VEGETATION COVER 47 YEARS AFTER WIND STORM AND CLEARCUT IN WESTERN LATVIA

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Abstract
Wind is an important natural disturbance factor in a forest ecosystem. It creates gaps in a forest canopy, providing microenvironmental conditions, suitable for forest regeneration and affects the species composition of ground vegetation. Most of the studies analysing consequences of wind-storm have addressed short-term changes or influence the stand structure, but the aim of our study is to analyse ground-vegetation long time after windstorm in hemiboral forests. Data on ground vegetation cover have been collected in areas affected by the storm of 1967, where due to salvage-logging 200-400 m wide clearcuts were created. Sample plots (1×1 m) were placed in different distance from the edge of former clearcuts and projective cover of ground vegetation assessed using Braun-Blanquet method in *Myrtillosa mel.* forest type on 5 sites in north-western part of Latvia. Results reveal that in all sites species belonging to boreal, boreal-temperate and temperate biome were present, but their proportions varied between sites. In total 82 species of vascular plants were found, most frequent among them *Maianthemum bifolium* (L.) F.W.Schmidt (species characteristic to Norway spruce forests), *Vaccinium myrtillus* L. and *Vaccinium vitis-idaea* L. (associated with Scots pine forests) as well as *Molinia caerulea* (L.) Moench and *Deschampsia caespitosa* (L.) P.Beauv. (both characteristic to wet soils). Results suggest, that even 47 years after the storm microenvironmental conditions in the sites are not stable. Ellenberg's indicator values reveal, that most of the sites are in semi-shade, cool and moist conditions, placed on acidic, nitrogen-poor (in few sites – also nitrogen rich) soils.
Key words: ground-vegetation, windthrow, natural disturbance, paludification, natural succession.

Introduction

Disturbances are characteristic to forest ecosystem. Natural disturbance can be caused by fire, water (flood), insects, pathogens, mammals, and wind (Kuuluvainen, 2002). Wind throw is an important natural disturbance factor in hemiboreal forests (Gromtsev, 2002). It is important, natural phenomena in the forest (Pickett and White, 1985; Kuuluvainen, 1994). Amplitude of wind disturbance ranges from minor, affecting (breaking or uprooting) only few trees in a particular stand to major, affecting notable forest areas at a landscape scale (Pickett and White, 1985; Kuuluvainen, 1994). Stands of coniferous trees are affected by wind, if its speed exceeds 20-25 m s^{-1}. Windthrows create a mosaic of forest structure, increasing a diversity of ground vegetation species and creating an uneven age forest stands (Gromtsev, 2002). As a result of wind damages on trees, gaps of different sizes are created in crown cover of the stand that, in turn, changes the light conditions on forest floor, moisture regime and other microclimatic conditions, affecting both natural regeneration and ground-vegetation. Effect of large scale (stand-replacing) windthrows can be comparable to that of clearcut, since in both cases forest stand, that ensured the specific conditions (minimized the temperature fluctuations and therefore risks of frost damages to ground vegetation and advanced regeneration, provided a shade, ensured a water uptake and transpiration) does not exist anymore. Especially significant is the impact on water balance, since transpiration of trees reduces excess moisture in wet (patches of) forest (Zālītis, 2012).

Increase of maximum wind-speed in storms and/or frequency of storms are predicted due to climatic changes (Beniston et al., 2007); consequently, more wind damages can be expected in forests. Most of the studies dealing with influence of windthrows focus on tree cover (stability, financial losses, regeneration) or short-term effects, however, it is important to understand a long-term consequences of this event to different components of forest ecosystem, including ground vegetation. Few studies have indicated an increase of species diversity in ground-vegetation few years after the storm as a result of changes in micro-relief (creation of pit-and-mound mosaic) (Ulanova, 2000). Some studies suggest that ground vegetation will stabilize 80-100 years after the storm and microrelief structures will completely disappear after 300-500 years (Skvortsova et al., 1983). Analysis of vegetation in gaps created wind in forest canopy in boreal forests in Russia reveals no significant changes in ground vegetation, if the size of the opening is smaller than the mean height of the neighbouring trees (Ulanova, 2000), but a storm affecting large forest might have a different impact. Therefore, the aim of our study was to characterise ground-vegetation long time after stand-replacing windstorm in hemiboral forests, the western part of Latvia.

