Forest Condition Monitoring in Finland – National report

Photo: Metla

Understorey vegetation on Level II plots during 1998–2009

By Maija Salemaa, Leena Hamberg, Nijole Kalinauskaite, Leila Korpela, Antti-Jussi Lindroos, Pekka Nöjd & Tiina Tonteri

Summary

Understorey vegetation survey on the Finnish ICP Forests Level II plots has been undertaken in 1998, 2003 and 2009. Here we present an overview of the third inventory (21 plots in the year 2009) and an analysis of the 11 years' change of vegetation (17 common plots during 1998–2009). The structure and composition of vegetation indicated well the site fertility and location on south-north climatic gradient in an ordination analysis (Non-metric Multidimensional Scaling, NMDS) in 2009. Especially the number of herb species showed a high correlation with site fertility. One vulnerable liverwort species (*Anastrophyllum cavifolium*), mentioned in the Red List of Finnish Species, was found on the northernmost plot (nr. 22, Kevo) in 2009.

In general, species turnover was very low during the 11 years. Two opposite forces - natural succession and silvicultural thinnings - explained majority of the observed changes in the understorey vegetation. Changes in the tree layer may have many effects on the understorey vegetation through root competition, canopy shading, litterfall and modifying the chemical composition of precipitation. However, the effect of nitrogen deposition on vegetation could not be separated from the effect of amount of precipitation in this study.

Background

Understorey vegetation considerably contributes to ecosystem properties and biodiversity of boreal forests. It plays an important role in biomass production, nutrient cycling and in forming the organic soil layer. By regulating the temperature and moisture level of soil, the understorey vegetation mediates the carbon storage in boreal soils. Changes in plant communities have a great indicative value in the monitoring of forest

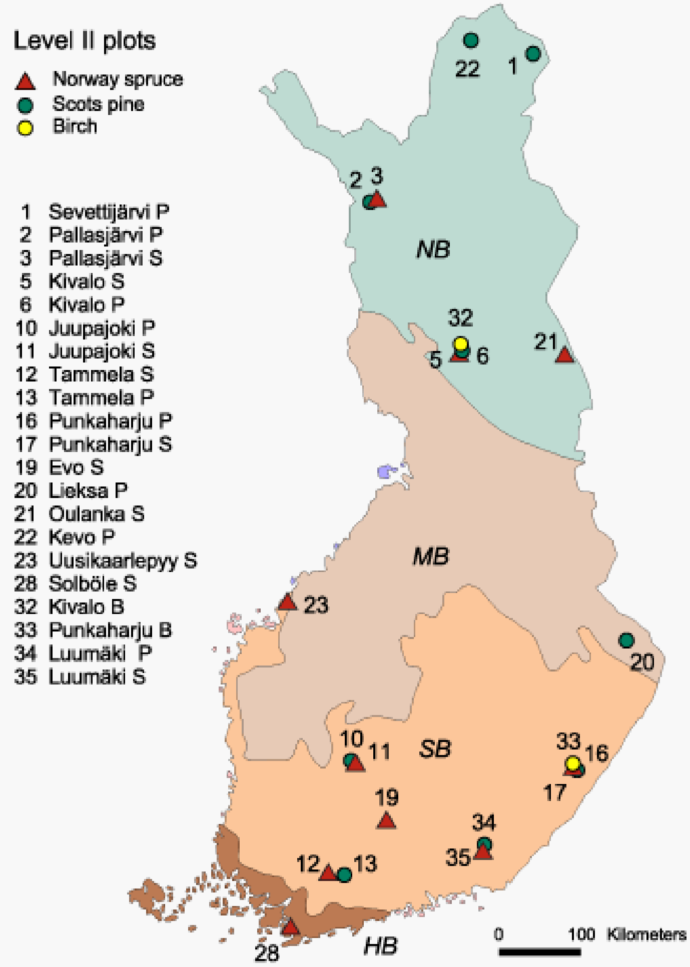

Figure 1. The location of the Level II plots in 2009 and the distribution of the vegation zones in Finland. HB = hemi-boreal, SB = southern boreal, MB = middle boreal, NB = northern boreal. P = Scots pine plot and S = Norway spruce plot.

ecosystems. Long-term series on the occurrence and abundance of plant species offer a possibility to relate the observed changes in vegetation e.g. to shifts in climate or anthropogenically derived factors.

Understorey vegetation survey on the ICP Forests Level II plots (Fig. 1) has been undertaken in 1998, 2003 and 2009. The two birch plots have been studied in 2004/2005 and 2009. The mean percentage cover of the species groups, decaying wood and needle/leaf litter on the ground is given in Table 1 (pdf). We present an overview of the third inventory (21 plots in the year 2009) and an analysis of the 11 years' change of vegetation (17 common plots during 1998–2009). In addition, we compare the changes in the cover of plant species between silviculturally unthinned and thinned plots.

Understorey vegetation serves as an indicator of site fertility

The vegetation data of 21 level II plots (year 2009) were ordinated by global non-metric multidimensional scaling (NMDS) in order to find the main ecological gradients in the vegetation (Vegan package in R software, Oksanen 2004). Plot and species scores of NMDS are displayed in two separate diagrams (Figs. 2a, b, pdf), and we examine them together when interpreting the ordination.

Two-dimensional ordination of the sample plots

The plots were ordered very well according to the Finnish forest types in the two-dimensional projection (Fig. 2a, pdf). The vegetation gradient was differentiated by the overstorey tree species: the more fertile, moist sites dominated by spruce or birch were located on the right, and the nutrient-poor, drier pine plots on the left in the ordination space. There was one birch plot representing herb-rich forests (*Oxalis-Maianthemum* type, Punkaharju nr. 33), and it was located in the utmost right. It was followed by herb-rich heath forests (*Oxalis-Myrtillus* type) and mesic heath forests (*Myrtillus* type in the south, *Hylocomium-Myrtillus* type in the north). Towards the left, there were sub-xeric heath forests (*Vaccinium* type, *Empetrum-Vaccinium* type and *Empetrum-Myrtillus* type from south to north) and xeric heath forests (*Calluna* type in the south, *Uliginosum-Vaccinium-Empetrum* type in the north). Within each site type, the northern plots were located slightly to the left of the southern ones, indicating lower fertility and cooler climate.

