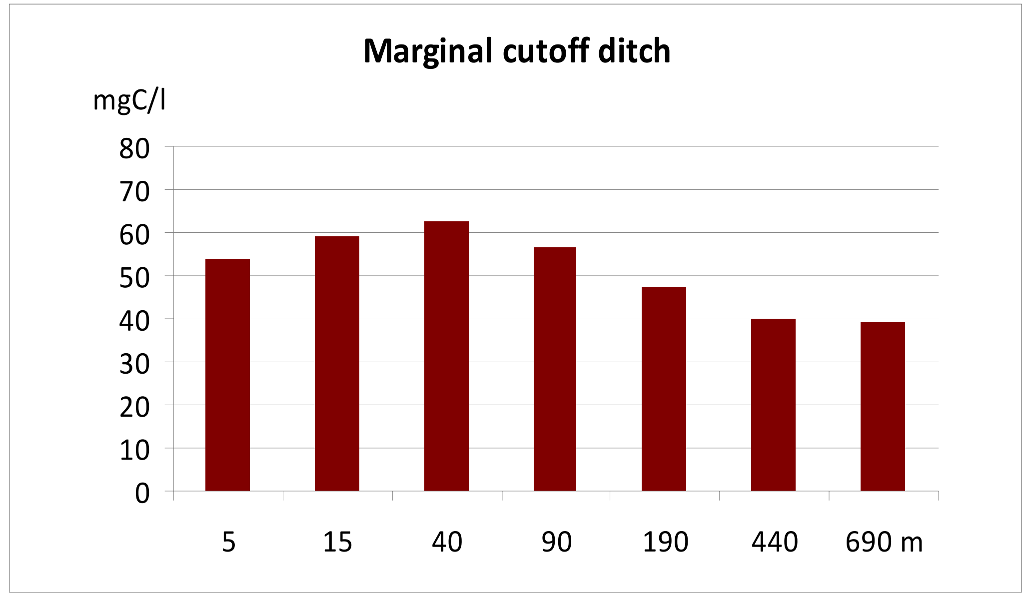
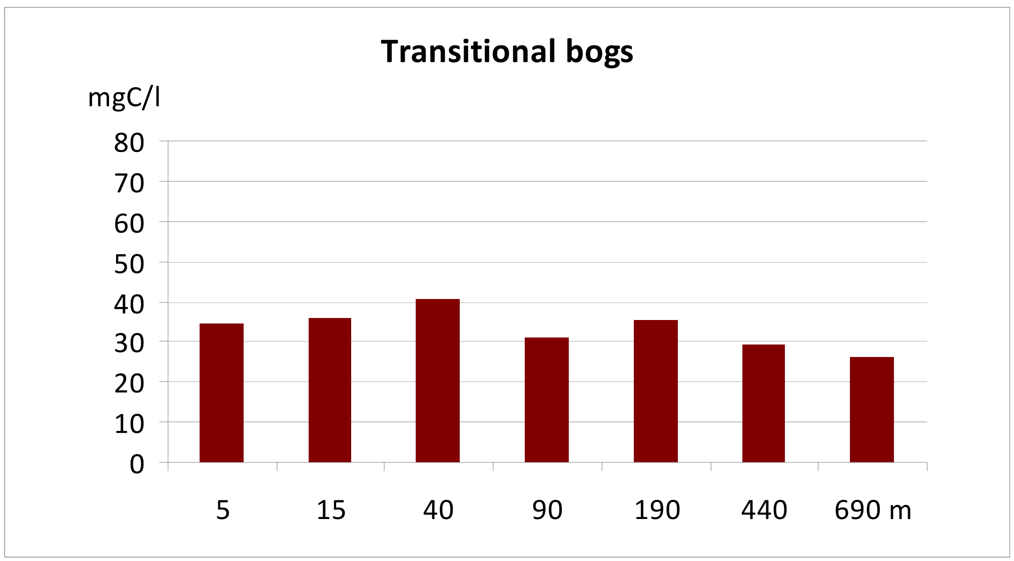
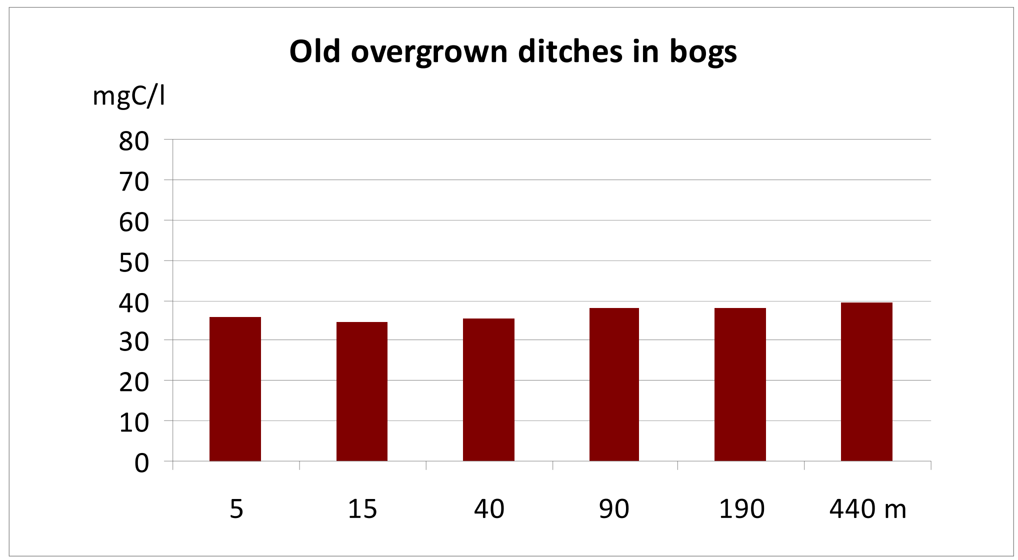
Humic substances in peat water