Materials and Methods

Data collection was carried out in the summer of 2014 in the north-western part of Latvia in five areas (close to Pope and Pāce) affected by the storm of 1967, where due to salvage-logging 200-400 m wide clearcuts were created in drained mineral soils (forest type: *Myrtillosa mel.*). Currently the young stands are dominated by Norway spruce *Picea abies* (L.) H. Karst. and silver birch *Betula pendula* Roth (together 85-90% from total number of trees) with admixture of Scots pine *Pinus sylvestris* L. and trembling aspen *Populus tremula* L. Transects were drawn perpendicular to the edge of the former clearcut. Sample plots (size 1x1m) were placed systematically (every 30 m) on those transects: 3 m on each side of the transect in each of the points. Altogether 69 sample plots were measured (from 8 to 31 in each study area). Data collection of ground vegetation was carried out using Braun-Blanquet method (Braun-Blanquet, 1964). Projective cover of each ground vegetation species (%) was assessed as well as total projective cover of layer herbaceous plants and shrubs (E1) and layer mosses and lichens (E0) with the precision of 1%. In case some species are detected, but projective cover does not reach 1%, it is stated as 0.1%.

Information from databases BioPop, Ecological Flora Database, Bioflora on functional types of plants, types of seed dispersal, plant strategies (c – competitors, s – stress-tolerators, r – ruderals), Raunkier *life forms* and Ellenberg's indicator values (Ellenberg et al., 1992) were assessed and compared between study areas. Occurrence of plants was characterized by their constancy, calculated as a proportion of sample plots, where the plant is present from the total number of sample plots. Based on frequency of occurrence constancy a class was assigned to each species (I – occurence < 21%, II – 21-40%, III – 41-60%, IV – 61-80%, V – 81-100%) (Markovs, 1965, Muller – Dombois, Ellenberg, 1974). Significance of differences was calculated using ANOVA.

Results and Discussion

In total, 45 plant species were found in *site Pope-I*, the number of species per sample plot ranged from 7 to 22 and was 14 on average. Most frequently occurring species (constancy class IV) were *Maianthemum bifolium* (L.) F.W.Schmidt (characteristic to Norway spruce forests), *Melampyrum pratense* L. and *Potentilla erecta* (L.) Raeusch. (characteristic to wet forests). Frequently occurring species (constancy class III) were *Deschampsia caespitosa* (L.) P.Beauv., *Filipendula ulmaria* (L.) Maxim., *Lysimachia vulgaris* L. (characteristic to black alder swamp forests), indicating wet conditions on the site, as well as *Viola riviniana* Rchb. (characteristic to dry sites). The rest of the species were rare (14 species had constancy class I and 11 species constancy class II). Boreo-temperate species dominated on the site (60%), boreal species and temperate species were represented similarly (21.8% and 18.1%, respectively). Dispersal of seeds or spores was determined primarily by wind (29% the ground-vegetation species), to some extent by water, ants and birds (17.5, 16.3 and 8%, respectively), but notable proportion of species (22.7%) had self-dispersal strategy. Majority of species were hemicryptophytes (78.1%) with over-wintering buds close to surface of the ground (herbaceous plants), but chamaephytes (mostly dwarf shrubs with over-wintering buds in snow-cover), geophytes (with over-wintering buds under the ground) and helophytes (plants characteristic to wet soils) were represented similarly (7.1%, 7.3% and 6.6%, respectively). Therophytes (plants overwintering in a form of seeds or spores) were less than 1% form total number of species. Changing conditions in the site was indicated by plant strategies: most frequent were plants with mixed strategies (67.1%) followed by competitors (23.8%), characterized by ability to colonize the areas and well developed root system (Grime, 1979). Ellenberg's indicator values showed that semi-shade, cool and moist conditions dominated in the site, soil was moderately acidic, poor to moderately rich in nitrogen.

