Changes in the condition of ground vegetation exposed by technogenic emissions from nitrogen fertilizer plant under reduced pollution

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Introduction

The importance of research on the components of forest ecosystems has grown in the early eighties of the last century with the appearance of one of the most important environmental problems of the era – massive forest dieback, which also spread in Lithuania. The main reason for this negative development was environmental pollution by acidifying pollutants (Kandler, 1992; Landmann, Bonneaun, 1995; Santamaria, Martin, 1998; Augustaitis, 2003; Dobbertin, 2005; Augustin et al., 2005; Lorenz, Mues, 2007; Sheng et al., 2012). Some of these chemicals are acidifying sulfur (S) and nitrogen (N) oxides, and their oxidation products, which due to their chemical characteristics and prevalence in nature are considered as the main factors governing the acidification of natural environmental systems (Schulze, 1989; Manion, Lachance, 1992; Mylona, 1996; Augustaitis, 2003a; Juknys et al., 2003a). High concentrations of these compounds can lead to thinning out of the canopy and yellowing of leaves and needles (Manion, Lachance, 1992; Ozolinčius, Stakėnas, 2001; Filipika, Napierała-Filipiak, 2009); changes in species composition of the ground vegetation (Nordin et al., 2005); forest soil acidification (increase in the amount of Al^{3+} ions, leaching of Ca^{2+} and Mg^{2+} ions) (de Vries et al., 2000), as well as disruption of the activity of micro-organisms and loss of mycorrhizal vitality (Brandrud, 1995). It may also alter the ratio of early and late wood of annual growth ring (Schweingruber, 1996), while in the lower part of the stem – complete annual rings may fail to form (Banks, 1991). Research of forest ecosystem components has increased even more under reduced amounts of emissions (1990) (Augustaitis, 2003). Changes in ecological situation preconditioned the recovery process of forest ecosystems (Bishop, Hultberg, 1995; Likens et al., 1996).

In Lithuania the largest negative impact on forest ecosystems was caused by one of the largest plants of nitrogen fertilizers Achema, in the impact zone of which forest ecosystem components have been exposed to eutrophying and acidifying pollutants (Armolaitis et al., 1999). Abundant emissions (SO_2, NO_x, NH_3, etc.) over thirty years have caused massive forest dieback. Due to accumulation of nitrogen and sulfur compounds not only trees dried out, but changes occurred in the ground vegetation, i.e. nitrophilous plants, such as *Rubus idaeus* L., *Epilobium angustifolium* L. and other species (Armolaitis, Stakėnas, 2001) have started spreading; damages of needle cuticle have emerged (Kupčinskienė, 2001); an anomalous form of needles (three needles instead of two grow in tufts) and curving of shoots were detected (Barauskas et al., 1989); lower annual radial increment was recorded (Augustaitis 1999; 2005; Juknys et al., 2002; 2003a; Stravinskiene, 2004); sulfur and nitrogen compounds started accumulating in the soil, the balance of nutrients was disrupted, and the processes of organic matter decomposition was slowed down (Armolaitis et al. 1999; Armolaitis, Stakėnas, 2001). With the improved environmental indicators (updated technological processes, treatment plants and control of emissions), reduction in industrial output and emissions, the processes of stabilization of damaged forest ecosystems began and were followed by improvement in the condition of ecosystems (Armolaitis 1998; Augustaitis, 1999; Armolaitis, Stakenas 2001; Armolaitis, 2002; Juknys et al., 2002; 2003a; Stravinskiene, 2004; Marozas et al., 2008).

Materials and Methods

Investigations were conducted in six damaged semi-mature (80–90 years old) Scots pine (*Pinus sylvestris* L.) stands at different distances up to 22 km in the north-east directions. The forest type of these stands is *Pinetum vaccinio–myrtillosum*, according to forest soils classification – *Arenosols*. Site conditions and the main stand characteristics of the monitored stands were similar.

