Exceedances of Critical Loads for S and N in relation to forest soil chemistry and biodiversity changes

26th CCE Workshop and 32nd Task Force Meeting of the ICP Modelling and Mapping, 19 – 22 April 2016, Dessau, Germany

Irena Skořepová [1], Zora Lachmanová [2], Václav Buriánek [2], Jaroslav Skořepa [5],
Vít Šrámek [2], Radek Novotný [2], Monika Vejpustková [2],
Kateřina Neubertová Hellebrandová [2], Iva Hůnová [3], Miloš Zapletal [4]

[1] Czech Geological Survey, [2] Forestry and Game Management Research Institute, [3] Czech Hydrometeorological Institute,
[4] Centre for Environment and Land Assessment - Ekotoxa, s.r.o., [5] SVUOM, s.r.o

Introduction

The aim of the elaboration is to show the data of critical loads for S and N included in the Call for Data 2014/2015 and their exceedances by atmospheric depositions. The data are summarized in schematical maps of the Czech Republic. Location of forest plots involved in the elaboration is in the Figure 1. Critical loads and exceedances from forest plots of the intensive monitoring (level II) included to the International Cooperative Programme for Forests (Fig. 2) represent more detailed data set. Monitoring of forest plots operated by the Forestry and Game Management Research Institute has been giving the data on forest environmental properties since 1994 (Boháčová et al., 2010). Indicators such as Bc/Al, N leaching and the number of ground vegetation species complete exceedances of critical loads. The evaluation of relationships between atmospheric depositions and biodiversity was partial results of the grant Forest soil state as a determining factor of health state development, biodiversity and filling productivity and outside productivity functions of forests solved under the sponsorship of the Ministry of Agriculture of the Czech Republic (Novotný et al., 2015).

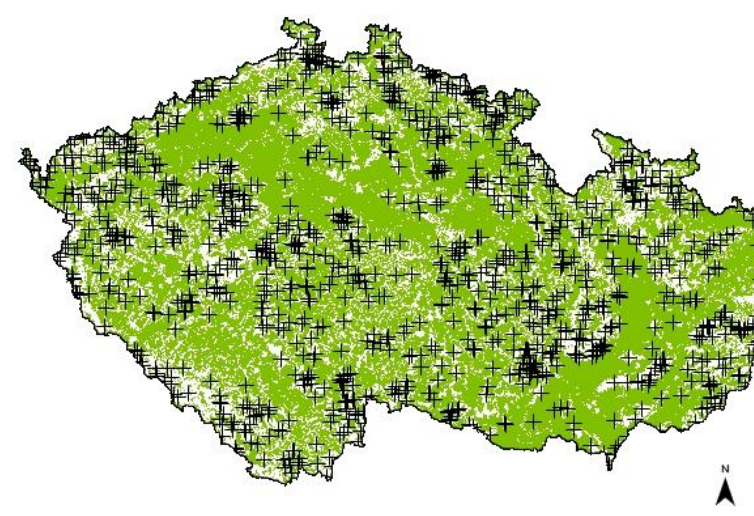

Figure 1: Location of forest plots included in the Call for Data 2014/2015 (total number ca 1200)