In total, 39 plant species were found in *site Pope-II*, the number of species per sample plot ranged from 4 to 14 and was 8 on average. Most frequently occurring species (constancy class IV) was *Deschampsia caespitosa*, but frequently occurring species characteristic to Scots pine forests was *Vaccinium myrtillus* L. (constancy class III). Other species occurred infrequently (28 species had constancy class I). Most represented in the site were temperate species (45.3%), slightly less represented: boreo-temperate species (34%) and boreal species (20.5%). Dispersal of seeds or spores was predominantly done by ants (32.4% species), to lesser extent by birds, wind, water (20.5%, 19.8% and 11.8%, respectively) and also plants with self-dispersal were present (12.7%). Most of the species were hemicryptophytes (32.9%) or therophytes (28%), but chamaephytes and helophytes were less common (16.7% and 14.2%, respectively). Least represented plant group was geophytes (7.6%). Also changing environmental conditions were found on this site: most plants had mixed strategies (80.3%) followed by competitors (10.4%) and stress-tolerators (8.7%). Ellenberg's indicator values showed that semi-shade, cool and moist conditions dominated onn the site, soil was moderately acidic, poor in nitrogen.

Notably lower number of species was found in *site Pope-III*: in total only 16; the number of species per sample plot ranged from 2 to 6 and was 4 on average. Most frequently occurring species (constancy class V) was *Molinia caerulea* (L.) Moench, characteristic to coniferous and mixed forests with high soil humidity and grass swamps; also *Vaccinium myrtillus* and *Vaccinium vitis-idaea* L. characteristic to Scots pine forests as well as *Deschampsia caespitosa* were frequent (constancy class IV). *Melampyrum pratense* had constancy class III, but other 12 species - constancy class I. Temperate plant species dominated the site (46.8%), followed by boreal species (44.2%); boreo-temperate species were notably less common (8.9%). Most of the pants, similar to other sites, had seeds or spores dispersed by ants (46.6%), other dispersal factors were birds (32.1%), wind (11.9%) and water (8.3%); plants with self-dispersal were less common (<1%). Different from other sites, most of species were chamaephytes (39.9%) and therophytes (33.6%), but hemicryptophytes and helophytes were much less common (19.4 and 6.3% respectively). Plants with mixed strategies dominated in this site (85.3%). Ellenberg's indicator values showed that semi-shade, cold and moist conditions dominated on the site, soil was acidic, poor in nitrogen.

In total, 37 species were found on *site Pope-IV*, the number of species per sample plot ranged from 3 to 14 and was 10 on average. Most frequently occurring species (constancy class IV) was *Maianthemum bifolium* (characteristic to Norway spruce forests). *Vaccinium vitis-idaea* L., characteristic to Scots pine forests, was frequently present (constancy class III), but the rest of the species were not (22 ground-vegetation species had constancy class I). Temperate plant species dominated the site (48.4%), followed by boreal species (33.2%); boreo-temperate species were notably less common (18.4%). Most of the plants, similar to other sites, had seeds or spores dispersed by ants (34.6%), other dispersal factors were water (20.3%) and wind (17.4%). Self-dispersal was relatively common (16.5%); smaller proportion of species were dispersed by birds (11%). Most of the plant species were hemicryptophytes (54.8%), fewer – therophytes (20.1%) and helophytes (14.6%), but very few – chamaephytes and geophytes (6.5% and 3.7%, respectively). Most of the plants belonged to the group with mixed strategies (82%) or competitors (17.1%). Ellenberg's indicator values showed that semi-shade - semi-light, cool and moist conditions dominated in the site, soil was moderately acidic to acidic, poor in nitrogen.