Ground vegetation in 2012 were conducted in 6 observation plots, as in 1988 and 1999, according to the modified American forest ecosystem monitoring methodology for the assessment of species cover, i.e. selecting at four vegetation observation plots, while in each plot selecting at four 1 m^2 vegetation inventory squares (a total of 16 inventory squares) (Fig. 1). Vegetation is monitored with 3 replications and in each square the species and projection coverage (%) of herbaceous plants, shrubs and mosses are determined.

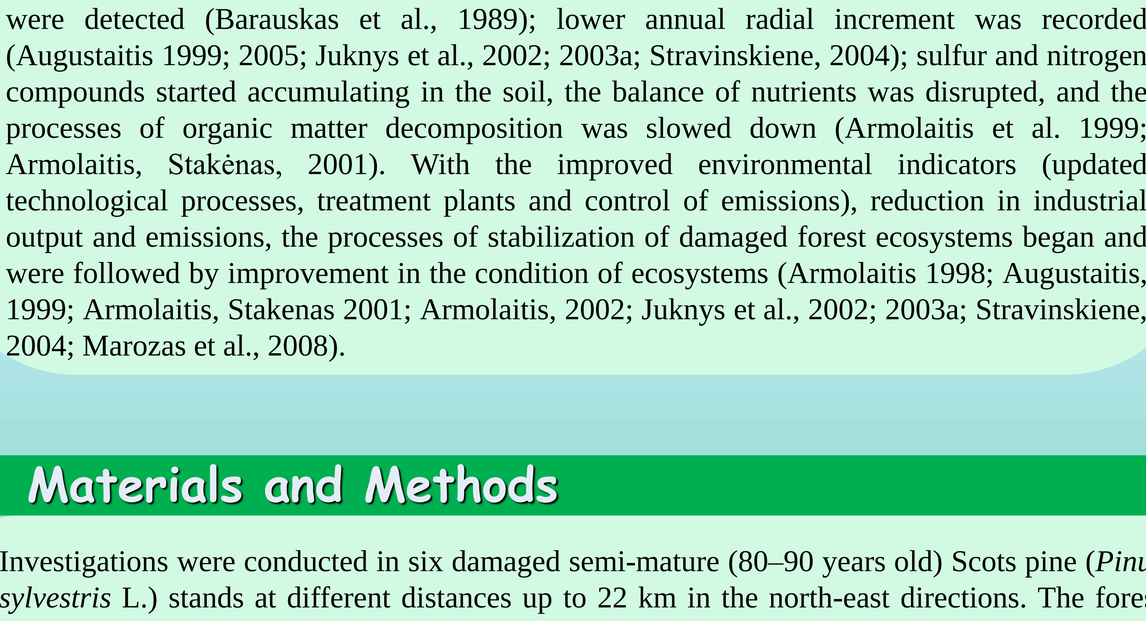

Fig. 1. Scheme of American Forest Health Monitoring study site (A) and location of vegetation sample quadrates (B) in vegetation sample microplot (Tallent-Halsell, 1994)

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Results

Over the past 24 years (since 1988), the number of the most common pine forest species in the ground vegetation has remained essentially unchanged ($p > 0.05$), however, the number of nitrophilous species ($p<0.05$) has increased (Fig. 4A). Although the number of typical for pine forest plant species over the years has not changed substantially (Fig. 4A), but the projection coverage in 1999 significantly differed ($p<0.05$) in comparison with the other years of studies (Fig. 4B). During this period, projection coverage decreased from 97±2.7% (in 1999) to 43±1.6% (in 2012).