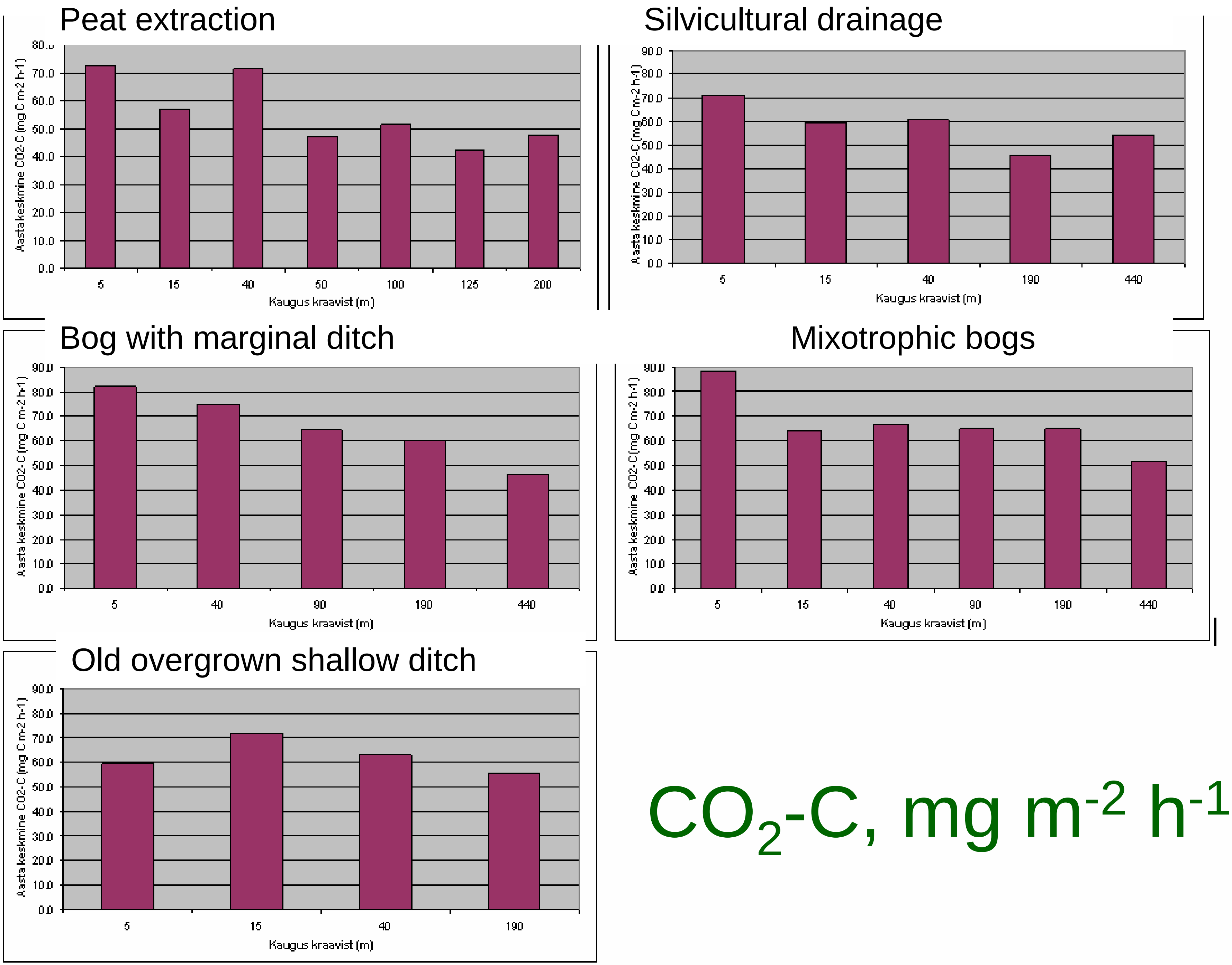




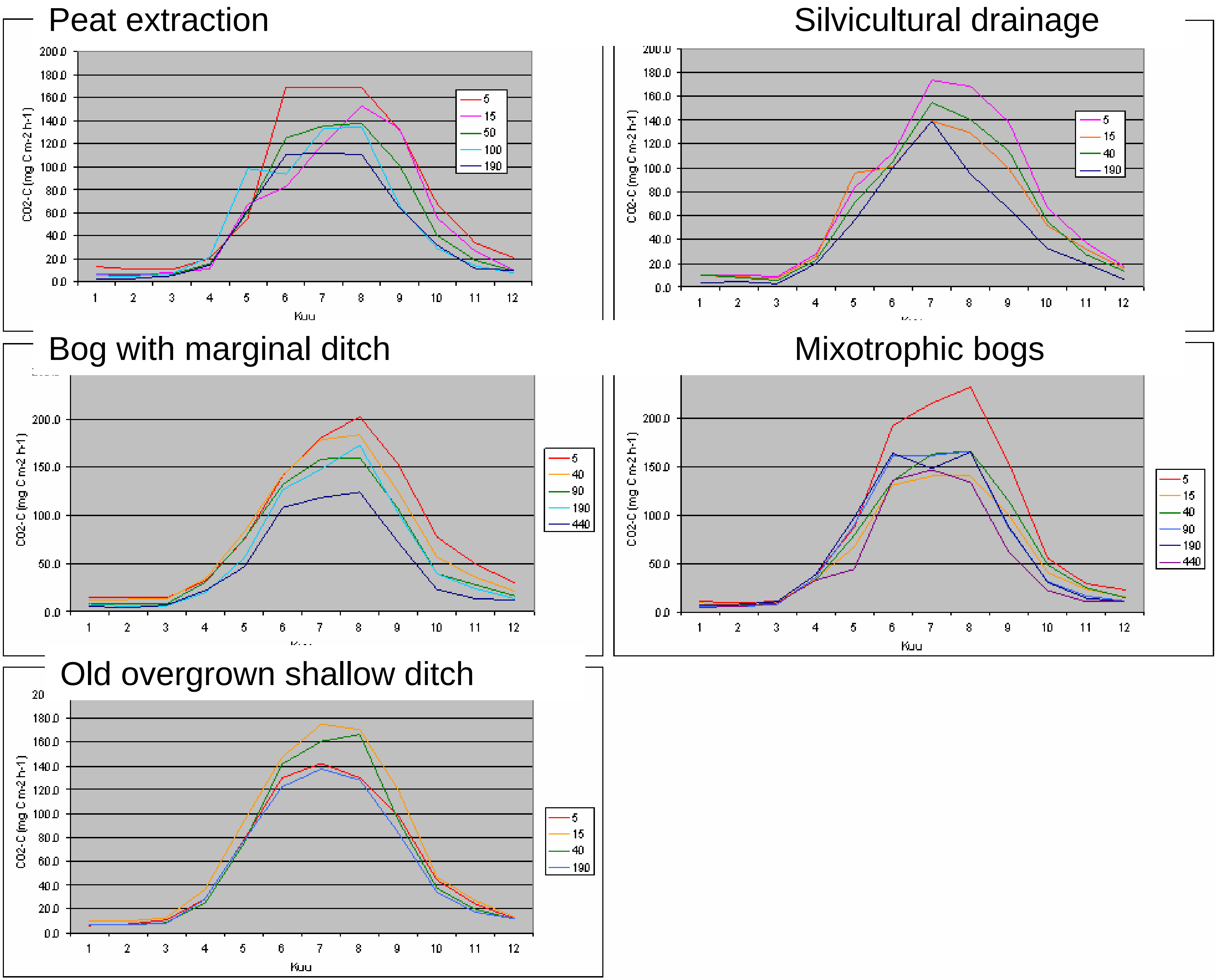
Greenhouse gases fluxes

Field data on fluxes of CO_2, CH_4 and N_2O are collected monthly since June 2012 using the closed chamber method in 3 replicates per measurement site following the gas-chromatograph analysis.

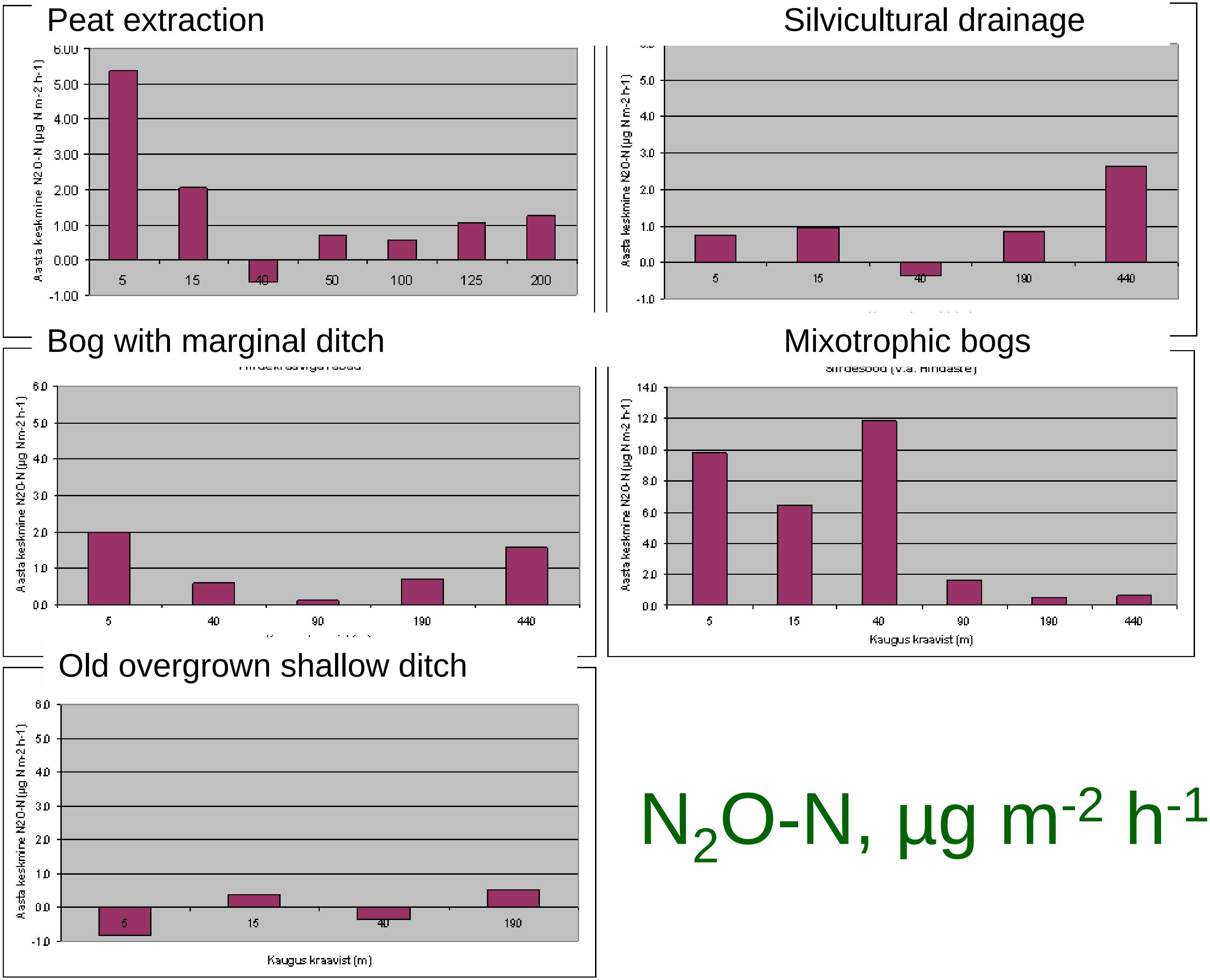
CO_2, CH_4 and N_2O emissions and $CH_4/CO_2/N_2O$ ratio are the integral indicators reflecting water level change and concurrent mineralization (N_2O), change in pH and vegetation



Joonis 3.1.27. Süsihappegaasi (CO_2-C, mg m^{-2} h^{-1}) aasta keskmise voo sõltuvus kuivendustüübist ja kaugusest kuivenduskraavist.