The highest number of species was found on *site Priedaine* – in total 43, but the number of species per sample plot ranged from 1 to 11 – not higher than on other sites. Most frequently occurring species (constancy class III) were *Maianthemum bifolium* (characteristic to Norway spruce forests) and *Vaccinium vitis-idaea* L. (characteristic to Scots pine forests). The rest of the species were present relatively un-frequently (33 ground-vegetation species had constancy class I). On this site almost half of all species (45.8%) were boreal, 38.0% were temperate and only 16.2% boreo-temperate. Seeds or spores were dispersed to a similar extent by wind, ants and birds (25.2%, 24.1% and 23.2%, respectively). Also, water and self-dispersal played an important role (15.4% and 11.7%, respectively). Most of species were chamaephytes (35.7%) and hemicryptophytes (28.0%), followed by therophytes (21.1%) and helophytes (14.0%). Plants with mixed strategies were more than half on this site (64.8%), followed by

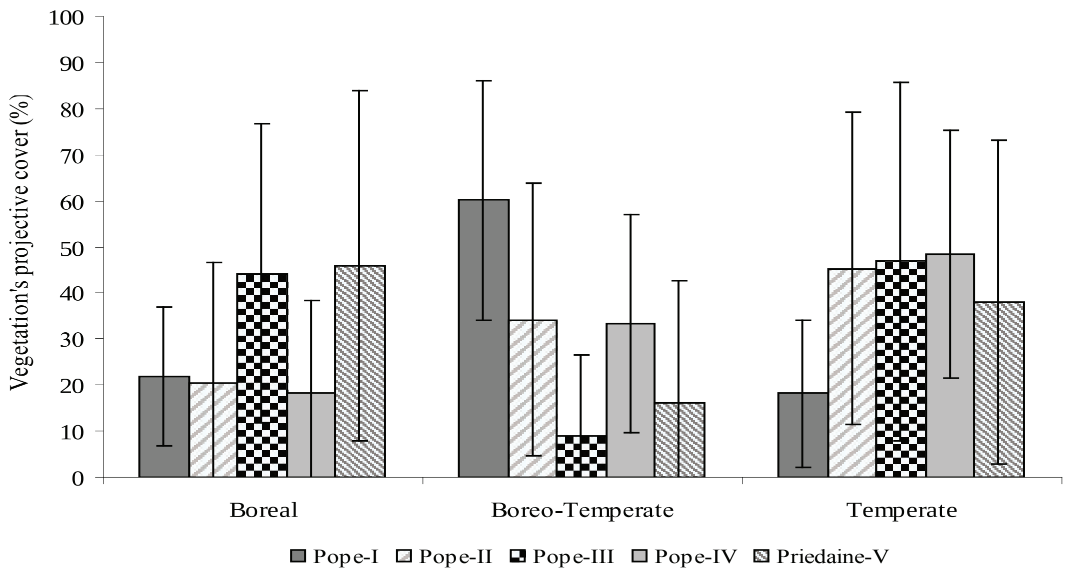

Figure1. The proportion (%) of plant species for biomes in objects (±SD).

competitors and stress-tolerators (18.5% and 15.3%, respectively). Ellenberg's indicator values showed that semi-shade, cold and moist conditions dominated on the site, soil was acidic, poor in nitrogen.

The proportion of temperate biome species on the sites were similar (from 38 to 48%), only on *site Pope-I* it was significantly smaller (18%). From 20 to 46% from herbaceous plant layer species belonged to boreal biome, on *site Priedaine* this proportion was significantly ($p<0.05$) higher than on *sites Pope-I*, *Pope-II* un *Pope-IV* (Fig. 1); also proportion of these groups of species on *site Pope-III* was relatively high, but differences with other sites were not statistically significant. Proportion of species belonging to boreo-temperate group differed notably between sites and on *site Pope-I* it was significantly ($p<0.05$) higher than on others.