Arrangement of the species

The arrangement of the species scores corresponded to the site fertility level and the stand succession stage. For vascular plants, the focus in demanding herbs (e.g. *Oxalis acetosella*) and grasses (e.g. *Milium effusum*) was on the right, in generalist species (e.g. *Vaccinium myrtillus*) in the centre, and in the least demanding species adapted to nutrient-poor, acidic substrates (e.g. *Empetrum nigrum*) on the left in the two-dimensional projection (Fig. 2b, pdf). The demanding bryophyte species (e.g. *Cirriphyllum piliferum*) on the right were replaced by generalist bryophytes in the centre (e.g. *Pleurozium schreberi* and *Dicranum polysetum*), and by drought-tolerant lichens (e.g. *Cladina arbuscula*) on the left in the species ordination (Fig. 2b, pdf). The abundance of moisture-demanding liverworts (e.g. *Lophozia* spp.) increased towards the northern old stands, which can provide suitable humidity and coarse woody debris for their growing substrates (Fig. 2b, pdf).

The number of vascular plant species varied from 7 to 44 in southern and from 6 to 20 in northern plots. The number of bryophyte and lichen species increased with latitude on the pine plots, whereas no south-north trend was found on the spruce plots. Liverworts were most abundant in the north. One vulnerable liverwort species (*Anastrophyllum cavifolium*), included in the Red List of Finnish Species (Rassi et al. 2010), was found in the northernmost plot (nr. 22, Kevo) in 2009.

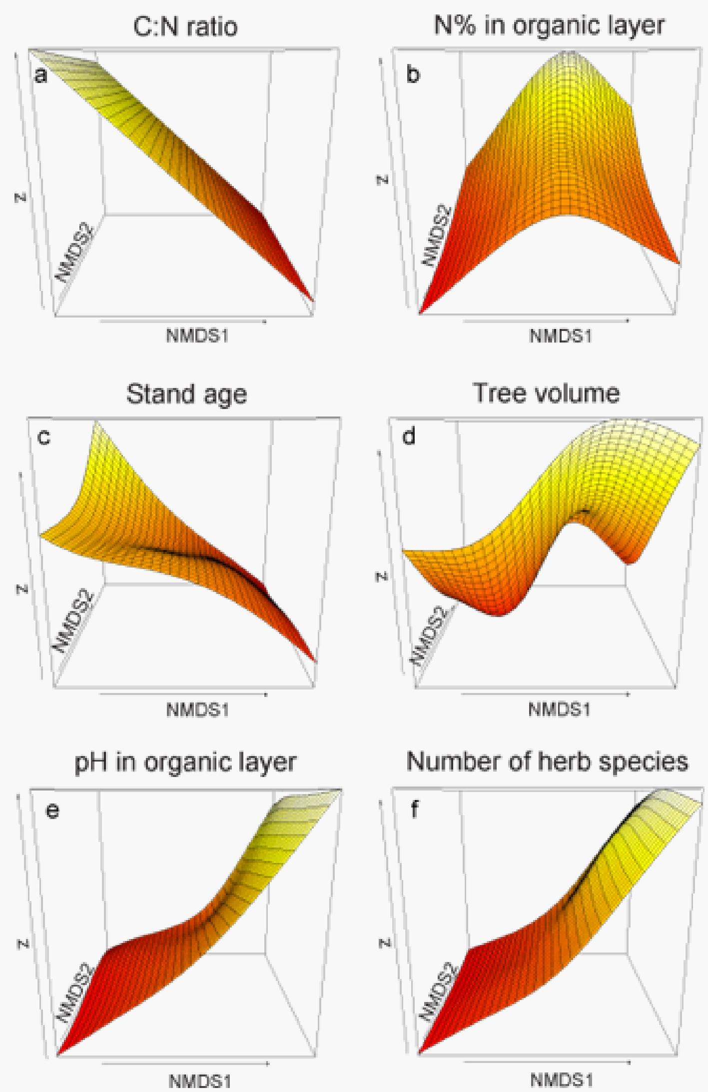

Figure 3. Non-linear surfaces (GAM) of a) C:N ratio of the organic layer, b) N% of the organic layer, c) stand age (years), d) stand volume (m^3/ha), e) pH of the organic layer and f) number of herb species in two dimensional NMDS ordination (see Fig. 2a). The surfaces depict the smooth trends between the environmental variables and plot scores. z = predicted values of the model.

Explanatory variables

In general, the plot ordination was strongly related to the C/N ratio, N % and pH in the organic layer as well as to stand age and volume (Figs. 3a-e) when smooth surfaces were fitted to ordination space using generalized additive models (GAM). The surface pattern for C/N ratio was closely linear with high values on xeric northern plots and low values on southern herb-rich and mesic plots (Figs. 2a pdf, 3a). On the other hand, the surfaces for pH and number of herb species faced to the opposite direction (Figs. 3e, f). Stand age increased almost linearly towards the northern plots in the upper left part of the ordination space, but the surfaces depicting tree volume and N % in the organic layer had maximum values in south (Fig. 3b–d). The number of herb species well depicted the general fertility level of the sites and it showed the highest correlation of the studied explanatory variables with the ordination pattern ($r = 0.900$, $p > 0.001$). In an earlier analysis of the vegetation-stand relationships on Level II plots it was found that the number of herb species was also a good indicator of site index (h 100) (Salemaa et al. 2008).

Silvicultural thinnings explain the change in understorey vegetation

Vegetation change during 1998–2009 (n = 17 plots)

In general, species turnover was very low during the 11 years, but abundance relationships between the species changed in some plots (Table 1, pdf). The cover of dwarf shrubs and tree seedlings increased on the plots where no silvicultural thinnings were carried out (n = 12), especially in South Finland (Fig. 4a, pdf). Simultaneously the abundance ratio between the bryophyte species changed so that shade-tolerant *Hylocomium splendens* increased and more shade-sensitive *Dicranum* spp. decreased (Fig. 4b, pdf). On the other hand, the cover of herbs and grasses increased on the thinned plots (n = 6) with increasing light level, wheareas they decreased on the unthinned plots (Fig 4c, pdf). Also *Vaccinium myrtillus* increased after thinning of the stand (Fig. 4a, pdf), but the cover of lichens decreased (Fig. 4d, pdf).

Two opposite forces – natural succession and silvicultural thinnings - explained the majority of the observed changes in the understorey vegetation. This can also be seen in the ordination solution in which the two surveys (years 1998 and 2009) of 17 Level II plots were analysed together (Fig. 5). Excluding the two most northern plots (Sevettijärvi nr.1 and Kevo nr. 22) the change in the plant communities followed the direction of an increase in stand volume. On the other hand, on the thinned plots the change in the vegetation went to the opposite direction, towards the younger succession phase.