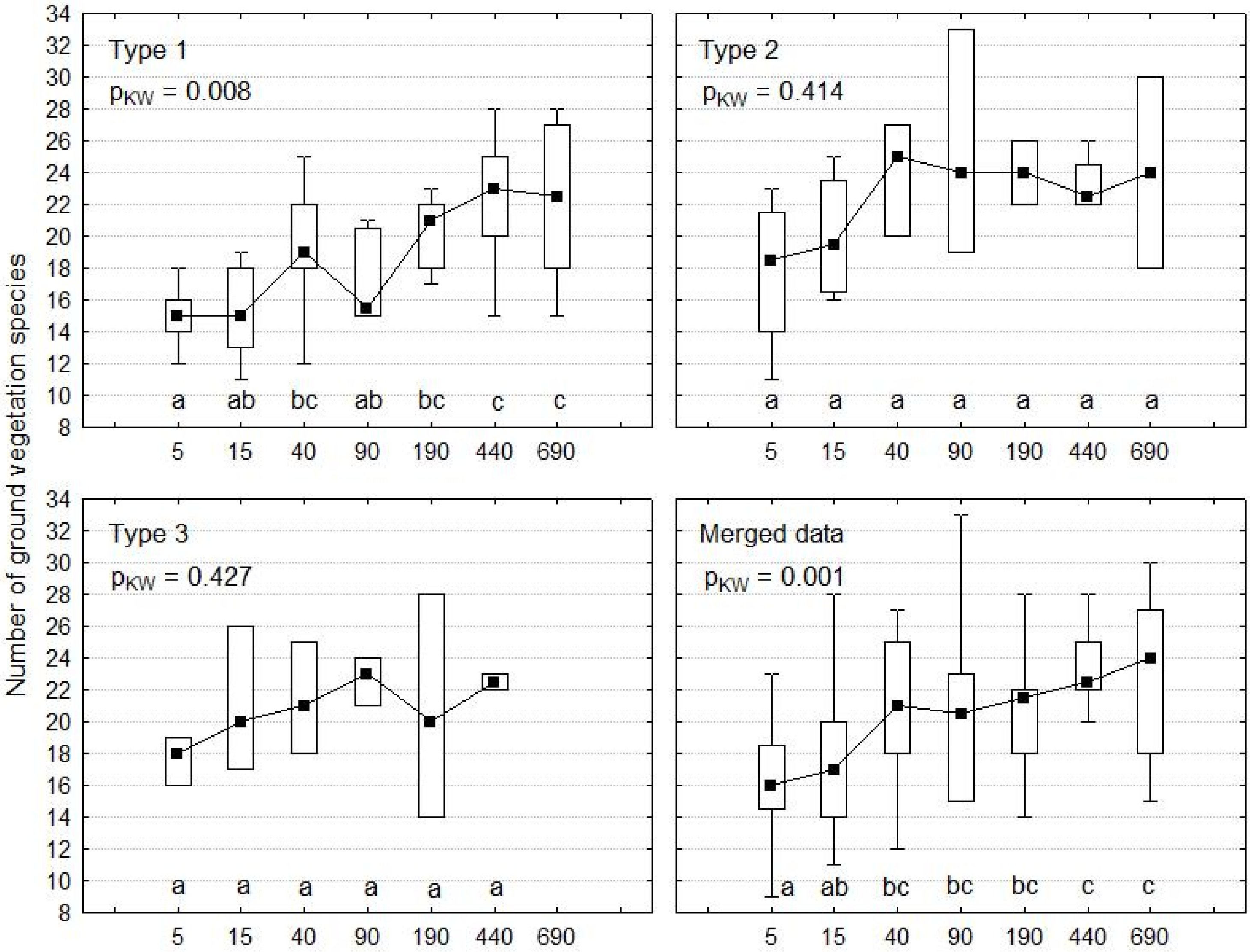


Joonis 3.1.28. Süsihappegaasi (CO_2-C, mg m^{-2} h^{-1}) voo aastane käik vastavalt kaugusele kuivenduskraavist (m) ja kuivendustüübile.

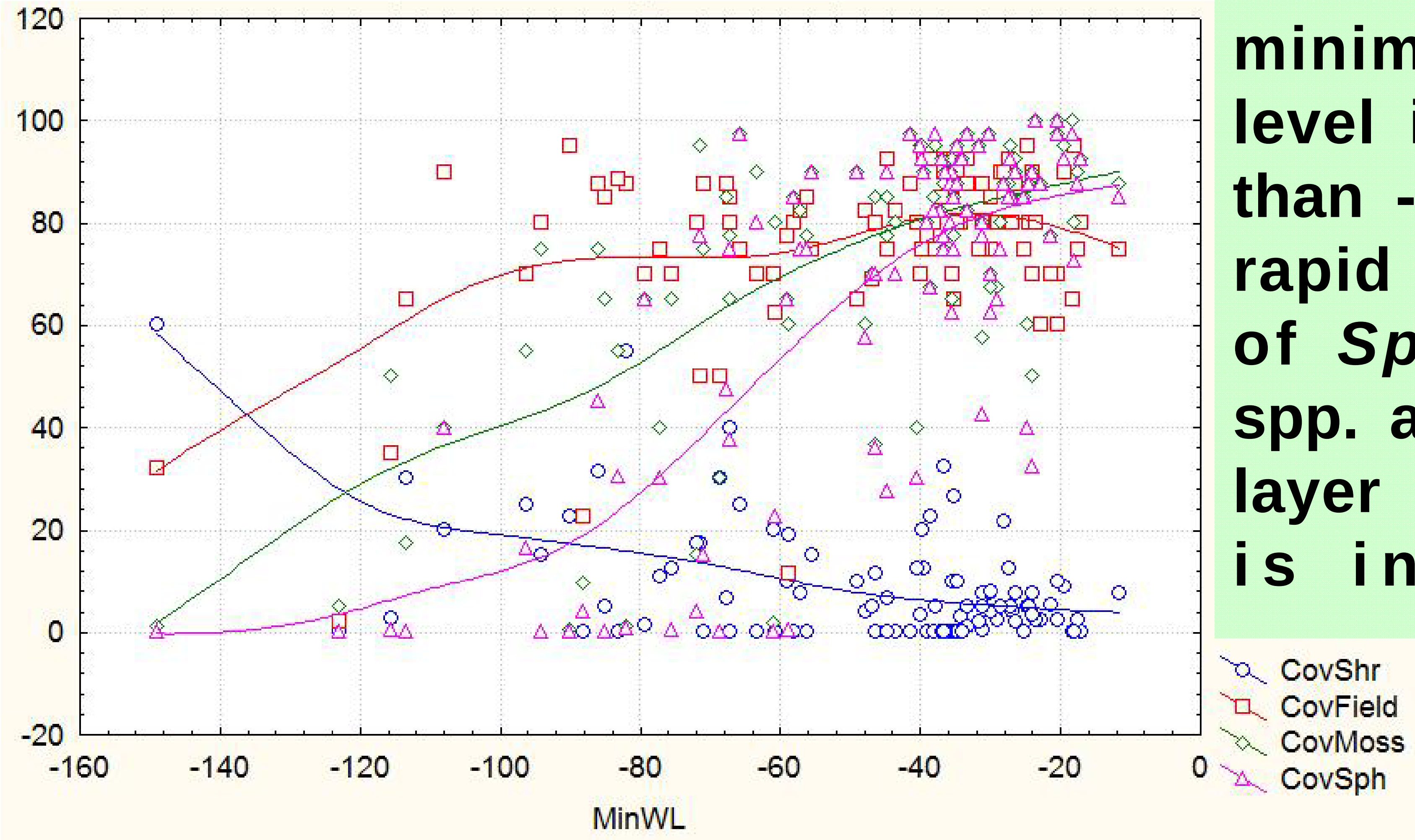


Joonis 3.1.29. Naerugaasi (N_2O-N, µg m^{-2} h^{-1}) aasta keskmise voo sõltuvus kuivendustüübist ja kaugusest kuivenduskraavist.

Drainage effect on the number of ground vegetation species

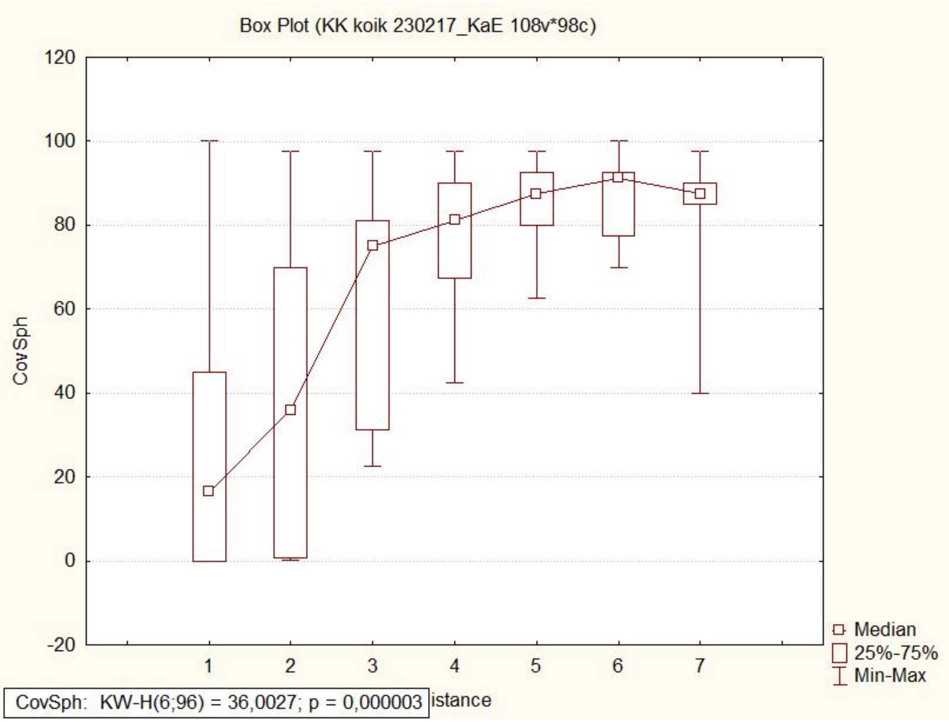


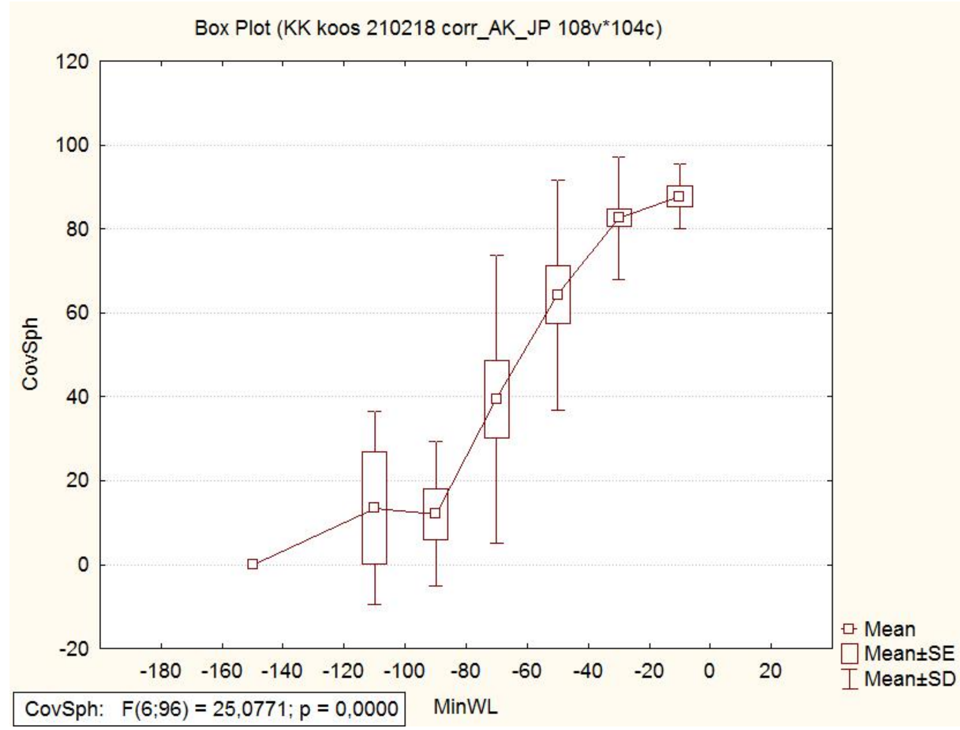
Dependency of different vegetation layers coverage on minimal water level.

