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# Changes of ground vegetation after shelter wood cuttings in pine forests, the hemiboreal zone, Lithuania

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*Abstract*

Sustainable forestry plays an important role in applying forest management measures. In many forests, management is oriented towards closer natural forest processes. Silvicultural systems that retain some part of the trees in the stand, such as shelter wood cuttings have been introduced. The aim of the study was to evaluate the early changes of ground vegetation after shelter wood cuttings in sites of different soil fertility gradient in pine dominated stands on sandy soils in the European hemiboreal zone. The Scots pine stands in which first step of shelter wood cuttings was applied were investigated. The stands were selected in fresh (normal humidity) sites according to soil fertility gradient: very poor, poor and medium fertility soils. All mosses, lichens, herbaceous vegetation and dwarf shrubs were recorded, and projection cover was estimated in June–August. Ellenberg's indicator figures were used to evaluate site conditions. In shelter wood cuttings (5-6-year-old) the number of species was higher in medium fertile sites than in very poor sites. After shelter wood cuttings the abundance of herbaceous species increased in all sites, while the abundance of mosses and lichens decreased. Within the first year after shelter wood cuttings, the abundance of Ericaceae species decreased, and abundance of Rosaceae and Poaceae species increased. Average Ellenberg's indicator values showed that site conditions changed after shelter wood cuttings. The changes were more intensive in medium fertile sites than in poor sites. After shelter wood cuttings the richness and abundance of ground vegetation changed. The intensity of change differed in sites of certain soil fertility and was caused by alteration of site conditions, which were more homogenous in sites of the certain fertility in uncut stands than in cuttings.

**Keywords**: herbs, mosses, non-clear cuttings, vegetation

## Introduction

Since forests provide different ecosystem services, the sustainable forestry plays an important role in applying forest management measures (Kangas and Kangas 2005, Lussier and Meek 2014, Petrokas 2016). In many forests, management is oriented towards closer natural forest processes (Gamborg and Larsen 2003, Brang et al. 2014). In this case mimics of natural disturbances are important measures of sustainable forestry (Haeussler et al. 2002, Rydgren et al. 2004, Wang and Kemball 2005). Natural and anthropogenic disturbances affect microclimate, ground vegetation and soil properties (Keenan and Kimmins 1993, Brazaitis et al. 2005, Marozas et al. 2005, 2009, 2013, Kreutzweiser et al. 2008, Eroğlu et al. 2016).

Canopy removal changes microclimatic conditions during forest harvesting. The light intensity increases, air humidity decreases, air temperature changes, and the risk of extreme temperatures and frosts increases (Heithecker and Halpern 2006, Wagner et al. 2007, Soto et al. 2015).

These conditions change the structure and composition of ground vegetation (Nieppola and Carleton 1991, Pitkänen 1997, Palviainen 2005, Balandier et al 2006, Marozas 2014). Cuttings may increase the cover and diversity of ground vegetation (Burke et al. 2008). The creation of gaps results in increased resources which promote tree seedling growth (Drössler et al. 2015).

There is a growing concern about clear cuttings. Silvicultural systems that retain some part of the trees in the stand such as shelter wood cuttings have been introduced. Shelter wood cuttings cause fewer changes in soil properties (Barg and Edmonds 1999, Siira-Pietikäinen et al. 2001) and ground vegetation than clear-cuttings. Shelter wood cuttings may mitigate the impact of harvesting on composition and structure of forest ecosystem.

Previous research on forest harvesting effects on the ground vegetation has focused on the impacts of clear cuttings (Nieppola 1992, Brakenhielm and Liu 1998, Bergstedt and Milberg 2001, Karazija 2002, 2003). It is little known about shelter wood cuttings impact on ground vegetation in the European hemiboreal zone, therefore, more detail studies are needed.

The aim of this study was to evaluate the early changes of ground vegetation after shelter wood cuttings in pine dominated stands on sandy soils in the European hemiboreal zone. We hypothesized that development of ground vegetation after shelter wood cuttings differs in sites of different soil fertility.

The objectives of the study were: to identify changes of ground vegetation after shelter wood cuttings within the forest soil fertility gradient; to compare intensity of ground vegetation changes in different sites; to evaluate changes in site conditions applying Ellenberg's indicator values.