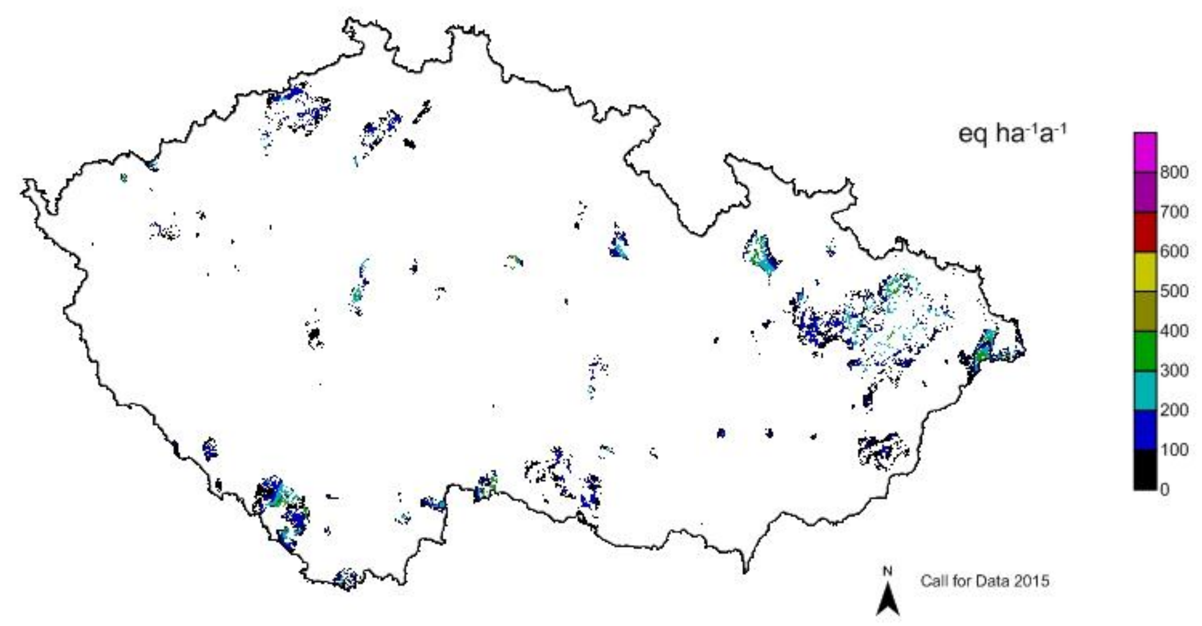

Figure 3: Schematical map of S and N critical loads exceedances indicating acidification

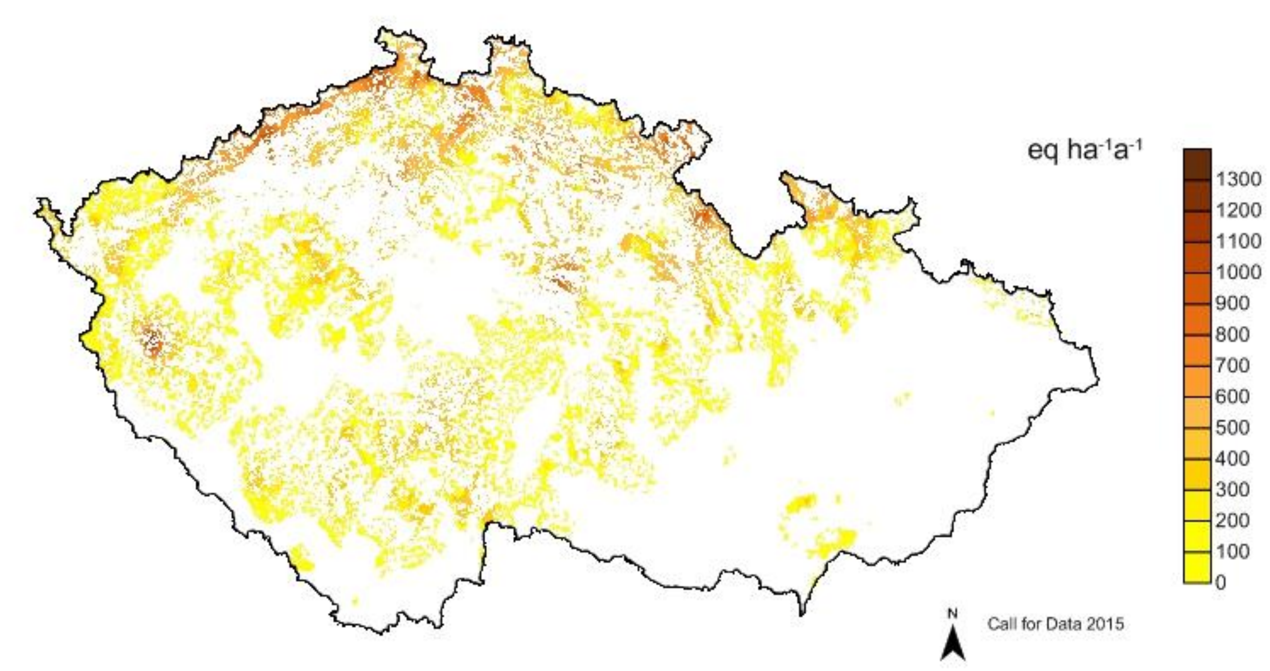

Figure 4: Schematical map of nutrient N critical load exceedances indicating eutrophication