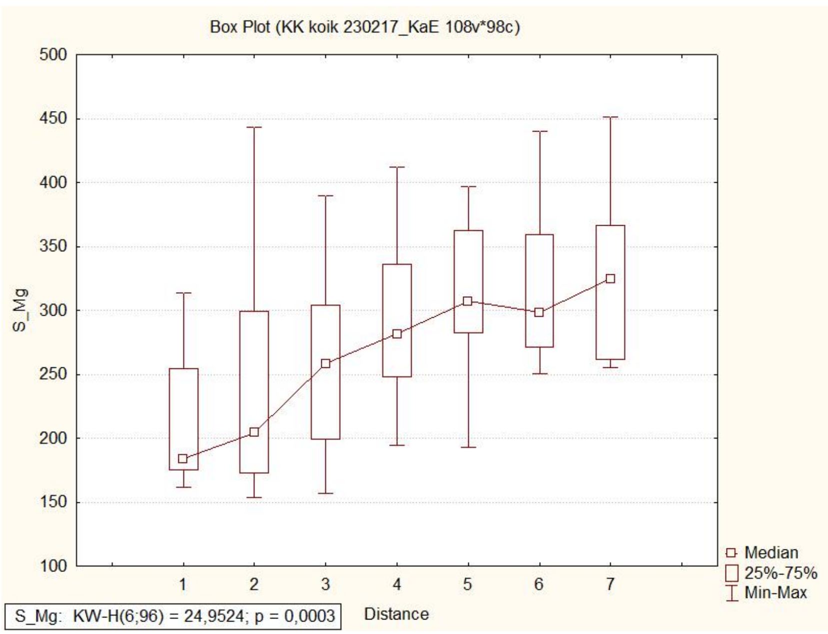


Where the minimal water level is higher than -50 cm, a rapid increase of *Sphagnum* spp. and moss layer coverage is induced.

Mg, water and sphagnum







Sphagnum and Mg in soil strongly correlated

Sphagnum almost missing if MinWL < -80 cm, it is dominant if MinWL > -20 cm

Species as drainage indicators

Species	D	p	Relative frequency						Relative abundance					
			Distance step											
			1	2	3	4	5	6	1	2	3	4	5	6
Juniperus communis	1	0.248	**40**	20	20	0	0	0	**95**	5	0	0	0	0
Sorbus aucuparia	1	0.249	**40**	20	0	0	0	0	**67**	33	0	0	0	0
Fragaria vesca	1	0.255	**40**	20	0	0	0	0	**75**	25	0	0	0	0
Tetraphis pellucida	1	0.264	**40**	20	0	0	0	0	**68**	32	0	0	0	0
Calypogeia integristipula	1	0.352	**40**	40	0	20	0	0	**79**	18	0	3	0	0
Carex canescens	1	0.536	**40**	40	20	20	20	0	**53**	12	18	12	6	0
Brachythecium oedipodium	1	0.638	**40**	40	40	0	0	0	**39**	22	39	0	0	0
Vaccinium vitis-idaea	1	0.902	**20**	**20**	20	20	0	0	**61**	30	6	3	0	0
Plagiothecium laetum	2	0.225	20	**40**	40	0	0	0	5	**67**	28	0	0	0
Lophocolea heterophylla	2	0.295	40	**60**	40	40	20	0	15	**38**	15	23	8	0
Cephalozia connivens	2	0.296	0	**40**	20	0	20	0	0	**50**	17	0	33	0
Potentilla palustris	2	0.446	20	**40**	20	60	40	0	3	**64**	23	2	9	0
Campylium sommerfeltii	2	0.476	20	**40**	20	20	0	0	38	**46**	8	8	0	0
Trientalis europaea	2	0.519	40	**80**	60	40	40	0	33	**36**	28	1	2	0
Melampyrum pratense	2	0.646	20	**40**	20	20	0	0	30	**37**	31	1	0	0
Potentilla erecta	2	0.861	0	**40**	40	40	20	0	0	**32**	2	5	61	0
Brachythecium rivulare	2	0.921	20	**20**	0	20	0	0	32	**48**	0	19	0	0
Carex pauciflora	2	0.923	20	**20**	20	0	0	0	1	**56**	42	0	0	0
Carex echinata	2	0.928	20	**20**	20	0	0	0	39	**53**	8	0	0	0
Fissidens adianthoides	2	0.934	20	**40**	20	20	20	0	1	**27**	26	13	32	0
Dactylorhiza sp	3	0.233	20	0	**40**	0	0	0	14	0	**86**	0	0	0
Dicranum scoparium	3	0.245	40	60	**60**	20	0	0	21	29	**43**	7	0	0
Agrostis ps	3	0.919	20	20	**20**	0	0	0	1	33	**66**	0	0	0

Vegetation indicator species, their relative frequency and relative abundance in relation to the distance from cutoff ditch.

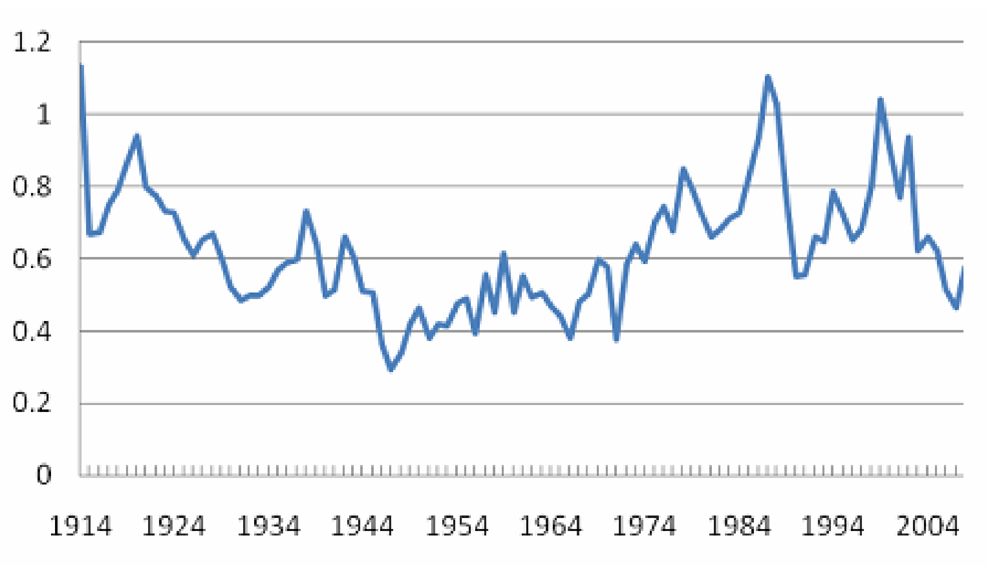
Similar indicator tables were calculated also for **diatomeas** and **invertebrates**.

Distance steps: 1 – 5m, 2 – 15m, 3 - 40m, 4 – 90m, 5 – 190m, 6 – 440 meters from ditch

Dendrological study

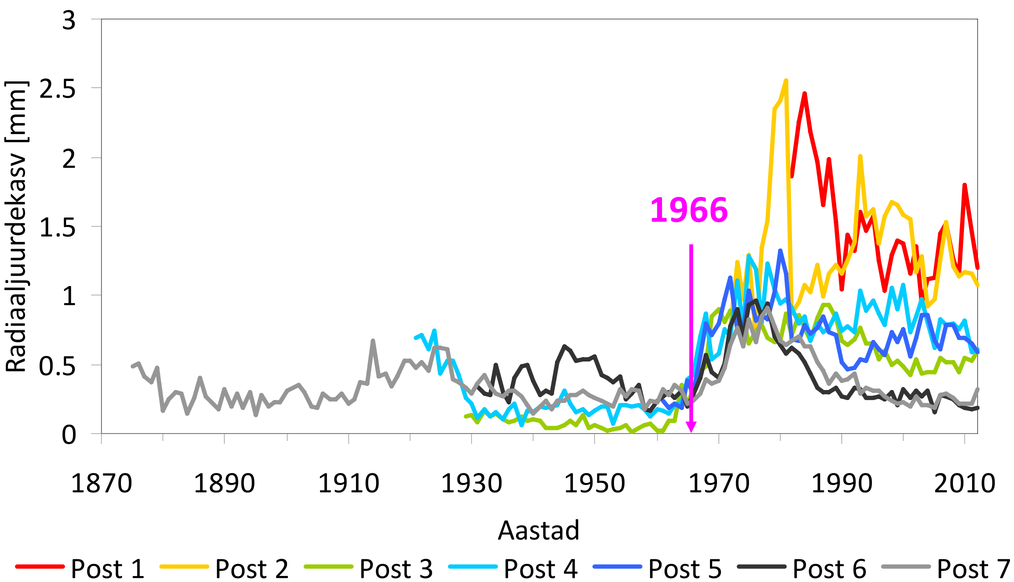
Integral indicator, reflecting dynamics of drainage effect by expressing response to the change of water regime (quick response in annual growth increment) and consequent long term effect due to increased mineralization (slow steady increase in growth increment)

Dendrological analysis is prolonged along the transect toward the mineral soils to consider local regional effects.