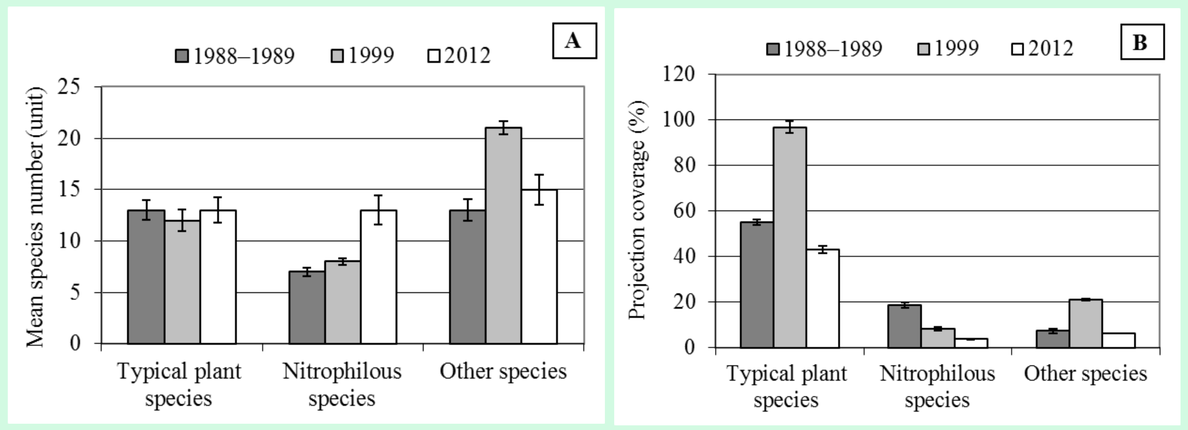

Fig. 2. Mean number of species (A) and projection coverage (B) in the study year

Close to the plant (2 km) ground vegetation is dominated by herbaceous plants (Fig. 3A), i.e. in the soil cover a typical nitrophilous species are widespread (*Chelidonium majus* L., *Galeopsis tetrahit* L., *Mycelis muralis* (L.) Dumort., common meadow-grass *Poa pratensis* L., rosebay willowherb *Epilobium angustifolium* L., three-veined sandwort *Moehringia trinervia* (L.) Clairv, et al.), while further away from the plant (20–22 km) projection coverage of herbaceous plants decreases and mosses prevail in the ground cover (Fig. 3B).

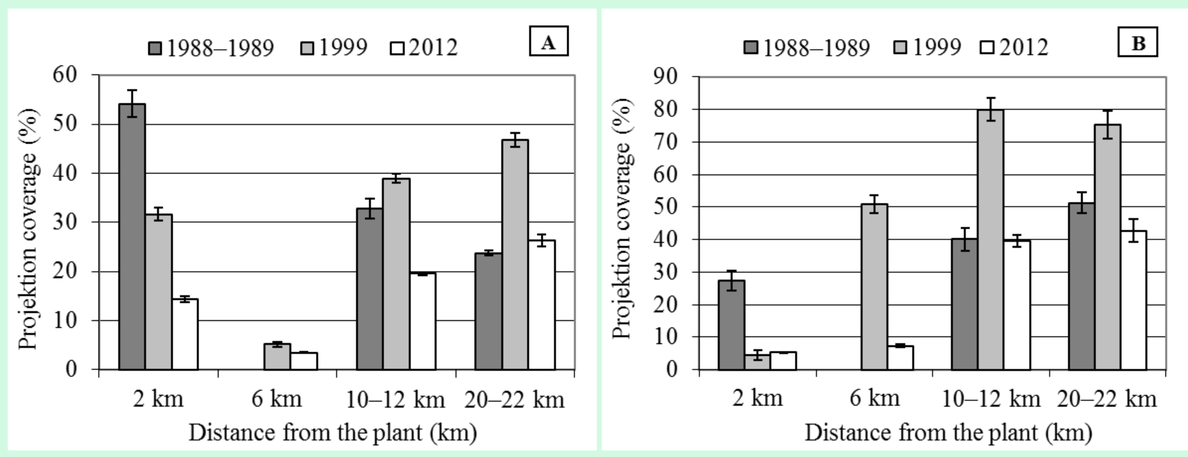

Fig. 3. Projection coverage of herbaceous plants and brush (A) as well as moss (B) depending on the distance from the plant

The analysis of shrubs, grasses and moss surface coating types of variation the only nitrophilous species and typical plant species (Fig. 4). After correspondent analysis found that shrubs, grasses and moss cover variability significantly associated with distance from the source ($p<0.05$). Plant based coating with distance from the source of pollution increased, the left of the graph types (1988-1989) (Fig. 4A) and right (1999 and 2012) (Fig. 4 B, C), which decreased - 1988-1989 on the right, and in 1999 and 2012 on the left.