Methodology

Forest ecosystems of the Czech Republic represented by the selected plots fall into five main EUNIS forest habitats according to forest type classification (Chytrý et al., 2001). They are G 1.4 Mixed oak-elm-ash woodland of great rivers, G.1.7 Medio-European neutrophile beech forests or Medio-European subalpine beech forests (a) or Medio-European acidophilous beech forests (b), G.1.8 Medio-European acidophilous oak forests, G 3.2 Hercynian subalpine spruce forests and G3.5 Scots pine mire woods. Empirical critical loads of N range from 5 to 10 kg $ha^{-1} a^{-1}$ for these habitat types. The following species represent characteristic (diagnostic) species for each type (behind the word - the assessment of Bc/Al according to Sverdrup and Warfvinge, 1993):

G 1.4
Tree and shrub layer
Fraxinus angustifolia subsp. danubialis (2)
Quercus robur 0.6
Ulmus laevis (6)
U. minor (6)
Herb layer
Milium effusum

G 3.2
Tree and shrub layer
Picea abies 1.2
Sorbus aucuparia subsp. aucuparia –0.6-1.0
Herb layer
Blechnum spicant
Homogyne alpina
Luzula sylvatica
Streptopus amplexifolius
Trientalis europaea

G 1.7
Tree and shrub layer
Abies alba 1.4
Fagus sylvatica – buk lesní 0.6
Herb layer
Actaea spicata
Dentaria bulbifera
D. enneaphyllos
Hordelymus europaeus
Polygonatum verticillatum
Prenanthes purpurea
Scrophularia nodosa
Viola reichenbachiana

G 1.7 a)
Tree and shrub layer
Acer pseudoplatanus 0.6
Fagus sylvatica 0.6
Herb layer
Aconitum callibotryon
Adenostyles alliariae
Athyrium distentifolium
Chaerophyllum hirsutum
Cicerbita alpina
Lysimachia nemorum
Petasites albus
Ranunculus aconitifolius
R. platanifolius
Rumex alpestris
Thalictrum aquilegiifolium

G 1.7 b)
Tree and shrub layer
Fagus sylvatica 0.6
Herb layer
Avenella flexuosa
Calamagrostis arundinacea
C. villosa
Carex brizoides
Luzula luzuloides subsp. luzuloides
Vaccinum myrtillus

G 1.8
Tree and shrub layer
Betula pubescens 2
Frangula alnus
Populus tremula 6
Herb layer
Dryopteris carthusiana
Hieracium laevigatum
Lysimachia vulgaris
Molinia arundinacea
Potentilla erecta

G 3.5
Tree and shrub layer
Betula pubescens 2
Frangula alnus
Pinus sylvestris 1.2
Moss layer
Dicranum polysetum
Polytrichum commune

The state of ground vegetation in the experimental forest plots is assessed using semi-quantitative method of phytocenological snaps. Eight-member, modified, combined scale of abundance and dominance, by Braun-Blanquet (1965) is used. The presence of all vegetation species in tree and shrub layers, herb layer and moss layer was registered, Coverage of the species is visually estimated and classified. We used the number of ground vegetation species in this presentation for bio-indication. Biodiversity observations in forest plots have been realized since 1995 (Buriánek et al., 2013). Phytocenological snaps from the localities of the level II monitoring represent the period from 2005 to 2014 in most cases. Exceedances of critical loads calculated for the given plots were compared to the values of soil solution Bc/Al and N_{le} as chemical indicators.

Critical loads were calculated with use of the SMB method for 50 cm forest soil layers (CLRTAP, 2015).

$$CL_{max}(S) = BC_{we} + BC^*_{dep} - Bc_{upt} - (-ANC_{lecrit})$$

$$CL_{min}(N) = N_{upt} + N_{imacc}$$

$$CL_{max}(N) = CL_{min}(N) + CL_{max}(S)/(1-f_{de})$$

$$CL_{nut}(N) = N_{upt} + N_{imacc} + N_{leacc}/(1-f_{de})$$

BC_w weathering rate
BC^*_{dep} base cation deposition corrected
Bc_{upt} base cation uptake
ANC_{lecrit} alkalinity leaching (according to Mapping Manual, 2004, eq. V.31, for K_{gibb} table V.9)
Bc/Al ratio according to main tree species (Sverdrup and Warfvinge, 1993)
N_{upt} nitrogen uptake (annual average 2005-2010)
N_{imacc} immobilization of N (for soils with C/N > 20)
N_{leacc} leaching of N (1mg 1^{-1})

The data on precipitation amounts, temperatures and radiations were taken from continuous measurements. Their daily data were used and processed by the MetHyd model (Bonten et al., 2010). Soil properties such as the texture and basic chemical compositions were measured in 2006. Soil characteristics represent the soil layer of 50 centimetres measured from the top. The average annual values on temperature, precipitation surplus and soil moisture were used in the calculation of critical loads. The data represent the period of 2005 – 2010. Parameters such as concentrations of nitrogen, base cations, pH and alkalinity of the soil solution were observed in soil solution samples collected under the soil layer of 30 cm thickness.