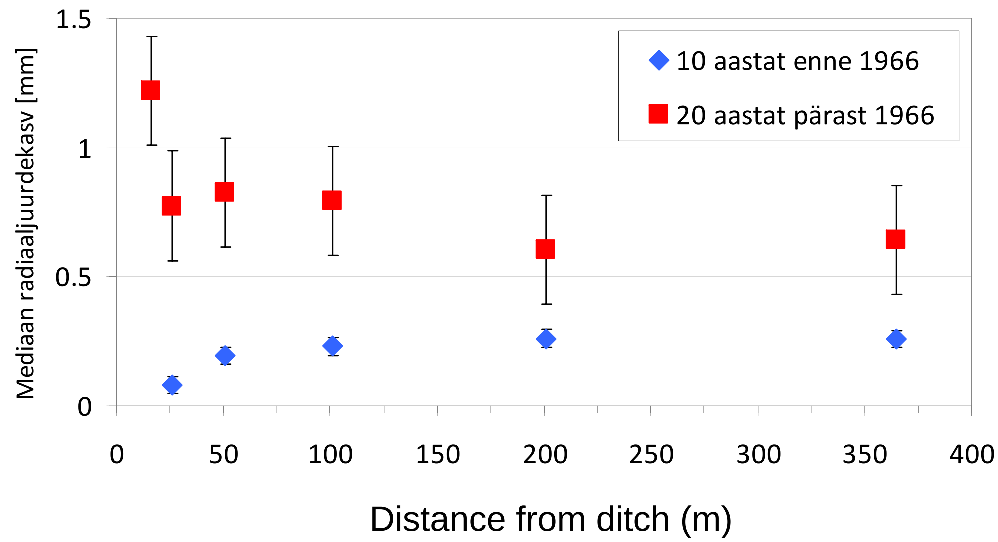
Umbusi and Laukasoo
(peat extraction area)