Dispersal strategies of plants were rather different between sites. From 16 to 47% of plants had seeds or spores dispersed by ants, significant differences in proportion of this group of plants ($p<0.05$) was found between sites *Pope-I* and *Pope-III*. On *site Pope-III* proportion of plants with self-dispersal strategy was significantly ($p<0.05$) smaller than on the rest of the sites. Plants with other seed dispersal strategies (by birds, water, wind etc.) were represented differently in different sites; however, observed differences were not statistically significant.

The proportion of chamaephytes ranged from 7 to 40% on different sites; it was significantly higher on sites *Pope-III* and *Priedaine* thanon the rest of the sites. Geophytes and helophytes were the least represented groups and there were no significant differences between sites in the proportion of these groups of plants. The presence of helophytes indicates the existence of different microrelief forms on all sites and occurrence of wet patches. The proportion of hemicryptophytes ranged from 19 to 78% from all plants in ground vegetation,o site *Pope-I* they were significantly ($p<0.05$) more than on sites *Pope-II*, *Pope-III* and *Priedaine*. Therophytes were represented similarly in all sites (20-36%) except in *Pope-I*, where proportion of this group of plants were significantly ($p<0.05$) smaller. It indicated presence of open ground, where this group of plants can be regenerated by seeds.

Plants with mixed strategy were the most represented group on all sites and significant ($p<0.05$) differences in their presence were found only between sites *Pope-I* and *Priedaine* (Fig. 2). On *Pope-I* higher proportion of mixed-csr strategy plants were detected, but in *Priedaine* – higher proportion of mixed-cs strategy plants. Presence of these groups of plants indicates unstable microevironmental conditions. Proportion of plants with competitor strategy ranged from 6 to 24%, on site *Pope-I* it was significantly higher than on sites *Pope-II* and *Pope-III*. Stress-tolerators had minor representation on all sites (differences between sites were not significant). Ruderals were the least represented group, indicating, that early succession phase (characterised by high representation of weeds) has been replaced by the next phase, dominated by perennial herbaceous plants.

Diversity of microenvironmental conditions on the sites was defined also by high number of plant species, that presumably will be replaced with fewer, more stress-tolerant plants in later phases of succession. Light conditions, described by Ellenberg's indicator values, demonstrated, that *site Priedaine* was significantly ($p<0.05$) more shady than sites *Pope-I* and *Pope-II*. Significant differences in this trait between the rest of the sites were not found

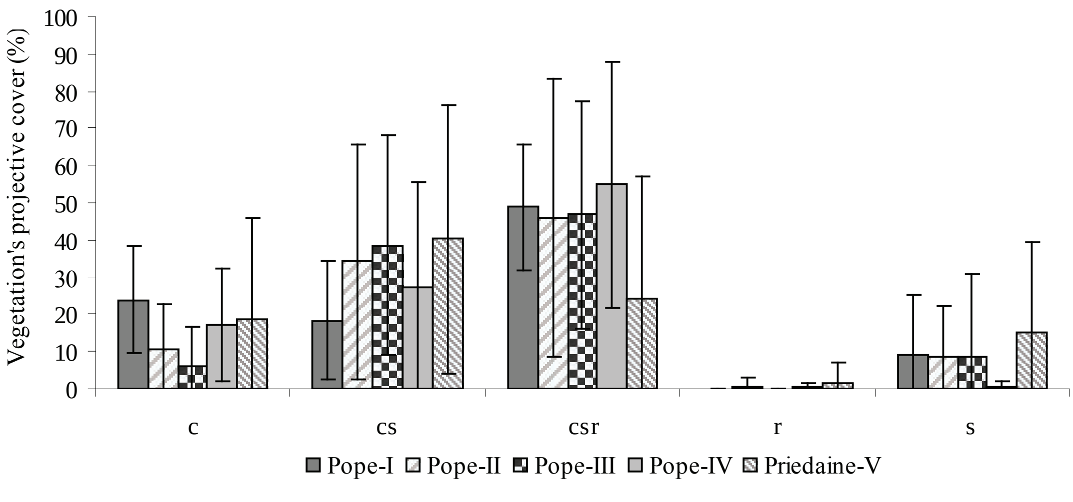

Figure 2. The proportion (%) of plant species for plant strategies in objects (±SD): c – competitors, s – stress-tolerators, r – ruderals, cs and csr – mixed strategies.