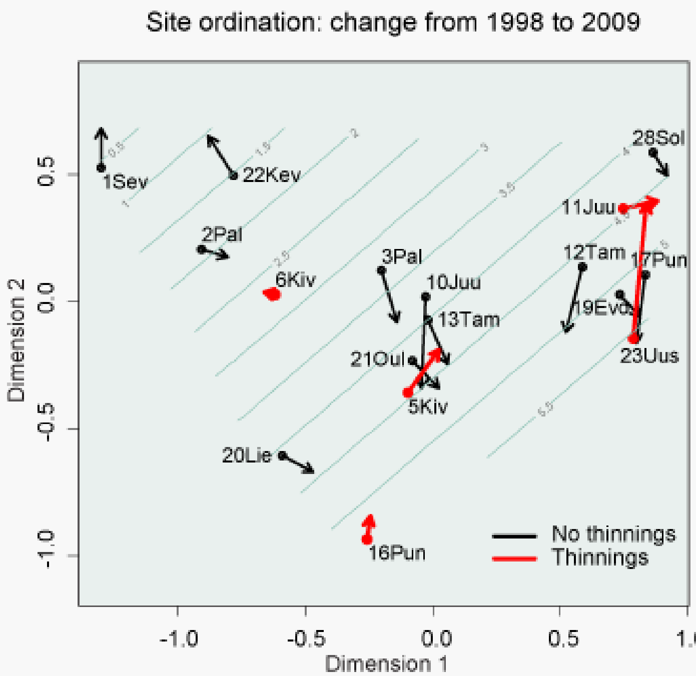

Figure. 5. The NMDS ordination of the same 17 Level II sample plots in 1998 and 2009 (12 unmanaged plots black, 5 thinned plots red). The temporal change of the plots depicted by arrows (1998 base and 2009 point of the arrow). Stand volume is fitted by non-linear GAM surface (lines) to the ordination space.

Probably the tree layer regulates in many ways the dynamics of the understorey vegetation through root competition, canopy shading, leaf/litterfall and throughfall precipitation. In addition, annual variation in temperature and precipitation affected the cover of plant species. Deposition is dependent on the amount of precipitation, and in this data it was not possible to separate the effect of moisture from the effect of nitrogen input on plant occurrence.

Methods

One of the three sub-plots in a monitoring site was selected for vegetation monitoring. The size of the sub-plot is 30 x 30 m. Altogether 16 sample quadrats, each 2 m^2 (1.41 x 1.41 m) in area, were marked out systematically (4 x 4 design) on the sub-plot. The location of the quadrat was moved only in cases where there was an exceptional surface (e.g. path or large stone) occupying more than 20% of the area. In addition, four 10 x 10 m quadrats (A–D) were marked out to give four 100 m^2 areas (Fig. 6). These areas provide vegetation data

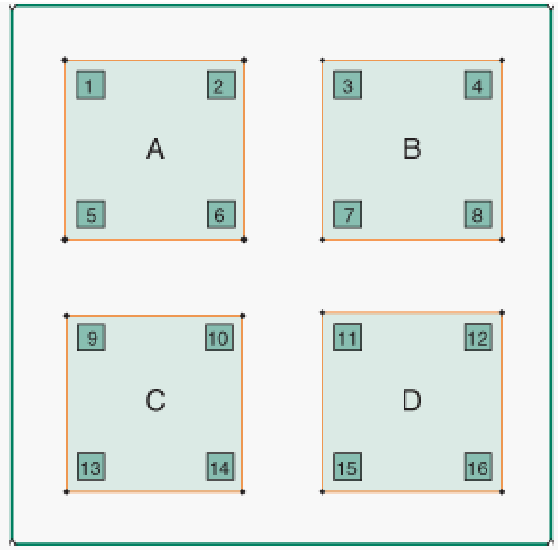

Figure. 6. The plot (30 x 30 m = 900 m^2) used for the inventory of understorey vegetation. Percetage cover (%) of plant species was assessed on the small sample quadrats (16 x 2 m^2). The larger quadrats (A–D) were 10 x 10 m =100 m^2 in area. The additional plant species growing outside the small quadrats were recorded within areas of 4 x 100 m^2 (A–D) forming the so called Common Sample Area (CSA).

representing the Common Sample Area (= 400 m^2), which is used in all countries participating in the ICP Forests monitoring programme.

Estimation of plant percentage cover

The vegetation inventory was carried out during July - August. The percentage cover (%) of the individual plant species was assessed visually using the following scale: 0.01 (solitary or very sparsely growing shoots), 0.1, 0.2, 0.5, 1, 2, …99, 100 %. The bottom layer (mosses, liverworts and lichens), the field layer (height < 50 cm vascular plants: herbs, grasses, sedges, dwarf shrubs and tree seedlings) and the shrub layer (height 50–150 cm) were analysed. Plants growing on stones, stumps or fallen stems were excluded. The cover of needle and leaf litter, dead plant material, dead branches, fallen tree stems, stumps, bare soil and stones was also assessed. Additional species, i.e. species occurring on the monitoring area (400 m^2 and 900 m^2) but not on the sample quadrats, were recorded. Four to two botanists inventoried the vegetation simultaneously on the same plots. Field tests were carried out to check the assessment level, and to calibrate it when necessary.

A 2 m^2 frame divided into 100 small quadrats by a net of elastic strings was used in the assessment of the plant cover. "An open corner frame" without a net was placed on sites where a tree, shrubs or high vegetation are growing. The cover of withered early summer species (e.g. *Anemone nemoralis*) was assessed according to their expected maximum biomass. The height of the field and shrub layers was measured at 10 points in different parts of the monitoring sub-plot. Samples of unknown plant species (mainly bryophytes and lichens) were later identified on the basis of microscopic characteristics.

Organic layer samples were collected and analysed as described in Lindroos et al. in this publication.

References

Lindroos, A.-J., Derome, K., Nieminen, T.M., Tamminen, P. & Ilvesniemi, H. 2012. Soil condition monitoring on Level II plots – parameters related to acidity and buffering status.

Oksanen J. 2004. 'Vegan' Community Ecology Package: ordination methods and other functions for community and vegetation ecologists. University of Oulu, Oulu, FI.

Rassi, P., Hyvärinen, E., Juslén, A. & Mannerkoski, I. (eds.). 2010. Suomen lajien uhanalaisuus – Punainen kirja 2010. The 2010 Red List of Finnish Species. Edita Ltd. Helsinki. 685 p.