## Methods

### *Study area*

The Scots pine (*Pinus sylvestris* L.) is the most widely spread tree species in Lithuania. Scots pine occupies the biggest share of Lithuanian forests covering 35.0% of the forest area. Shelter wood cuttings in pine forests have been increasing during the last decade (LME 2016).

The study area covered different parts of Lithuania (Druskininkai, Jonava, Jurbarkas, Kaunas, Šiauliai, Švenčionėliai and Telšiai districts). It falls in the transitional deciduous coniferous mixed forest hemiboreal zone of Europe (Ahti et al. 1968).

The mean annual temperature ranges from +5.7 to +6.7°C, with a mean January (the coldest month) temperature of –5.9 to –4.4°C and a mean July (the warmest month) temperature of 16.1–17.5°C. Annual mean precipitation is between 600 and 850 mm. The period with permanent snow cover continues from 75 to 110 days (Bukantis 1994).

Nutrient-poor sandy soils (*Arenosols)* and Scots pine stands prevail in the study sites. The following species dominate in the ground vegetation cover: dwarf shrubs: *Vaccinium myrtillus*, *V. vitis-idaea*, *Calluna vulgaris*; herbs: *Festuca ovina* and *Melampyrum pratense*; and mosses: *Dicranum polysetum*, *Hylocomium splendens* and *Pleurozium schreberi*.

### *Sampling*

We used the chronosequence approach to describe the early ground vegetation dynamics after shelter wood cuttings by taking pine stands in similar sites according to the soil, topographic conditions and stand characteristics, but in different time periods after cutting (Pickett 1989).

We selected mature Scots pine stands, in which the first step of shelter wood cuttings was applied from 2003 to 2014. Pine stands were selected in fresh (normal humidity) sites according to the soil fertility gradient: very poor soils, poor and medium fertility soils. The pine stands were pure with dominant species of *Pinus sylvestris*. First step of shelter wood cutting was applied in wintertime. Density of the stands after cutting was 30%. Scarification of litter and topsoil layer was done. Uncut pine stands close to shelter wood cuttings on the similar sites were chosen as control.

We located 5–8 plots in each shelter wood cutting (selected according to the dominant sinusia in the cutting) of different age. The following categories of shelter wood cutting's age were used: 1–2, 3–4 and 5–6 years old. 636 plots were in the total. The size of a plot was 100 $m^2$ (10 × 10 m). All mosses, lichens, herbaceous vegetation and dwarf shrubs were recorded, and projection cover was estimated in June–August. Projection cover-abundance was estimated visually using the Braun-Blanquet cover-abundance scale (Braun-Blanquet 1964), and then in subsequent analyses, it was transformed into percentage cover according to recommendations of Otto Wildi (2013). Nomenclature follows Jankeviciene (1998) and Gudžinskas (1999).

### *Data analyses*

The nonparametric Kruskal-Wallis test was used to compare analyzed groups. Ellenberg's indicator values for light, moisture, soil pH and soil nitrogen were used to evaluate site conditions (Ellenberg et al. 1992). Average indicator values for plots were counted as weighted average according to the species abundance.

Relationship of the age of shelter wood cuttings (X), site fertility gradient (Y) and vegetation parameters (Z) were evaluated using contour plots. The contour plots were used to display a contour representing a smoothed image of data following second-order polynomial fitting procedures. A contour plot is a projection of a three-dimensional surface onto a two-dimensional plane. The values of the fitted surface in terms of the variable Z were depicted by shades of colour (areas) on an X-Y scatterplot. STATISTICA 8.0 software package (StatSoft 2007) was employed for statistical calculations according to Hill and Lewicki (2007).

## Results

The average number of species after shelter wood cuttings was the highest in medium fertility sites; it was lower in the poor sites and the lowest in the very poor sites (Figure 1a). In the very poor and poor sites, the average number of species was the highest in 3–4-year-old shelter wood cuttings. In the medium fertility sites the highest number was in 5–6-year-old shelter wood cuttings. The change in species number within 6 years after shelter wood cuttings was the highest in the medium fertility sites; and the lowest in the very poor sites.