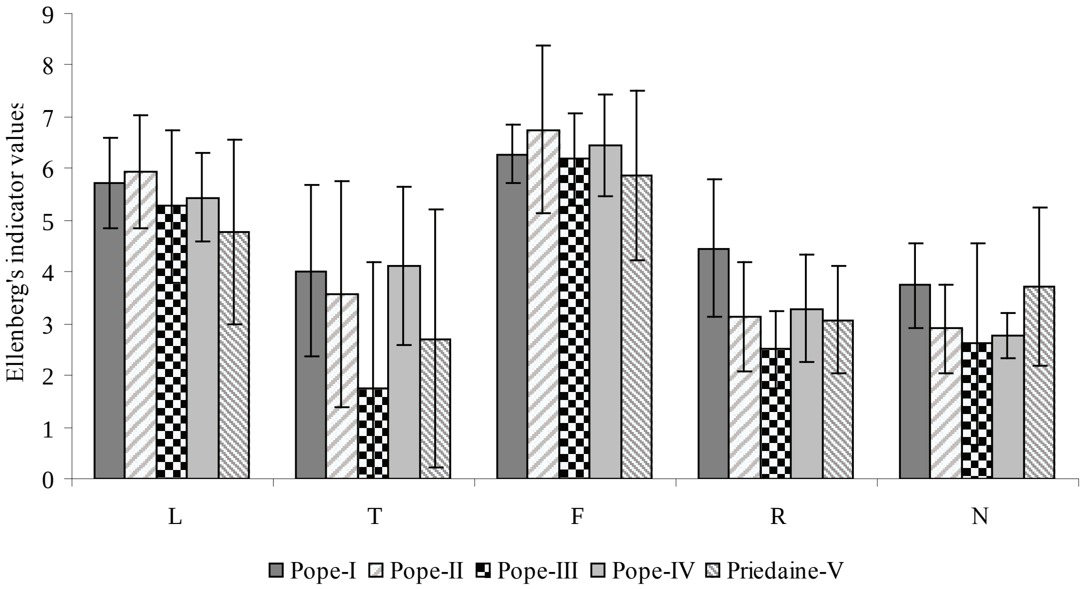

Figure 3. Ellenberg's indicator values of plant species in objects (±SD):
L – light, T –temperature, F – moisture, R – soil reaction, N – the amount of nitrogen in soil.

(Fig. 3). On sites *Pope-I* and *Pope-IV* microenvironment was significantly warmer than on sites Pope-III and Priedaine as indicated by Ellenberg's values, but no significant differences in soil moisture between sites were found. Soils on sites *Pope-I* and *Priedaine* have more nitrogen and on *Pope-I* is significantly less acidic than on the rest of the sites.

Conclusions

1. In all study areas temperate biome species are represented to a similar extent, less common are boreal biome species, but occurrence of species of boreal-temperate biome differ between sites.
2. Most frequent among them *Maianthemum bifolium* (L.) F.W.Schmidt (species characteristic to Norway spruce forests), *Vaccinium myrtillus* L. and *Vaccinium vitis-idaea* L. (associated with Scots pine forests) as well as *Molinia caerulea* (L.) Moench and *Deschampsia caespitosa* (L.) P.Beauv. (both characteristic to wet soils).
3. Most frequent dispersal agents of plants in the study area are wind, ants and birds, but also plants with self-dispersal strategy are common.
4. Plants with mixed strategy are the most common group in the areas 47 years after the windthrow, indicating unstable (changing) environmental conditions.
5. Ellenberg's indicator values reveal that most of the sites are in semi-shade, cool and moist conditions, placed on acidic, nitrogen-poor (in few sites – also nitrogen rich) soils.

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