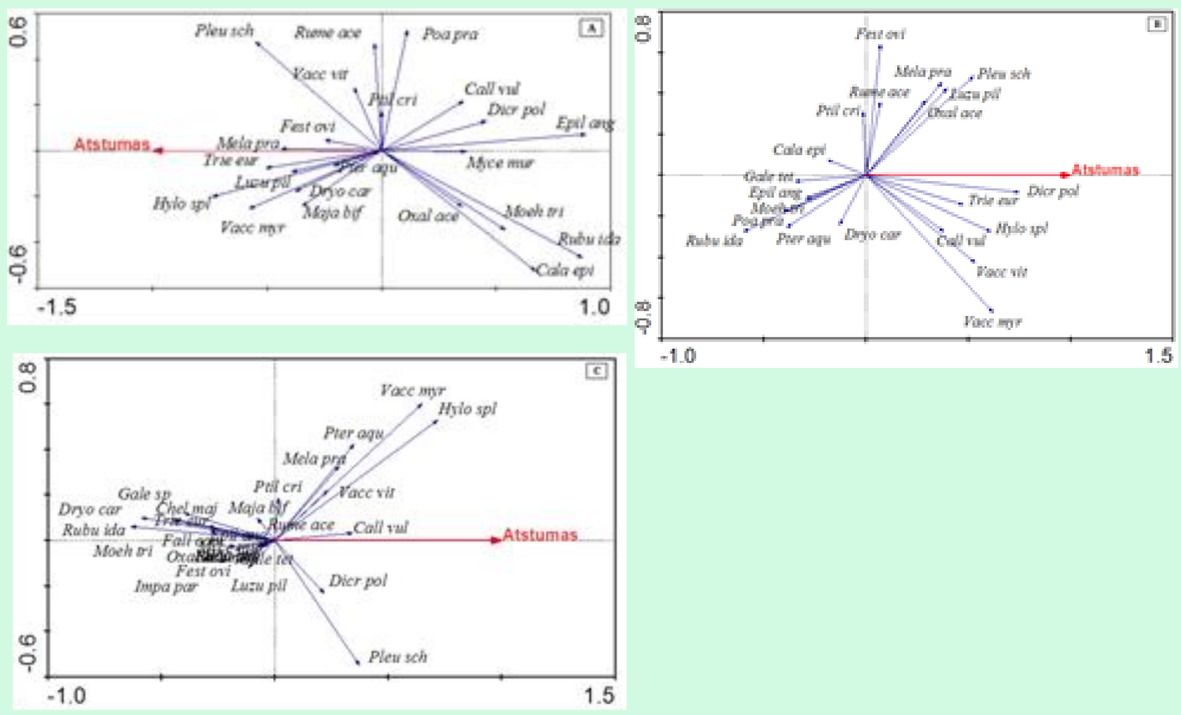

Fig.4. Shrubs, grasses and moss cover types of coverage (%) during 1988 to 1989 (A) 1999 (B) and 2012 (C) year, moving away from the plant Achema

Conclusions

Over the last 24 years, under reduced environmental pollution, projection coverage of light demanding species and nitrophilous plant species in the ground vegetation has decreased, but the coverage of typical for pine forests species has increased. However, ground vegetation in the nearest to the factory sites still contains nitrophilous plants which are not typical for uncontaminated pine forests. This shows that due to the irreversibility of the structure of stands near Achema, the cover of shrubs, herbaceous plants and mosses remains altered.