The average number of herbaceous and dwarf shrub species after shelter wood cuttings was the highest in the medium fertility sites and the lowest in the very poor sites (Figure 1b). In the very poor and poor sites, the average number of herbaceous and dwarf shrub species was the highest in 3–4-year-old shelter wood cuttings, whereas

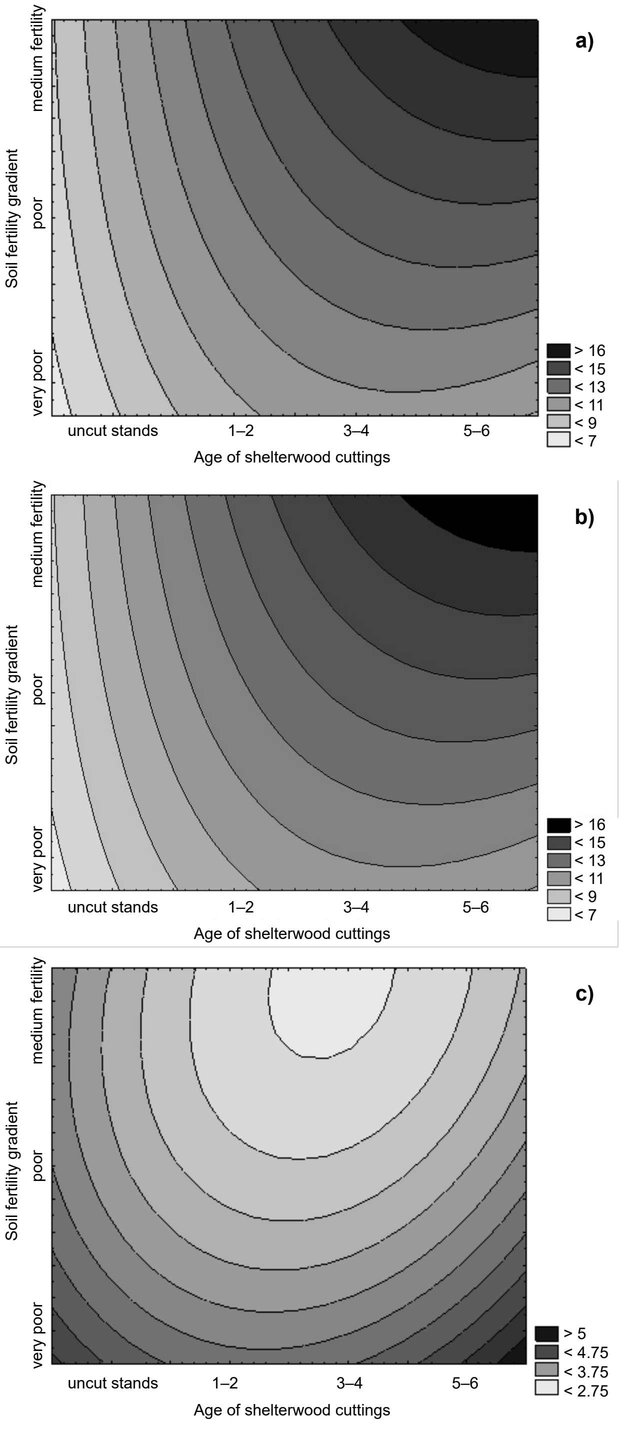


**Figure 1.** Total (a), herbs and dwarf shrubs (b) and mosses and lichens (c) species numbers after shelter wood cuttings

in the medium fertility sites it was the highest in older (5–6-year-old) shelter wood cuttings. The change in the number of herbaceous species within 6 years after shelter wood cuttings was the highest in the medium fertility sites; and the lowest in the very poor sites.

The average number of species of mosses and lichens decreased following shelter wood cuttings in all studied sites (Figure 1c). The lowest number of species of mosses and lichens was in 3–4 years-old shelter wood cuttings. In 5–6-year-old shelter wood cuttings, the number of these species increased in all sites.

There were minimal differences in projection cover of herbaceous and dwarf shrubs in uncut stands of different fertility sites, whereas in shelter wood cutting these differences were higher (Figure 2a). After shelter wood cuttings, the projections cover of herbaceous and dwarf shrubs were highest in medium fertility sites and lowest in very poor sites. In the medium fertility sites the highest projection cover of herbaceous and dwarf shrubs was in 5–6-year-old shelter wood cuttings, whereas in the poor and very poor sites higher projection cover was in 3–6-year-old cuttings.