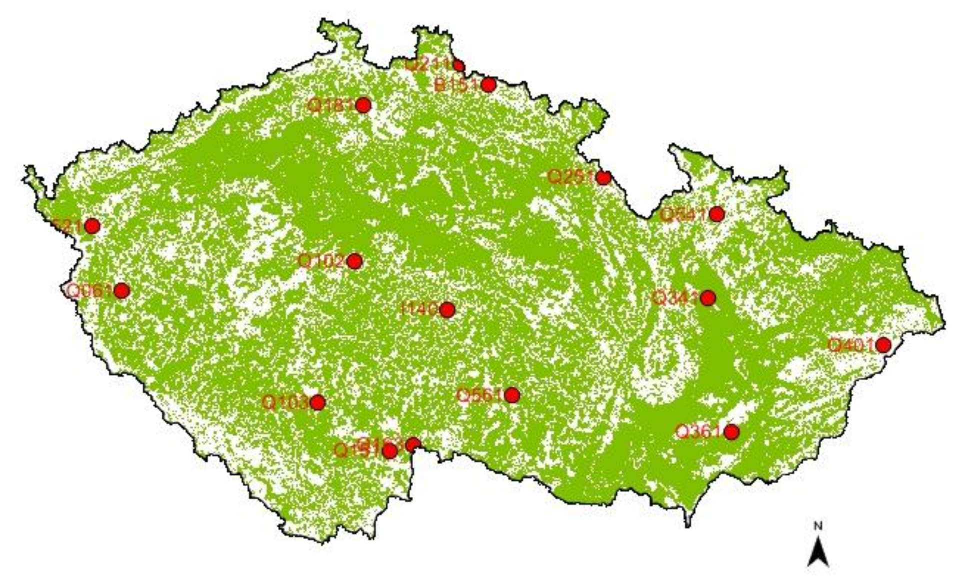

Figure 2: Location of forest plots included in monitoring of level II

Data on deposition measurements used for the elaboration were assessed on the base of bulk and throughfall samples and their analyses. Throughfall and bulk depositions have measured since 1996 (1997) in four plots (B151 Mísečky, I140 Želivka, Q 361Medlovice and Q 521 Lazy). The forest plot Q 102 Březka has provided deposition data from 2000. Another forest plots began to monitor in 2003 or latter (Q 251 Luisino údolí in 2004). Stemflow samples have been collected from the plots of deciduous forests - in Medlovice, Všeteč, and Mísečky. Procedures for measurements in the forest plots are comparable with other deposition measurements within ICP Forests and UN-ECE programmes (Clarke et al., 2010). Total depositions for the forest ecosystem were calculated according to the methodology published in Draaijers et al. (1995, 1998). Total depositions of reduced nitrogen forms contain dry depositions of gaseous form of ammonia based on measurements by passive samplers (Zapletal, 2013: In Novotný et al., 2013).

Exceedances of S and N critical loads for the territory of the Czech Republic were calculated with help of modelled data (Hůnová et al., 2013 In: Novotný et al., 2013). These data were corrected with the use of dry depositions of gaseous NH_3 .

Results

Exceedances of critical loads CLmaxS by S atmospheric depositions occur only in the small forest area of the Czech Republic. But acidification of forest ecosystems still continue (Fig.3). At present acidification is caused namely by nitrogen deposition. In many cases atmospheric depositions of N exceed both critical loads of nutrient nitrogen (and/or empirical critical loads of N) and limits given by minimum critical loads and maximum critical loads (steep side of the trapezoid). From the point of view of eutrophication critical loads for nutrient nitrogen are exceeded nearly in all forest ecosystems (Fig. 4). Results correspond to the observation of experts from the Czech Hydrometeorological Institute (Hůnová et al., 2014). They show that the value of nitrogen deposition flux of 1 g $m^{-2}year^{-1}$ is exceeded over a significant portion of the country.