Umbusi

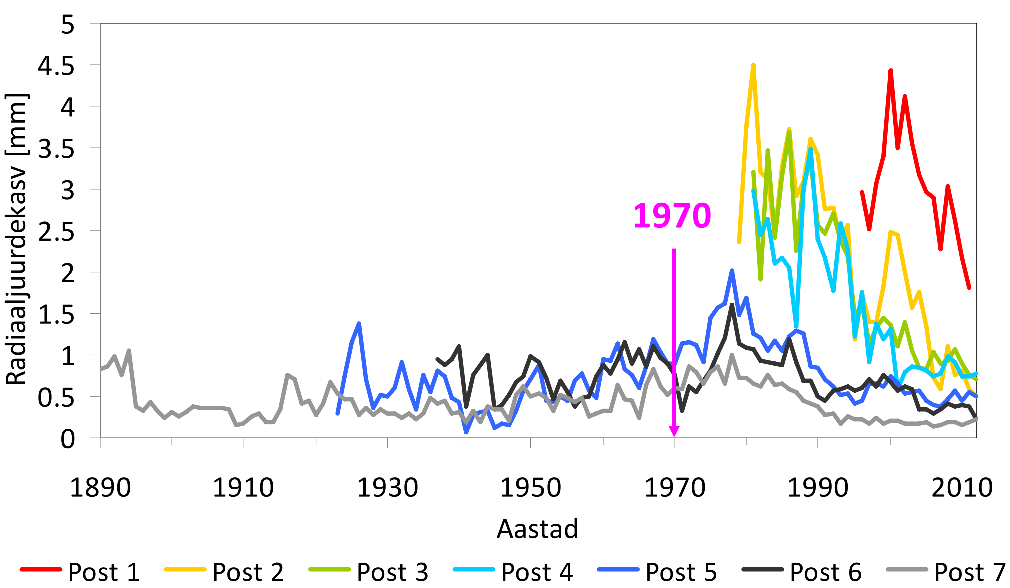


Umbusi

10-yr before and 20-yr after drainage

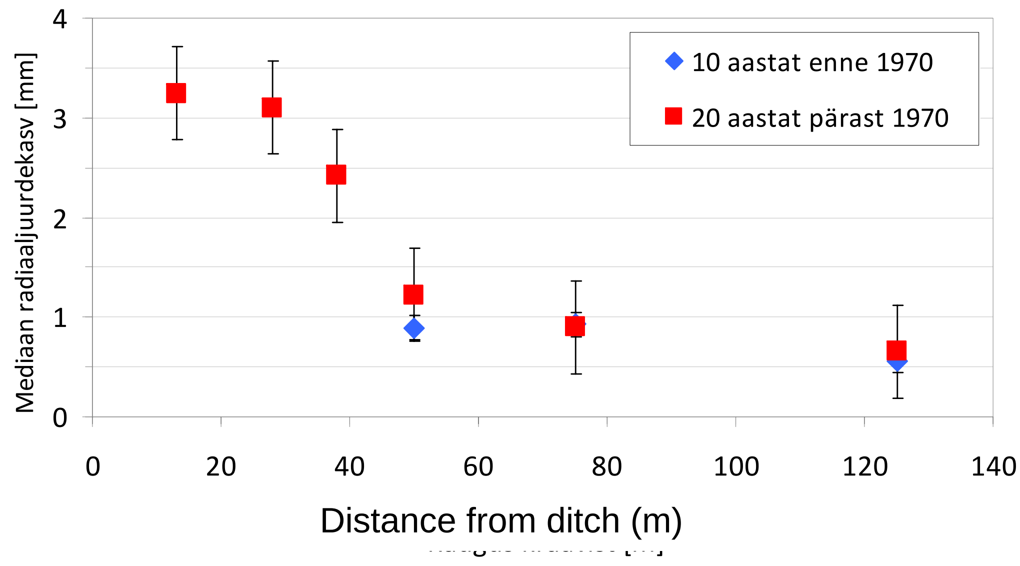


Laukasoo

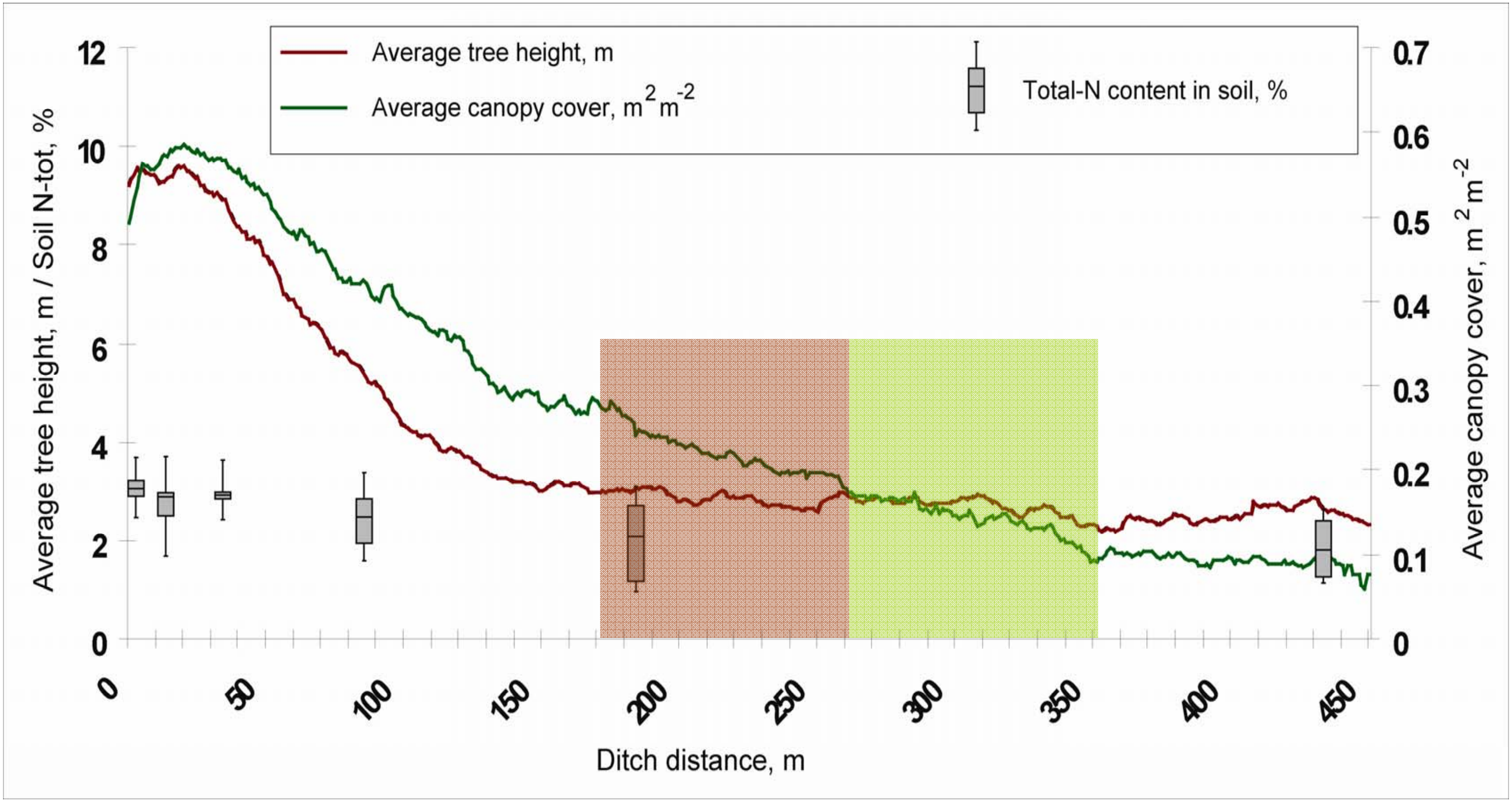


Laukasoo

10-yr before and 20-yr after drainage



Changes in tree height and canopy cover

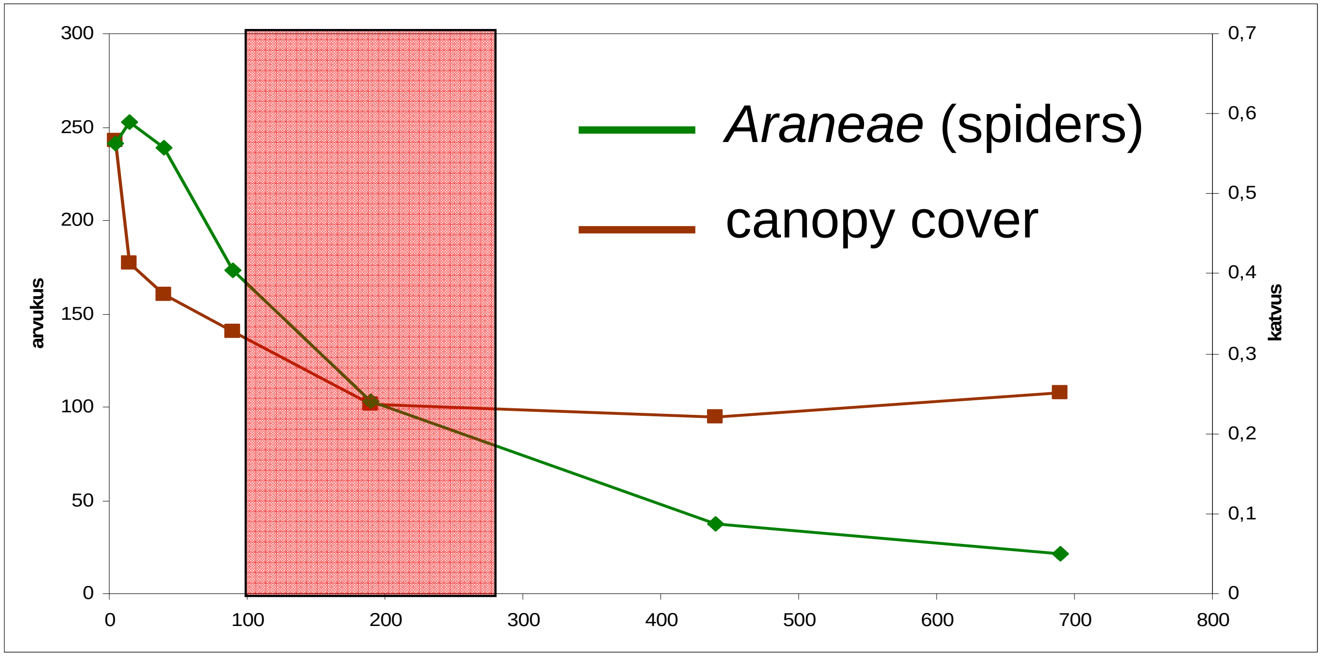


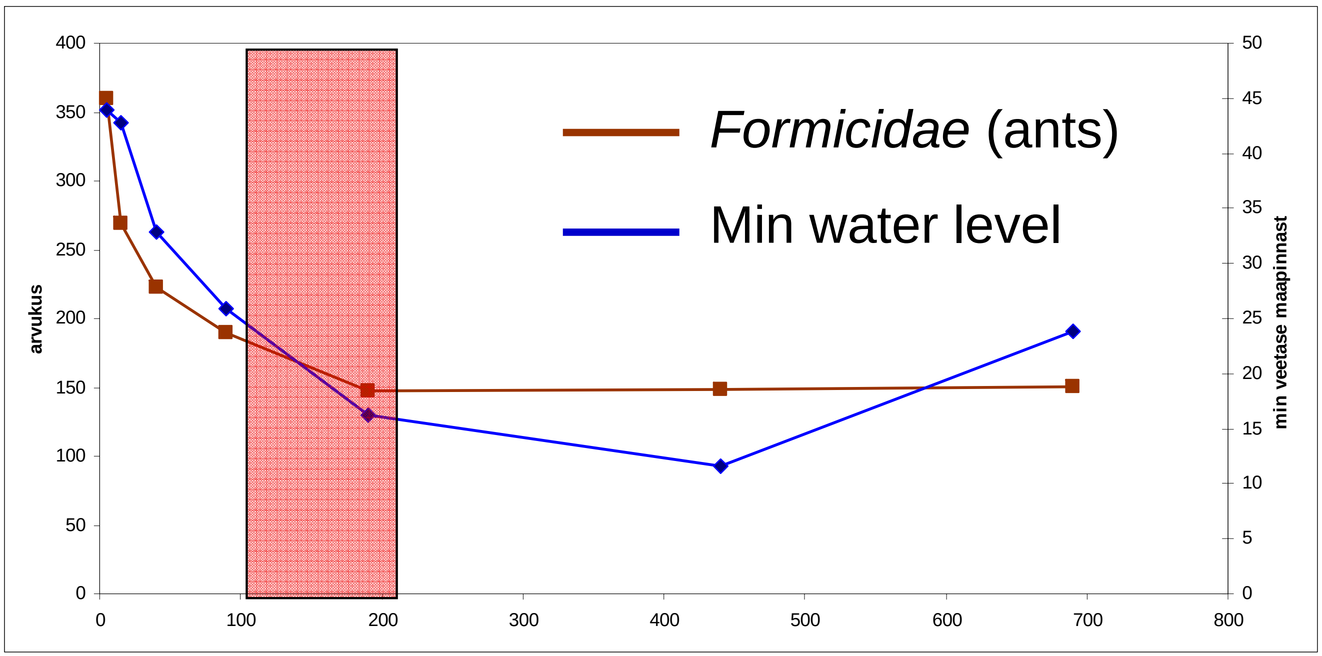
Main changes: increased number of saplings, canopy cover and height

Insectifaunistic diversity

- **Insects are studied as an indicator of biological diversity.** Species richness of insects depends on vegetation/water level but also management of the surrounding area (peat extraction dust, pesticides, fertilizers, forest management)
- In each sampling area **scoopnet catch** of insects (100 strikes) across the transect is carried out.
- **Trap catch.** In each sampling point ground trap and vegetation level traps are applied.

Insectifauna

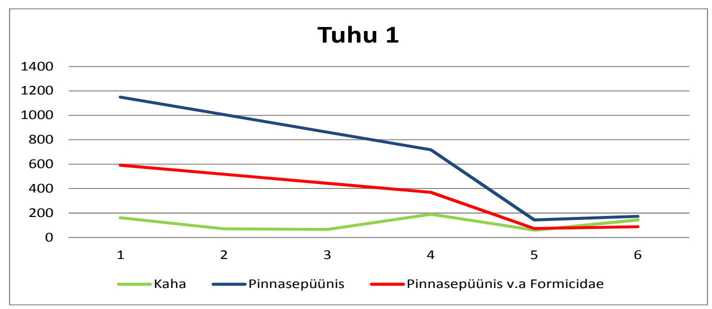




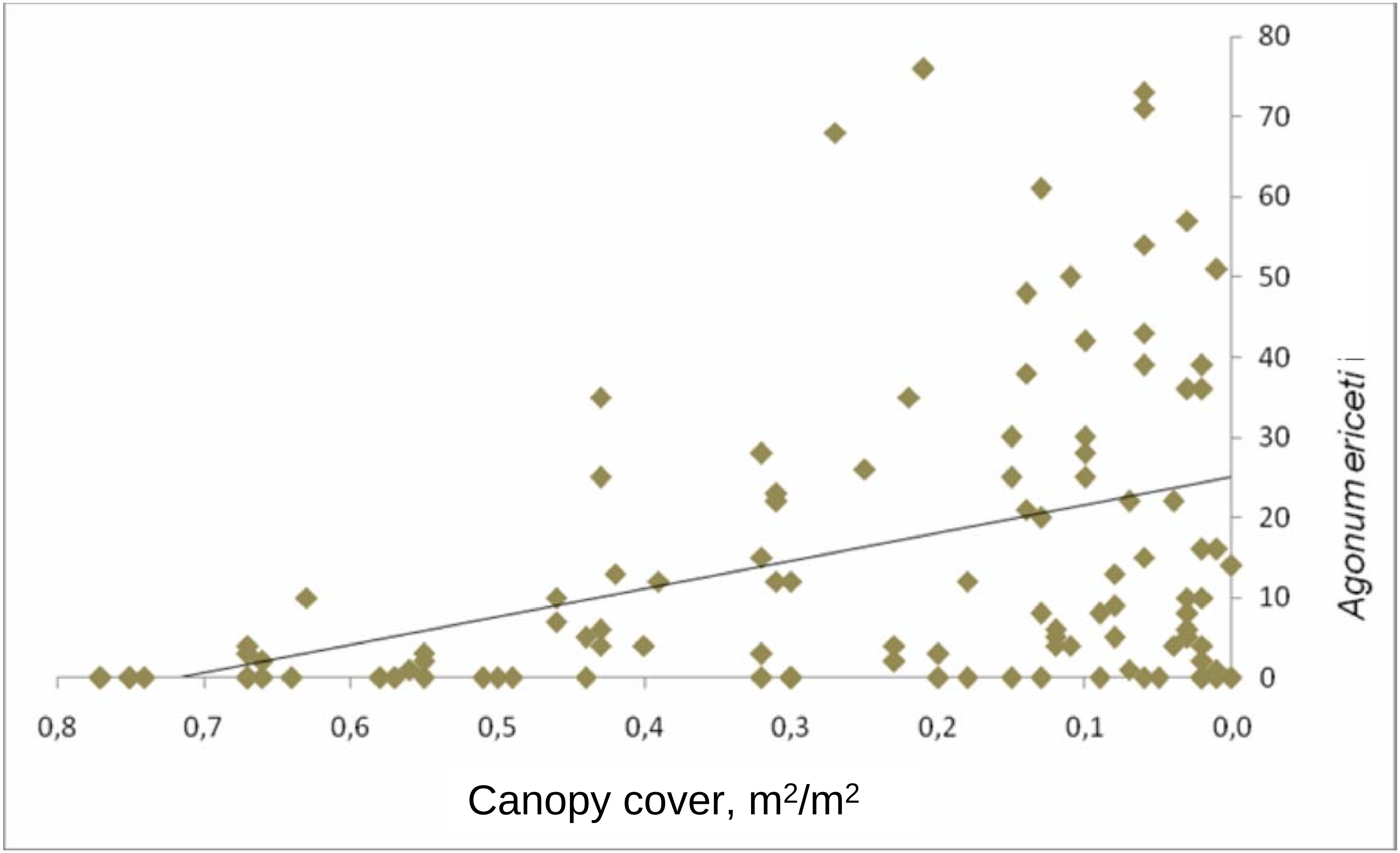
Clear correlation with vegetation and thereby by water level

Main factors affecting insectifauna:

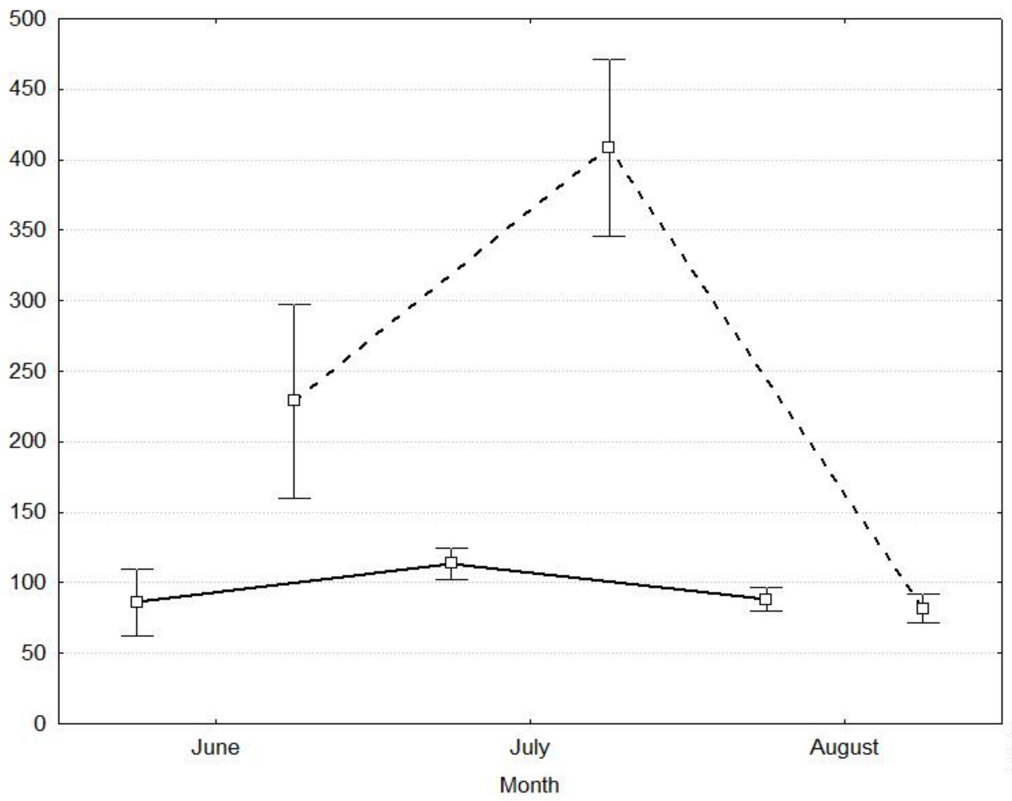
- min. water level
- tree height
- canopy cover
- mosses
- grasses

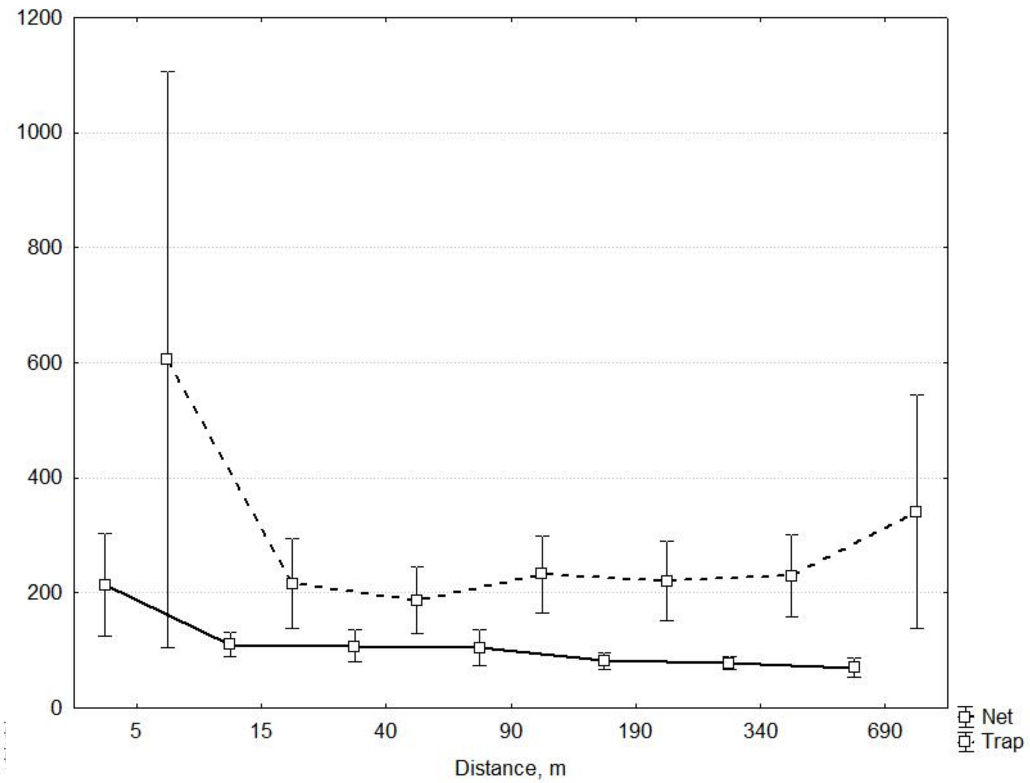


Agonum ericeti



Catch metods of invertebrates

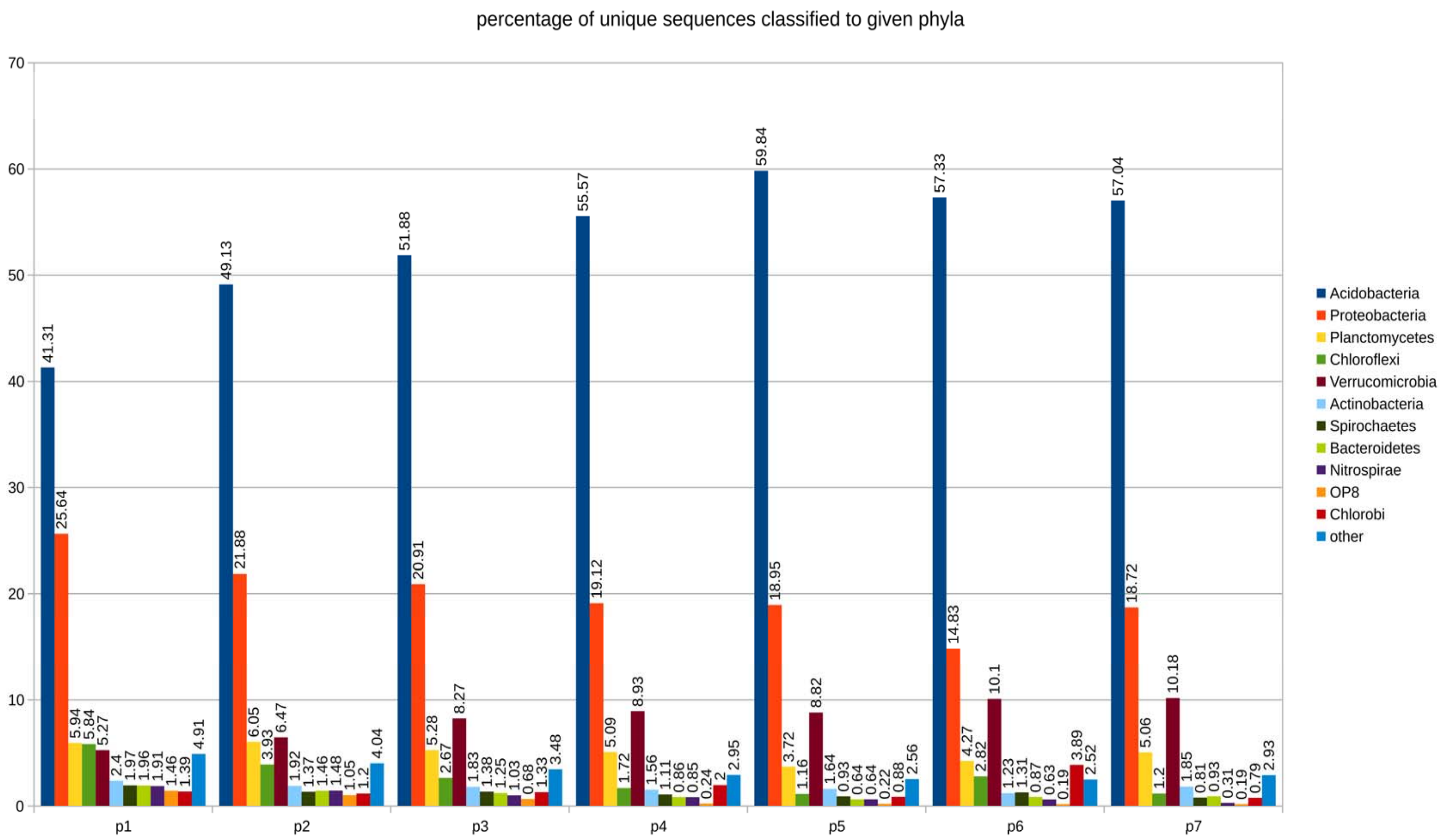




Scoopnet catch (solid line) is more stable over season than trap catch (dashed line).

Trap catch tends to have higher yield in number of individuals but not in species.