In uncut stands the average projection cover of mosses and lichens was the lightest and it was decreased due to shelter wood cuttings in all studied sites (Figure 2b). The lowest projection cover of mosses and lichens was in 3–4-year-old shelter wood cuttings. In 5–6-year-old shelter wood cuttings projection cover of mosses and lichens increased in all sites. After shelter wood cuttings the largest decrease of projection covers of mosses and lichens was in the very poor sites.

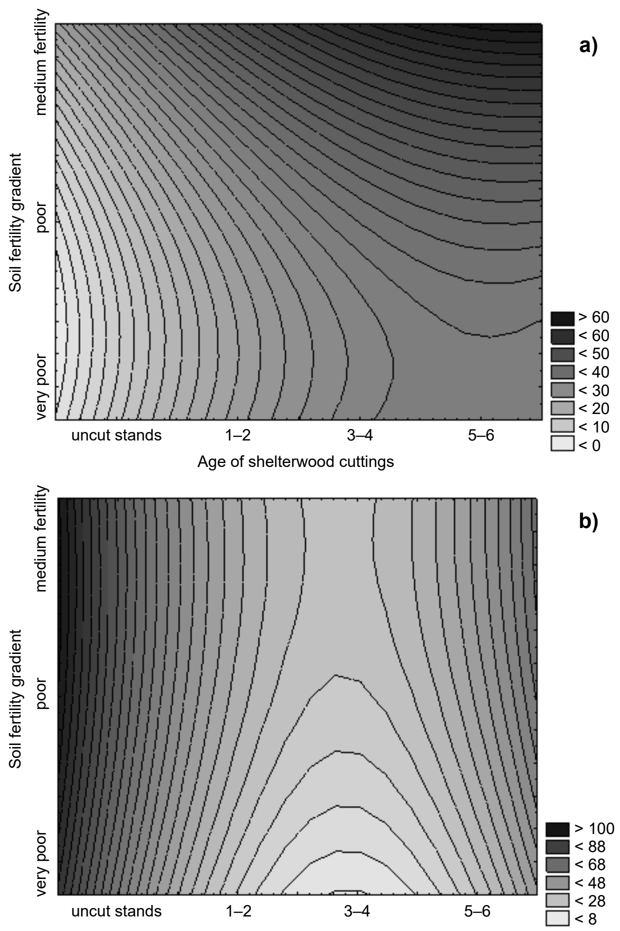


**Figure 2.** Herbs and dwarf shrubs (a) and mosses and lichens (b) projection covers after shelter wood cuttings

The most abundant species of herbs and dwarf shrubs in shelter wood cuttings in all sites were the following: *Vaccinium myrtillus, Vaccinium vitis-idaea, Rubus idaeus, Calamagrostis epigejos, Calluna vulgaris, Calamagrostis arundinacea, Agrostis capillaris*, *Chamerion angustifolium, Melampyrum pratense, Luzula pilosa, Maianthemum bifolium* and *Rumex acetosella* (Table 1).

In the very poor sites in uncut stands the most frequent herbaceous and dwarf species were *Vaccinium myrtillus, Vaccinium vitis-idaea, Melampyrum pratense,* and *Rumex acetosella*. Following shelter wood cuttings, the following species have spread: *Corynephorus cane*scens, *Agrostis capillaris, Calamagrostis epigejos, Calluna vulgaris,* and *Chamerion angustifolium*.

In the poor sites in uncut stands, the most frequent herbaceous and dwarf species were *Vaccinium myrtillus, Vaccinium vitis-idaea, Melampyrum pratense, Calluna vulgaris,* and *Luzula pilosa*. After shelter wood cuttings the following species have spread: *Agrostis capillaris, Calamagrostis epigejos, C. arundinacea, Calluna vulgaris, Chamerion angustifolium,* and *Rubus idaeus.*

In medium fertility sites in uncut stands, the most frequent herbaceous and dwarf species were *Vaccinium myrtillus, Vaccinium vitis-idaea, Rubus idaeus,* and *Maianthemum bifolium*. After shelterwood cuttings the following species have spread: *Calamagrostis epigejos, C. arundinacea, Calluna vulgaris, Chamerion angustifolium,* and *Rubus idaeus.*

The most abundant moss species were *Pleurozium schreberi, Hylocomium splendens,* and *Dicranum polysetum* (Table 2). In all sites, the cover of mosses was the lowest in 1–2-year-old shelter wood cuttings. In the very poor sites, *Dicranum polysetum* was relatively more abundant.