Salemaa, M., Derome, J. & Nöjd, P. 2008. Response of boreal forest vegetation to the fertility status of the organic layer along a climatic gradient. Boreal Environment Research 13(suppl.B): 48–66.

Citation: Salemaa, M., Hamberg, L., Kalinauskaite, N., Korpela, L., Lindroos, A-J., Nöjd, P. and Tonteri, T. (2013). Understorey vegetation on Level II plots during 1998–2009. In: Merilä, P. & Jortikka, S. (eds.). Forest Condition Monitoring in Finland – National report. The Finnish Forest Research Institute. [Online report]. Available at http://urn.fi/URN:NBN:fi:metla-201305087575. [Cited 2013-05-07].

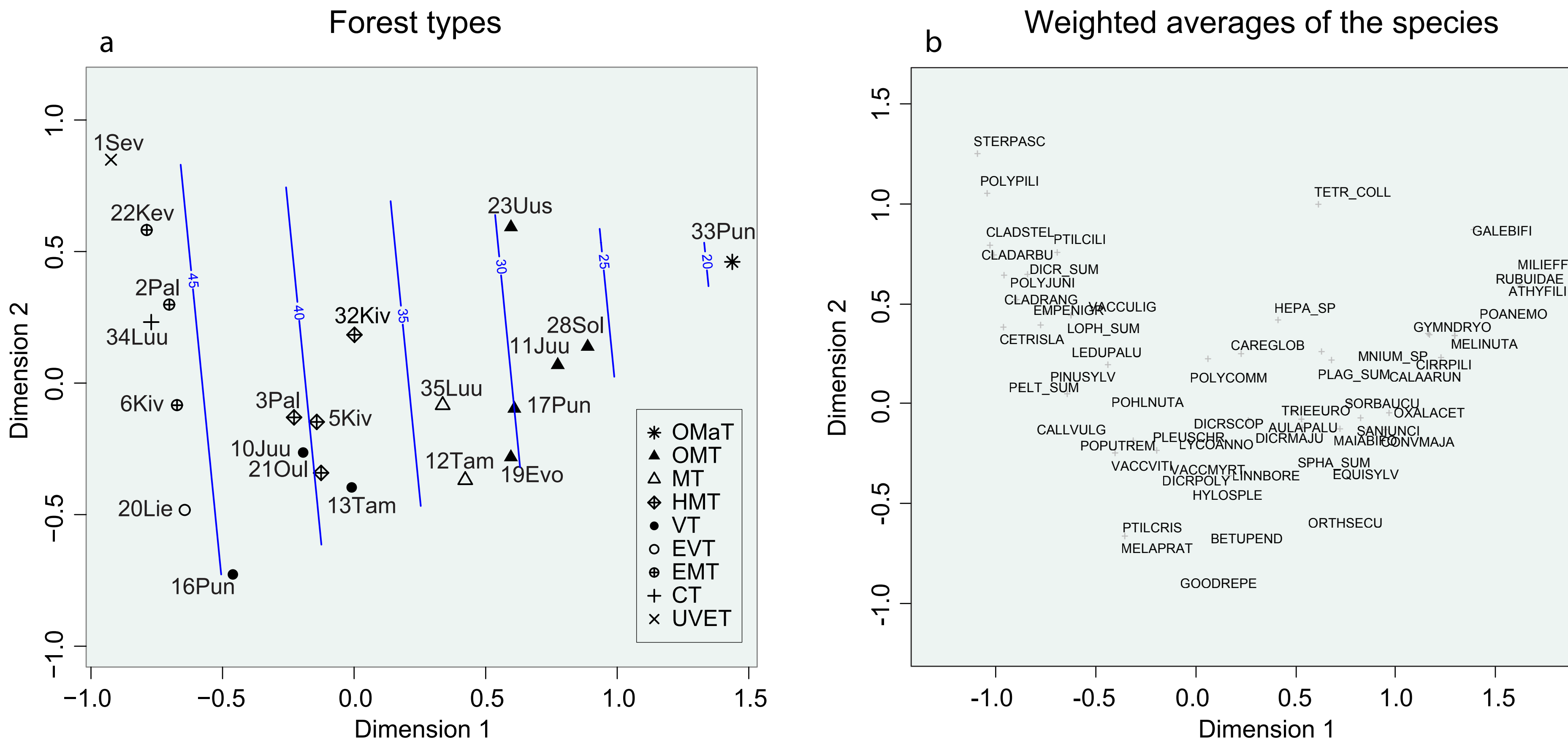

Figure 2. Global non-metric multidimensional scaling (NMDS) of the vegetation data on 21 Level II plots in 2009. The more similar the plant species composition in the plots, the closer they are located to each other in the ordination diagram. a) Two-dimensional ordination of the sample plots. Forest types marked with different symbols, C:N ratio in the organic layer depicted by GAM surface (lines). b) Weighted averages of the species. Abbreviation of the species names = first four letters from the generic and species names. The most abundant species labeled with names, other marked as crosses. HEPA_SUM = Other hepatics than *Barbilophozia*, BARB_SUM = *Barbilophozia* spp.