Effect on microbiological processes



5m 15m 40m 90m 190m 440m 690m

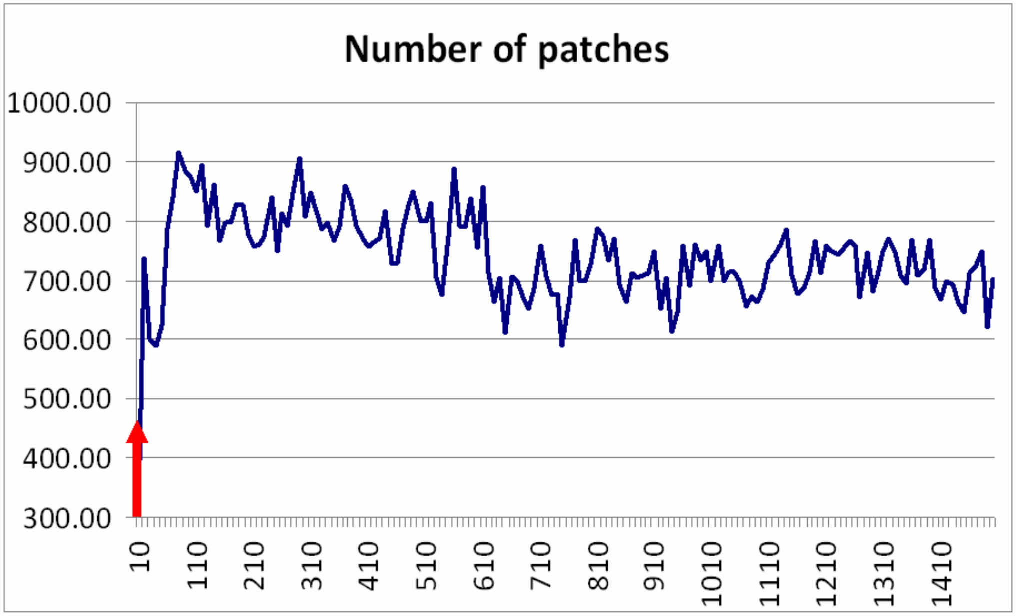
Changes in landscape structure

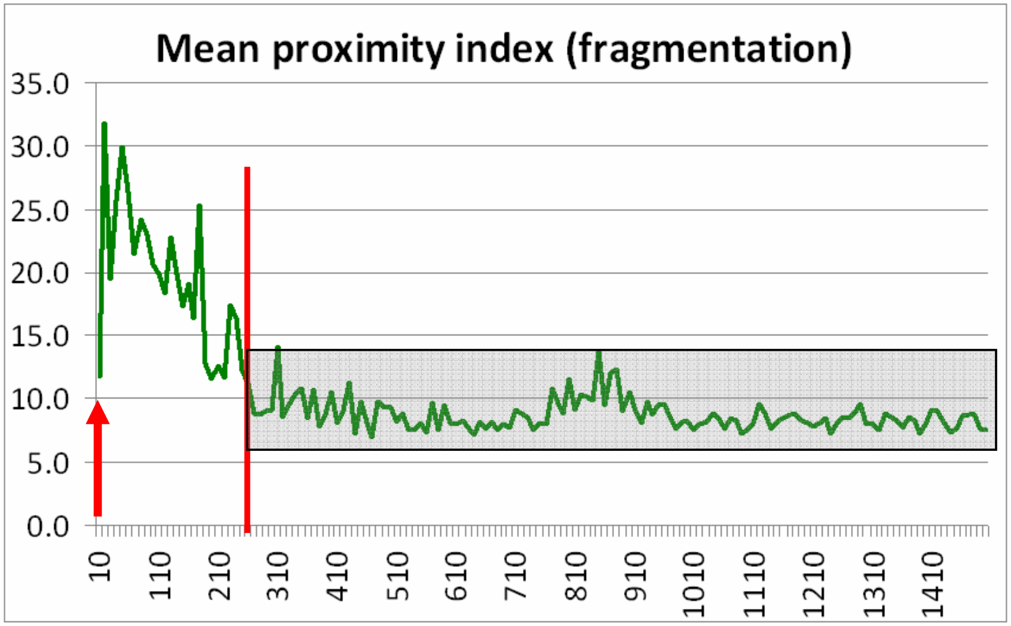
- Integral indicator

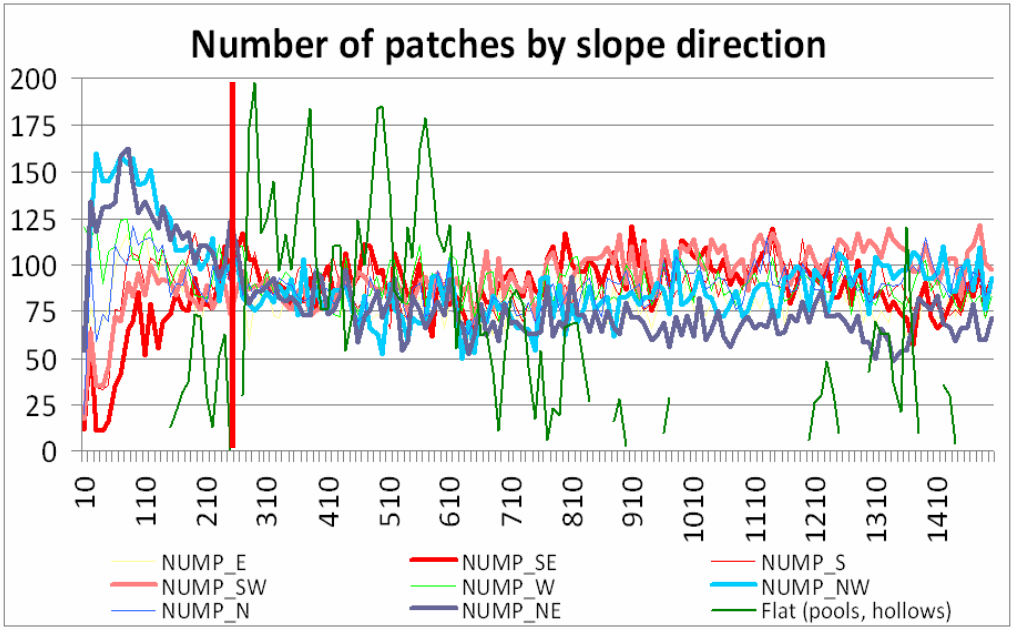
Can be calculated from variety of data sets with different resolution (orthophotos, drone images, satellite images, LIDAR data etc)

Relatively fast and cheap, unified protocol can be used and thus results between different years are easy to compare

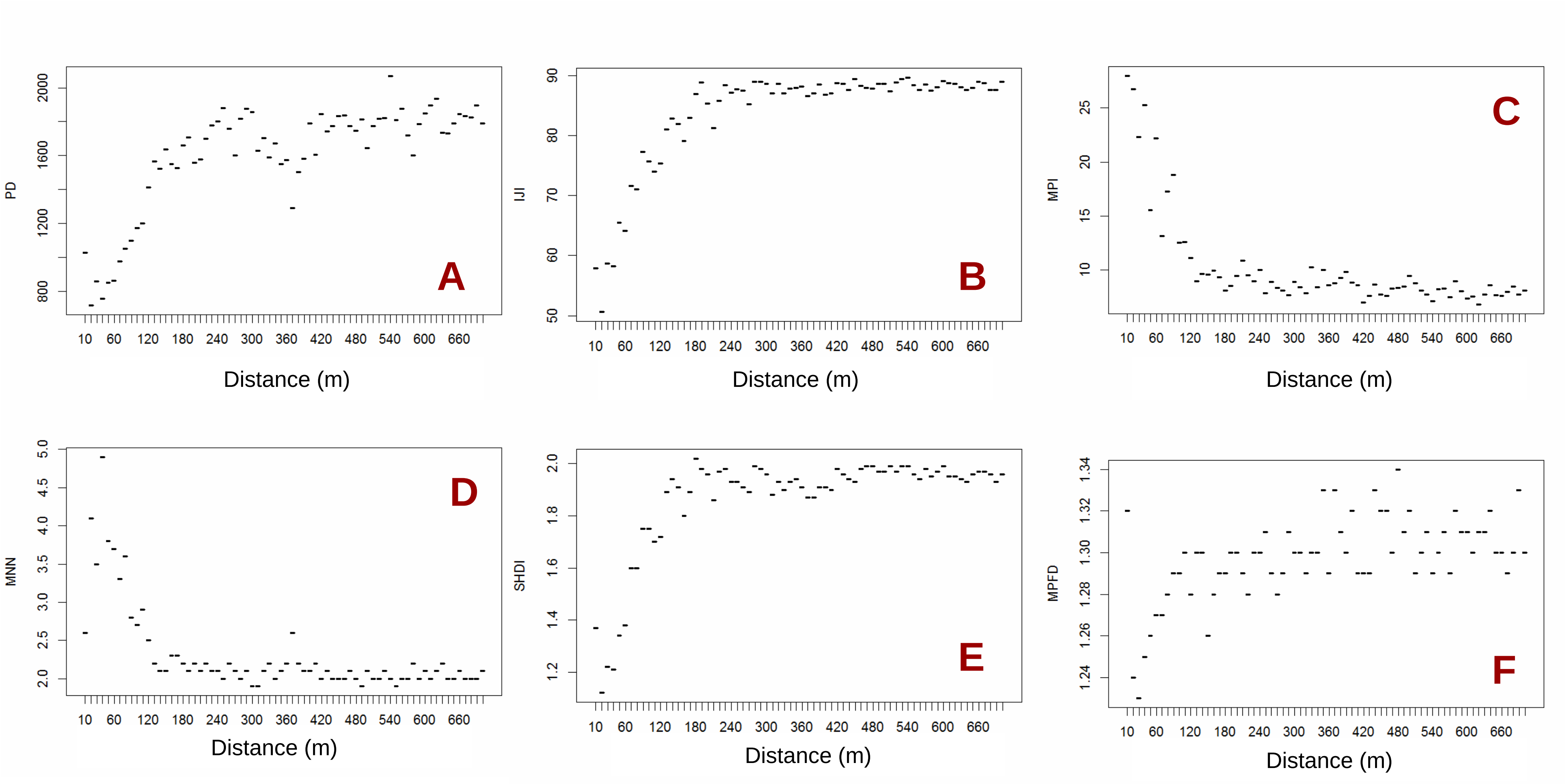
Changes in landscape structure







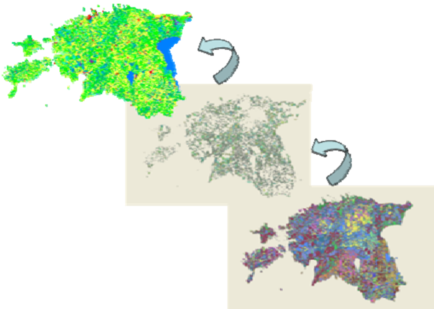
Landscape pattern indicators



A - patch density (PD), **B** - interspersion and juxtaposition index (IJI), **C** - mean proximity index (MPI),

D - mean nearest neighbour distance (MNN), **E** - Shannon's diversity index (SHDI), **F** - mean patch fractal dimension (MPFD)

Conclusions



- Landscape ecological indicators have different sensitivity and shows different width of drainage affected zone but the zone can be quantitatively distinguished.
- Depth of drainage system is an important but not the decisive factor.
- The simplest indicators are the minimum water level and from vegetation parameters the mean tree height and canopy cover.

According to preliminary estimates:

most sensitive parameters are affected up to 400m from the ditch;

significant impact of drainage on all parameters can be observed at least 100m distance;

most parameters are affected up to distance of 200m.