In uncut stands, the Ellenberg's indicator light value was the lowest in the medium fertility sites and the highest in the very poor sites (Figure 3a). After shelter wood cuttings the differences of light value among sites were less

**Table 1.** Herbs and dwarf shrubs projection cover after shelter wood cuttings (mean ± standard error; VP – very poor, P – poor, and MF – medium fertility soil)

| Name of species | Site | Age of shelter wood cuttings | | | |
|---|---|---|---|---|---|
| | | Uncut stands | 1–2 | 3–4 | 5–6 |
| *Agrostis capillaris* | VP | 0.10 ± 0.00 | 3.34 ± 4.67 | 0.10 ± 0.00 | 0.10 ± 0.00 |
| | P | 0.10 ± 0.00[ab] | 1.33 ± 3.54[a] | 2.71 ± 6.38[ab] | 2.21 ± 4.03[ab] |
| | MF | 0.25 ± 0.37 | 0.10 ± 0.00 | 0.26 ± 0.50 | 0.10 ± 0.00 |
| *Calamagrostis arundinacea* | VP | - | 0.10±0.00 | - | - |
| | P | 0.77 ± 0.45[ab] | 3.69 ± 6.81[ab] | 6.21 ± 10.96[b] | 2.73 ± 6.35[a] |
| | MF | 0.10 ± 0.00 | 0.10 ± 0.00 | 0.10 ± 0.00 | 1.78 ± 2.02 |
| *Calamagrostis epigejos* | VP | 1.00 ± 0.00[ab] | 1.02 ± 0.60[ab] | 10.00 ± 0.00[b] | 1.46 ± 2.14[a] |
| | P | 0.10 ± 0.00[a] | 2.33 ± 2.08[a] | 7.73 ± 6.95[b] | 5.26 ± 4.45[ab] |
| | MF | - | 0.10 ± 0.00 | 1.03 ± 0.97 | 3.14 ± 3.21 |
| *Calluna vulgaris* | VP | - | 1.20 ± 0.94 | 6.42 ± 8.15 | 1.00 ± 0.00 |
| | P | 0.75 ± 1.30[a] | 1.76 ± 2.20[a] | 3.79 ± 4.11[b] | 4.27 ± 4.64[c] |
| | MF | 0.10 ± 0.00 | 0.10 ± 0.00 | 1.43 ± 1.51 | 0.65 ± 0.65 |
| *Chamerion angustifolium* | VP | - | 0.10 ± 0.00 | 0.10 ± 0.00 | - |
| | P | - | 0.20 ± 0.30 | 0.58 ± 0.96 | 0.25 ± 0.35 |
| | MF | - | 0.10 ± 0.00 | 1.66 ± 1.36 | 0.40 ± 0.46 |
| *Luzula pilosa* | VP | - | 0.10 ± 0.00 | 0.28 ± 0.40 | 0.55 ± 0.52 |
| | P | 0.33 ± 0.40 | 0.48 ± 0.62 | 0.76 ± 1.06 | 0.62 ± 0.98 |
| | MF | 0.10 ± 0.00 | 0.49 ± 0.86 | - | 0.42 ± 0.45 |
| *Maianthemum bifolium* | VP | - | - | 0.10 ± 0.00 | - |
| | P | 0.10 ± 0.00 | 0.80 ± 0.91 | 0.35 ± 0.42 | 0.55 ± 0.52 |
| | MF | 0.25 ± 0.37 | 0.70 ± 0.46 | - | 0.15 ± 0.21 |
| *Melampyrum pratense* | VP | 0.10 ± 0.00 | 0.33 ± 0.45 | 1.30 ± 1.85 | 1.49 ± 2.03 |
| | P | 1.47 ± 4.05 | 0.93 ± 1.79 | 0.88 ± 1.29 | 1.09 ± 2.58 |
| | MF | 0.10 ± 0.00 | 0.10 ± 0.00 | - | 0.10 ± 0.00 |
| *Rubus idaeus* | VP | - | 0.10 ± 0.00 | 0.10 ± 0.00 | - |
| | P | 0.15 ± 0.24[a] | 4.60 ± 7.35[ab] | 11.26 ± 10.50[b] | 11.68 ± 10.32[b] |
| | MF | 0.10 ± 0.00 | 7.09 ± 8.39 | 26.35 ± 12.66 | 19.84 ± 19.81 |
| *Rumex acetosella* | VP | 0.10 ± 0.00 | 0.60 ± 0.79 | 0.55 ± 0.52 | 0.51 ± 0.47 |
| | P | 0.10 ± 0.00 | 0.64 ± 0.93 | 0.67 ± 1.11 | 0.65 ± 0.92 |
| | MF | - | 0.10 ± 0.00 | 0.10 ± 0.00 | 0.10 ± 0.00 |
| *Vaccinium myrtillus* | VP | 1.33 ± 2.45 | 0.39 ± 0.63 | 5.00 ± 0.00 | - |
| | P | 10.49 ± 9.04[a] | 8.57 ± 7.39[a] | 14.22 ± 9.22[b] | 9.96 ± 10.82[a] |
| | MF | 30.8 ± 15.78[c] | 20.00 ± 15.65[bc] | 6.39 ± 3.29[a] | 11.52 ± 10.38[ab] |
| *Vaccinium vitis-idaea* | VP | 2.00 ± 2.00[ab] | 2.48 ± 3.94[a] | 8.13 ± 9.47[ab] | 13.00 ± 5.29[b] |
| | P | 4.74 ± 6.75[a] | 7.38 ± 8.43[a] | 6.62 ± 5.90[a] | 8.41 ± 9.12[a] |
| | MF | 2.78 ± 2.60 | 0.37 ± 0.69 | - | 11.89 ± 10.72 |