Plot	Year	n	Vascular species					Bryophytes			Lichens				Trees & shrubs	Other cover		
			Trees &shrubs	Dwarf shrubs	Herbs	Grasses	Sum	Hepatics	Mosses	Sum	Cladina	Cladonia	Other	Sum	50–150 cm	Dead wood	Needle litter	Leaf litter
1 Sevettijärvi P	1998	16	0.1	34.9	0.0	0.0	35.0	0.8	7.4	8.2	28.1	1.0	0.8	29.9	0.0	4.0	56.3	1.9
	2003	16	0.1	46.6	0.0	0.0	46.7	4.1	11.6	15.7	38.3	4.4	0.4	43.2	0.0	2.0	29.3	0.8
	2009	16	0.2	40.6	0.0	0.0	40.8	3.6	13.1	16.7	47.6	1.5	0.4	49.5	0.0	1.5	29.8	1.4
2 Pallasjärvi P	1998	16	0.0	45.1	0.1	0.2	45.4	3.0	32.5	35.5	10.0	2.9	1.0	13.9	4.8	1.1	51.0	5.6
	2003	16	0.0	36.9	0.0	0.2	37.2	2.3	47.0	49.3	6.9	4.3	0.8	11.9	0.0	3.5	33.3	3.1
	2009	16	0.0	39.1	0.0	0.1	39.3	1.3	72.7	74.0	5.5	2.4	0.4	8.3	0.0	3.2	14.9	2.4
3 Pallasjärvi S	1998	16	0.3	67.0	0.8	2.1	70.2	3.0	84.3	87.3	0.1	0.0	0.3	0.4	15.8	2.3	6.8	0.1
	2003	16	0.2	55.0	0.4	1.8	57.3	2.0	84.5	86.6	0.0	0.1	0.1	0.3	3.2	3.1	7.3	0.0
	2009	16	0.1	53.1	0.3	1.2	54.6	3.9	89.3	93.3	0.0	0.0	0.1	0.2	1.8	2.2	5.2	2.0
5 Kivalo S	1998	16	0.0	34.1	0.1	1.6	35.9	9.1	71.2	80.3	0.0	0.0	0.0	0.0	22.8	0.8	24.3	0.0
	2003	16	0.0	31.7	0.1	0.2	32.0	8.6	76.0	84.6	0.0	0.0	0.0	0.1	0.0	5.6	11.0	0.0
	2009	16	0.0	45.8	0.0	0.5	46.3	3.1	86.4	89.6	0.0	0.0	0.0	0.0	0.0	4.0	6.8	0.0
6 Kivalo P	1998	16	0.1	35.6	0.0	0.0	35.7	0.1	88.3	88.3	3.2	0.2	0.4	3.7	0.1	0.2	5.9	0.6
	2003	16	0.1	35.4	0.0	0.0	35.5	0.0	91.5	91.5	1.8	0.2	0.2	2.2	0.1	4.2	9.5	0.0
	2009	16	0.0	22.3	0.0	0.0	22.4	0.0	84.0	84.0	0.3	0.0	0.2	0.5	0.1	7.6	12.4	0.0
10 Juupajoki P	1998	16	0.3	23.5	3.6	4.0	31.4	0.1	84.8	85.0	0.3	0.0	0.0	0.3	1.9	0.6	10.5	0.3
	2003	16	0.1	40.4	4.3	2.6	47.4	0.0	91.2	91.2	0.0	0.1	0.0	0.2	1.0	4.1	7.2	0.4
	2009	16	0.2	59.4	2.6	1.7	63.8	0.0	90.0	90.0	0.1	0.0	0.0	0.1	0.6	2.2	11.1	0.2
11 Juupajoki S	1998	16	0.8	11.1	21.1	6.2	39.1	1.7	59.5	61.1	0.0	0.0	0.0	0.0	0.3	2.4	29.0	8.0
	2003	16	0.9	10.9	19.4	3.0	34.1	0.7	43.6	44.2	0.0	0.0	0.0	0.0	1.1	16.4	26.8	18.0
	2009	16	1.7	23.1	41.2	18.2	84.2	0.4	56.4	56.7	0.0	0.0	0.0	0.0	1.0	14.6	6.4	12.9
12 Tammela S	1998	16	0.9	30.4	3.8	12.2	47.3	0.0	77.4	77.4	0.0	0.0	0.0	0.0	2.4	1.9	15.7	8.4
	2003	16	2.2	41.8	6.2	3.7	53.9	0.0	51.7	51.7	0.0	0.0	0.0	0.0	1.4	6.2	15.4	26.3
	2009	16	0.9	52.3	4.0	3.1	60.4	0.0	72.3	72.3	0.0	0.2	0.0	0.2	4.1	3.8	7.2	5.5
13 Tammela P	1998	16	0.0	22.4	3.8	7.4	33.5	0.0	86.1	86.1	0.2	0.3	0.0	0.6	1.2	1.9	21.4	1.1
	2003	16	0.1	36.2	7.1	1.8	45.2	0.0	46.9	46.9	0.1	0.2	0.0	0.4	0.6	6.1	39.6	4.4
	2009	16	0.1	33.9	6.7	4.3	45.0	0.0	59.6	59.6	0.1	0.1	0.0	0.2	0.3	4.5	29.1	0.4
16 Punkaharju P	1998	16	0.0	18.0	0.1	0.0	18.1	0.0	98.3	98.3	0.0	0.0	0.0	0.0	0.0	0.2	9.3	0.1
	2003	16	0.0	21.7	0.1	0.0	21.8	0.0	89.0	89.0	0.0	0.0	0.0	0.0	0.0	7.1	16.9	0.2
	2009	16	0.1	28.1	1.9	0.0	30.1	0.0	96.0	96.0	0.0	0.0	0.0	0.0	0.0	2.8	6.3	0.1
17 Punkaharju S	1998	16	1.2	1.7	12.3	0.5	15.8	0.0	70.1	70.1	0.0	0.0	0.0	0.0	0.1	5.2	23.9	1.4
	2003	16	1.8	3.2	12.2	0.5	17.6	0.0	68.3	68.3	0.0	0.0	0.0	0.0	2.1	11.0	28.9	0.2
	2009	16	1.2	3.1	16.5	0.3	21.2	0.0	75.1	75.1	0.0	0.0	0.0	0.0	1.0	4.5	17.5	0.0
19 Evo Sim	1998	20	0.7	11.4	5.3	0.9	18.4	0.0	18.6	18.6	0.0	0.0	0.0	0.0	3.0	2.6	21.0	55.0
	2003	16	0.1	13.2	5.0	0.6	18.9	0.1	41.2	41.3	0.0	0.2	0.0	0.2	0.0	6.7	12.3	50.0
	2009	16	0.3	23.1	4.7	0.5	28.6	0.1	43.2	43.3	0.0	0.0	0.0	0.0	0.0	3.3	9.1	40.9
20 Lieksa Pim	1998	16	0.2	53.6	3.3	0.0	57.1	0.0	96.3	96.3	1.2	0.0	0.1	1.3	0.8	0.5	1.5	4.4
	2003	16	0.2	62.1	0.1	0.0	62.3	0.0	93.2	93.2	0.5	0.2	0.2	0.8	0.0	4.1	2.5	10.8
	2009	16	0.2	65.4	4.5	0.0	70.1	0.0	93.1	93.1	0.2	0.0	0.4	0.6	0.0	2.0	1.1	1.5
21 Oulanka Sim	1998	16	0.2	58.7	0.5	0.9	60.2	0.6	92.7	93.3	0.0	0.0	0.0	0.1	0.6	2.0	6.0	24.7
	2003	16	0.0	57.9	0.2	0.9	59.0	0.3	89.3	89.6	0.0	0.0	0.0	0.0	1.3	5.2	5.4	16.1
	2009	16	0.0	72.4	0.4	0.7	73.5	0.2	89.6	89.8	0.0	0.0	0.0	0.0	0.4	2.7	1.8	8.8
22 Kevo Pim	1998	16	0.0	50.0	0.0	2.0	52.0	1.6	34.9	36.5	3.8	0.8	1.8	6.5	3.8	5.8	35.0	14.8
	2003	16	0.0	41.1	0.0	1.0	42.0	3.1	42.0	45.1	4.7	8.2	4.9	17.8	0.2	3.0	24.0	13.8
	2009	16	0.0	51.5	0.0	0.4	52.0	5.1	43.4	48.5	5.2	1.9	2.8	9.8	0.3	2.3	22.4	12.5
23 Uusikaarlepyy S	1998	8	1.3	0.0	1.0	1.0	3.3	0.1	20.8	20.9	0.0	0.0	0.0	0.0	0.0	2.0	76.8	0.0
	2003	8	0.8	0.0	2.6	1.2	4.6	0.1	15.8	15.9	0.0	0.0	0.0	0.0	0.3	21.9	85.1	0.0
	2009	16	1.1	0.0	5.4	4.4	10.9	0.1	39.9	40.0	0.0	0.0	0.0	0.0	0.2	20.2	29.4	1.4
28 Solböle	1998	16	2.1	33.4	40.9	11.5	87.9	0.1	80.2	80.3	0.0	0.0	0.0	0.0	5.3	0.5	10.1	0.5
	2003	16	3.9	39.0	24.9	5.2	73.0	0.0	69.3	69.3	0.0	0.0	0.0	0.0	3.3	2.8	12.4	1.6
	2009	16	6.9	43.4	17.0	3.6	70.9	0.0	74.9	75.0	0.0	0.0	0.0	0.0	4.1	2.2	8.8	2.2
32 Kivalo B	2005	16	1.9	48.1	0.8	7.9	58.8	0.1	25.0	25.0	0.1	0.1	0.0	0.2	4.0	3.3	0.2	71.3
	2009	16	1.2	61.1	0.8	7.8	71.0	0.1	28.2	28.2	0.1	0.1	0.0	0.2	2.9	2.0	0.1	73.2
33 Punkaharju B	2004	16	6.4	0.1	24.1	14.2	44.8	0.1	2.6	2.6	0.0	0.0	0.0	0.0	18.6	7.7	0.2	82.2
	2009	16	5.6	0.4	36.8	24.4	68.0	0.1	0.7	0.7	0.0	0.0	0.0	0.0	22.3	0.5	0.0	90.1
34 Luumäki P	2009	16	0.2	28.8	0.0	0.0	28.9	0.0	38.3	38.3	25.7	0.2	3.8	29.7	0.3	2.6	8.4	4.1
35 Luumäki S	2009	16	0.1	5.1	3.8	11.6	20.6	0.1	84.0	84.1	0.0	0.0	0.0	0.0	0.2	10.0	17.8	0.0