* superscripts *a*, *b* and *c* indicate significant differences of species between sites, $p < 0.05$, the Kruskal-Wallis test.

**Table 2.** Mosses projection cover after shelter wood cuttings (mean ± standard error; VP – very poor, P – poor, and MF – medium fertility soil)

| Name of species | Site | Age of shelter wood cuttings | | | |
|---|---|---|---|---|---|
| | | Uncut stands | 1–2 | 3–4 | 5–6 |
| *Dicranum polysetum* | VP | 7.69 ± 8.31 | 3.51 ± 0.00 | 8.89 ± 8.67 | 5.16 ± 10.14 |
| | P | 3.09 ± 3.57$^{ab}$ | 2.55 ± 4.17$^{a}$ | 4.21 ± 7.18$^{ab}$ | 6.78 ± 8.43$^{b}$ |
| | MF | 0.10 ± 0.00 | 0.10 ± 0.00 | 2.97 ± 3.30 | 5.05 ± 5.72 |
| *Hylocomium splendens* | VP | - | 2.03 ± 1.67 | 1.07 ± 1.67 | 0.10 ± 0.00 |
| | P | 32.08 ± 22.84$^{c}$ | 13.59 ± 10.90$^{b}$ | 7.31 ± 5.99$^{a}$ | 11.44 ± 9.35$^{b}$ |
| | MF | 20.52 ± 16.38 | 15.74 ± 10.32 | 16.67 ± 5.16 | 26.50 ± 11.07 |
| *Pleurozium schreberi* | VP | 47.40 ± 12.55$^{b}$ | 11.01 ± 15.07$^{a}$ | 6.45 ± 5.72$^{a}$ | 5.14 ± 3.46$^{a}$ |
| | P | 37.90 ± 23.02$^{c}$ | 17.88 ± 13.78$^{a}$ | 14.79 ± 11.79$^{a}$ | 23.38 ± 15.26$^{b}$ |
| | MF | 39.00 ± 5.01$^{b}$ | 17.50 ± 7.61$^{ab}$ | 10.59 ± 4.45$^{a}$ | 12.25 ± 8.73$^{a}$ |

* superscripts *a*, *b* and *c* indicate significant differences of species between sites, $p < 0.05$, the Kruskal-Wallis test.