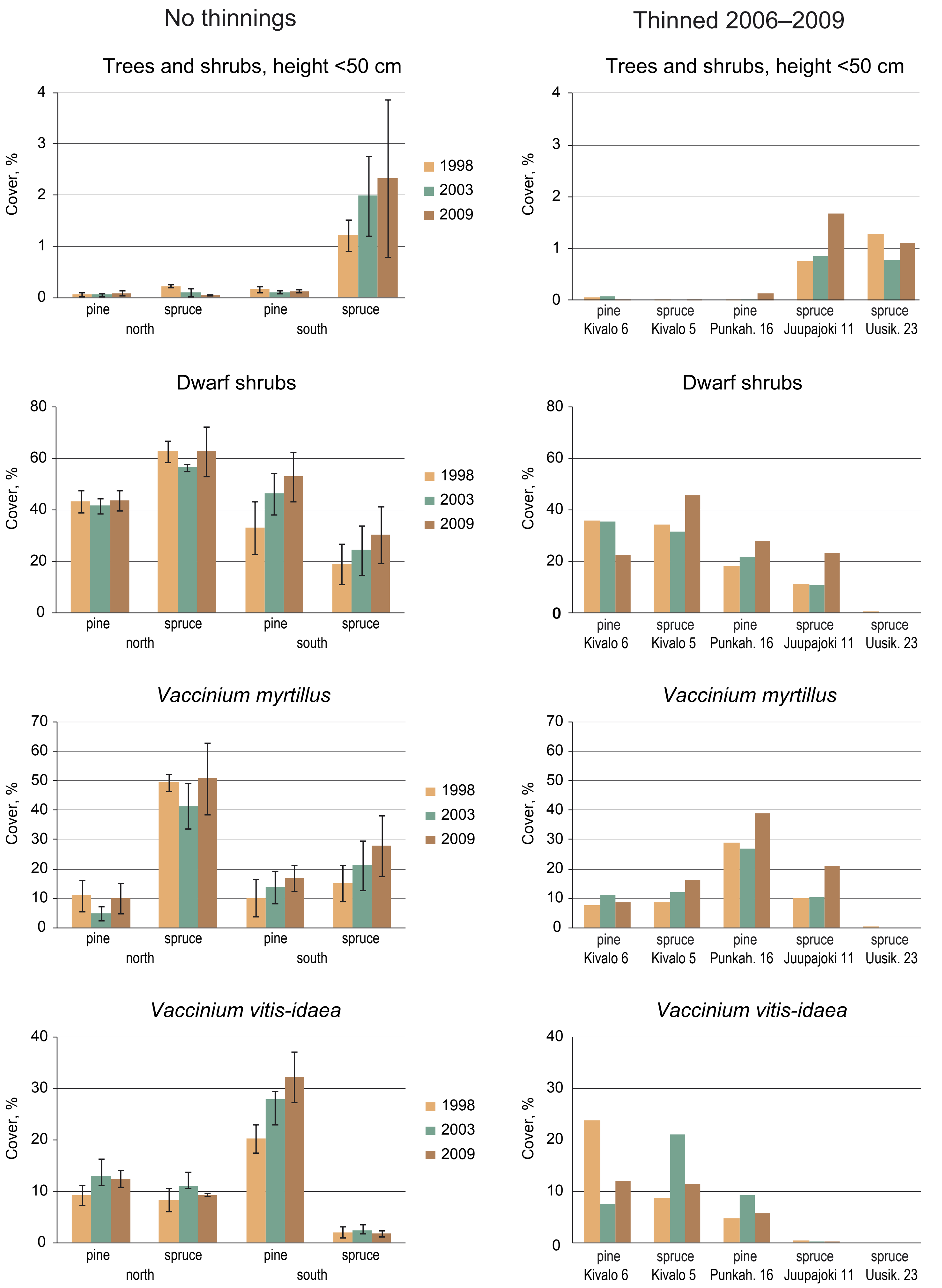

Figure 4a. The change in the mean (± se) cover (%) of wooded plant species on unmanaged and thinned (after the year 2003) Level II plots during 1998–2009 (11 years).