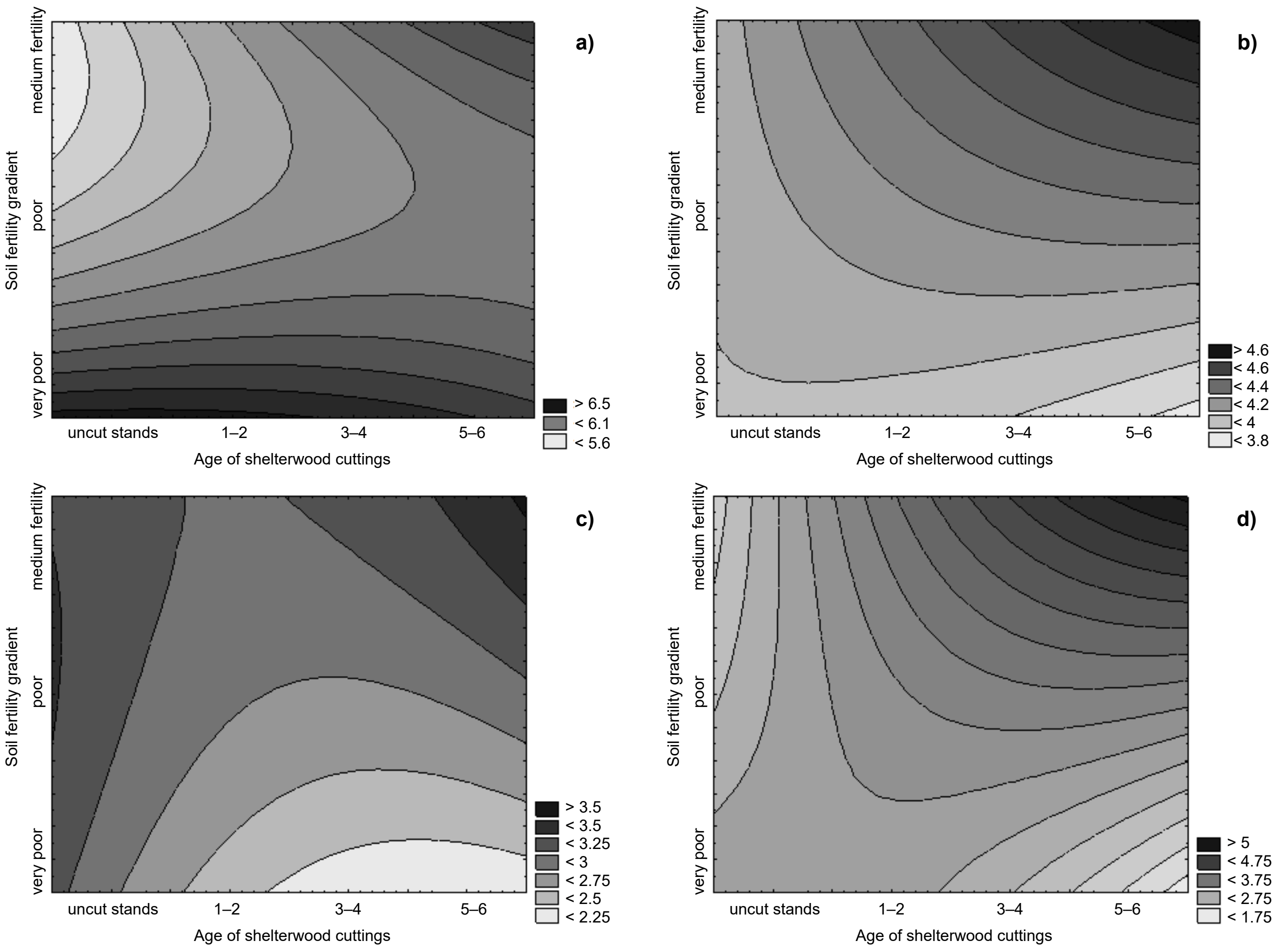


**Figure 3.** The average Ellenberg's indicator value: light (a), moisture (b), soil pH (c) and soil nitrogen (d) after shelter wood cuttings

remarkable, the difference being the lowest in 5–6-year-old cuttings. After shelter wood cuttings the light value increased in the poor and medium fertility sites, while it was slightly decreased in the very poor ones.

The soil moisture, pH and nitrogen value differed slightly in uncut stands (Figure 3b, c, d). After shelter wood cuttings these values increased in the poor and medium fertility sites, whereas they were the same or only slightly lower in the very poor sites. Larger differences in values were observed in oldest cuttings (5–6-year-old) with the highest values in the medium fertility sites and the lowest values in very poor sites.