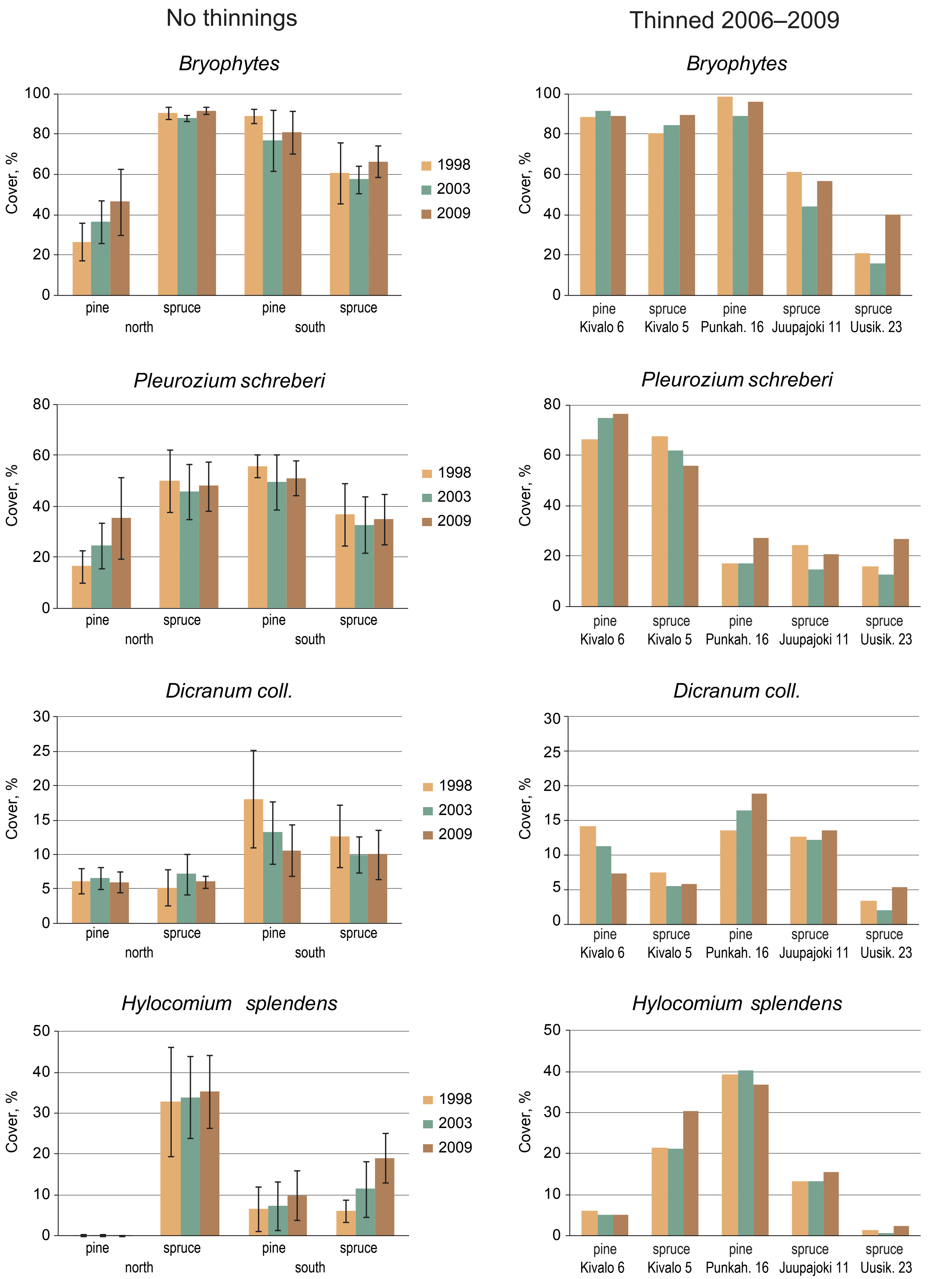

Figure 4b. The change in the mean (± se) cover (%) of bryophytes on unmanaged and thinned (after the year 2003) Level II plots during 1998–2009 (11 years).