## Discussion

In uncut stands, the total number of species and projection cover were similar in the sites of different fertility. In the oldest shelter wood cuttings (5–6-year-old) the number of herbaceous species in the medium fertile sites was higher than in the very poor sites. In the very poor sites, the number of herbaceous species only slightly increased. The projection cover of herbaceous species increased in all sites after cuttings.

Opposite to herbaceous species, after shelter wood cuttings the number of moss species was higher in the very poor sites. This could be probably explained by the spread of pioneer species such as *Polythricum* sp., *Ceratodon purpureus* and *Funaria hygrometrica*. The abundance of herbaceous species caused the lower number of mosses in the medium fertile sites.

Within the first year after shelter wood cuttings, the abundance of Ericaceae species (*Vaccinium myrtillus, Vaccinium vitis-idaea* and *Calluna vulgaris)* decreased, but later it increased. In contrast, the abundance of Rosaceae (*Rubus idaeus, Rubus caesius, Fragaria vesca* and *Geum urbanum*) and Poaceae (*Agrostis capillaris*, *Calamagrostis epigejos* and *Calamagrostis arundinacea*) species increased after cuttings.

Other studies in clear cuttings showed similar changes (Bergsted and Milberg 2001, Jalonen and Vanha-Majamaa 2001, Bock and Van Rees 2002, Karazija 2002, 2003, Fenton et al. 2003). The abundance of Ericaceae species and mosses decreased after cuttings while abundance of pioneer light demanding mostly Poaceae species and weeds increased. In clear cuttings changes of ground vegetation were more intensive compare to other types of cuttings (Bergstedt and Milberg 2001, Jalonen and Vanha-Majamaa 2001, Bergstedt et al. 2008).

In the study of plant communities in Canada, Haeussler et al. (2002) demonstrated that species richness was 30–35% higher 5–8 years after logging compared to the uncut forest. Similar results were found in Finland by Pykälä (2004), who concluded that the number of species was almost double in clear cuts compared to mature uncut forests.

Site conditions (light penetration, soil moisture, pH and fertility) are important for ground species development after clear and shelter wood cuttings (Honnay et al. 1999, Berger et al. 2004, Pykälä 2004). The most intensive changes were observed in moist, more fertile sites (Nilsson and Örlander 1999).

Many studies emphasized the effect of greater light availability on herb layer diversity (Hardtle et al. 2003, Hart and Chen 2008, Hofmeister et al. 2009, Tinya et al. 2009). However, others found no effect (Augusto et al. 2003, Leniere and Houle 2006). A higher light availability allows the presence of light demanding plant species, which could occur in forests ecosystems only sporadically.

Our analysis of average Ellenberg's indicator values for sites showed that site conditions have changed after shelter wood cuttings. The changes were more intensive in the medium fertile sites than in the poor sites. The soil conditions were more homogenous in the sites of different fertility in uncut stands than in cuttings. The change of site conditions was also reported in other studies (Lieffers et al. 1999, Pritchard and Comeau 2004, Balandier et al. 2006).

## Conclusions

Ground vegetation after shelter wood cuttings in pine dominated stands on sandy soils have changed in species richness and abundance.

In shelter wood cuttings (5–6-year-old), the number of species was higher in the medium fertile sites than in the very poor sites. After shelter wood cuttings the abundance of herbaceous species increased in all sites, while the abundance of mosses and lichens decreased.

Within the first year after shelter wood cuttings, the abundance of Ericaceae species decreased, and abundance of Rosaceae and Poaceae species increased. The average Ellenberg's indicator values showed that site conditions changed after shelter wood cuttings. The changes were more intensive in the medium fertile sites than in the poor sites.

The intensity of change differed in the sites of certain soil fertility and was caused by alteration of site conditions, which were more homogenous in the sites of certain fertility in uncut stands than in cuttings.

The results show increased competition from herbs to pine regeneration after shelter wood cutting, especially in the more fertile sites. We recommend for forest managers to take support measures for pine seedlings regeneration. More research is needed to evaluate natural regeneration after shelter wood cuttings in pine dominated forest in the hemiboreal zone.

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