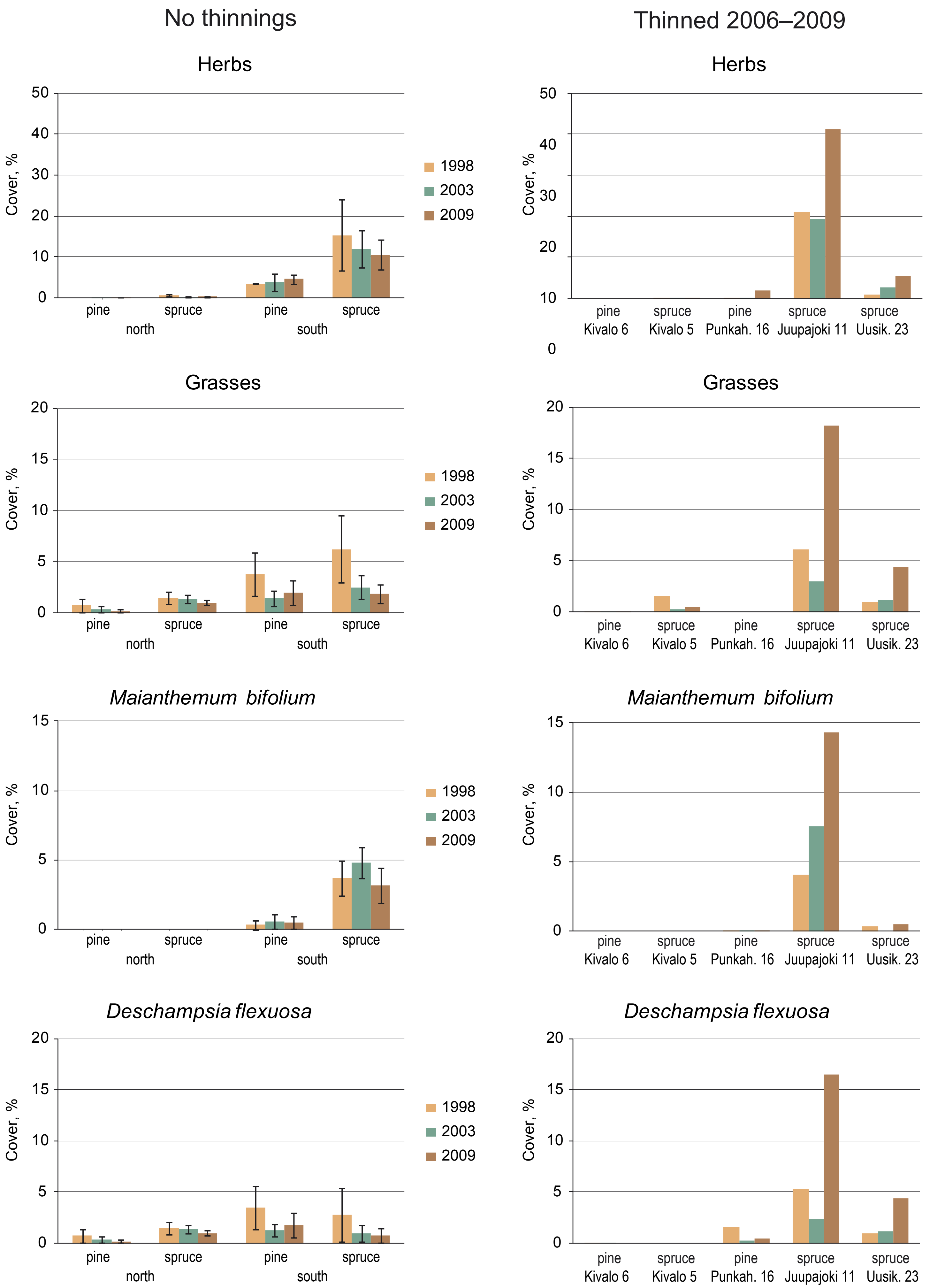

Figure 4c. The change in the mean (± se) cover (%) of herbs and grasses on unmanaged and thinned (after the year 2003) Level II plots during 1998–2009 (11 years).

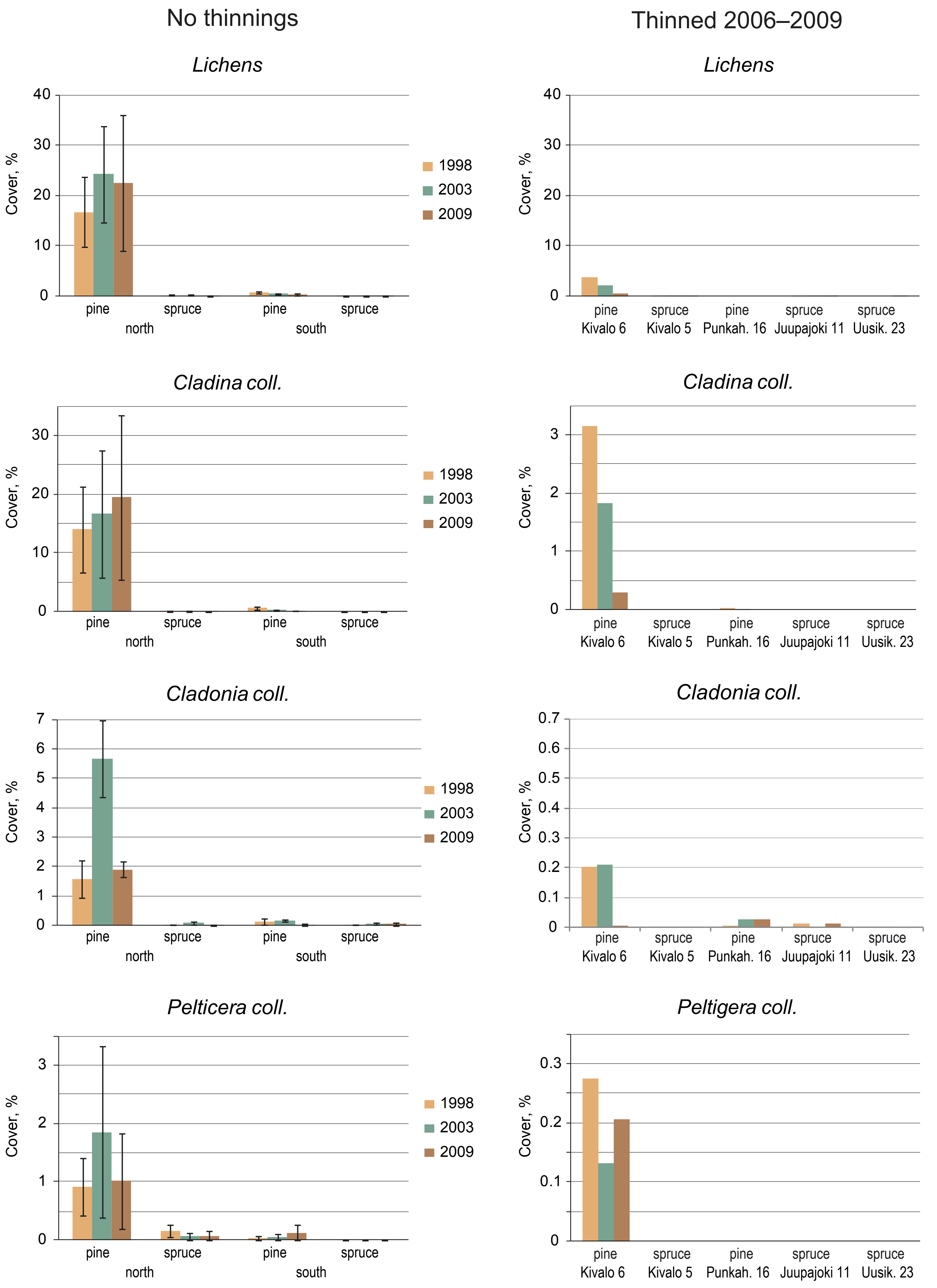

Figure 4d. The change in the mean (± se) cover (%) of lichens on unmanaged and thinned (after the year 2003) Level II plots during 1998–2009 (11 years). Notice that the scale of y-axis on thinned plots is not always the same with the unmanaged plots.