The forest ground vegetation species with exceedances of critical loads of N (including nutrient nitrogen) are reduced gradually in both number and their coverage (Fig. 5). Ground vegetation types are related to the herb layer. Phytocenological study of 16 forest plots of monitoring II shows 8 plots with decreasing number of species in time.

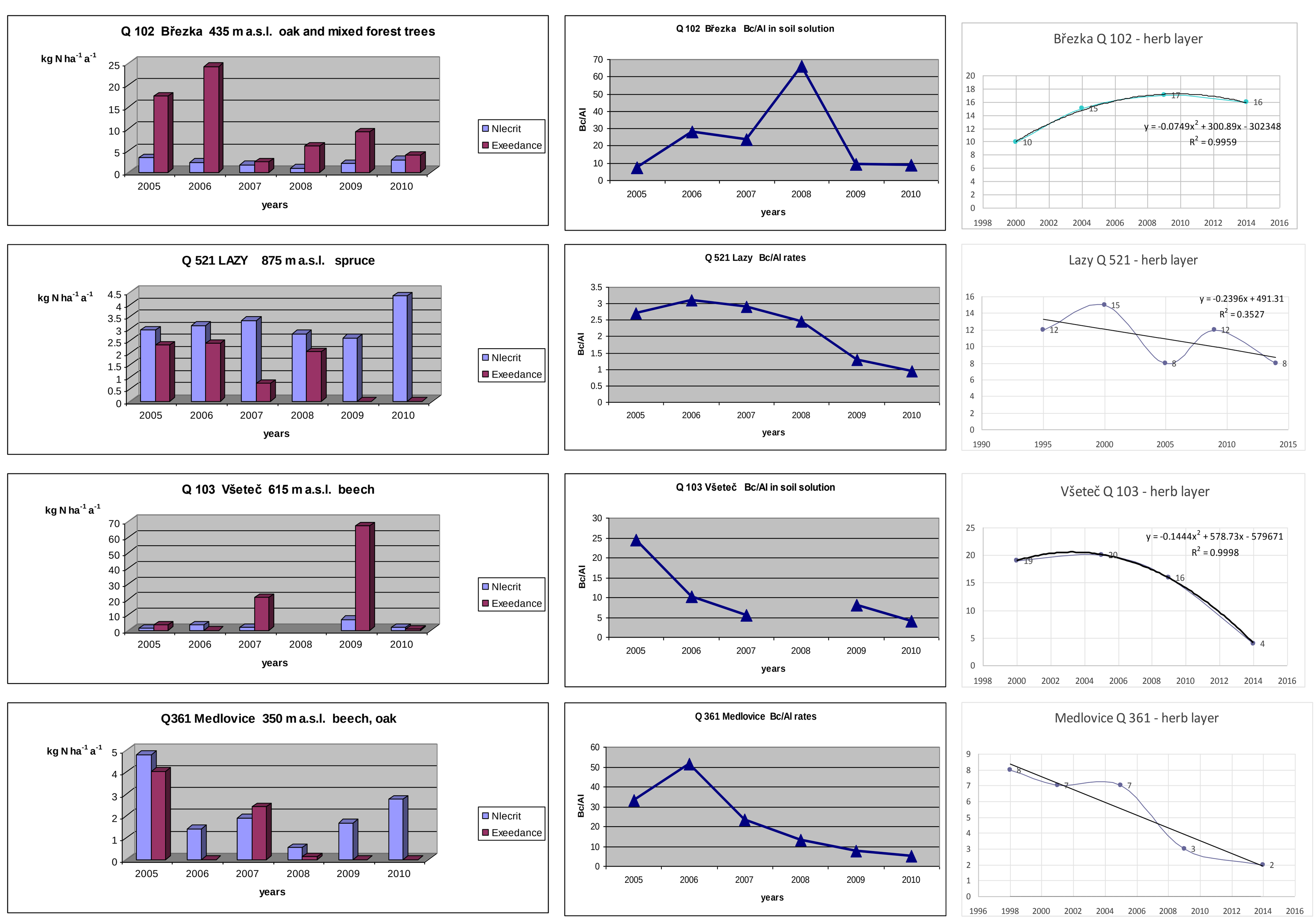

Figure 5: Relationship among exceedances of nitrogen leaching, soil solution Bc/Al ratios and number of species in the herb layer in four forest plots of monitoring II

Nitrophilous species were observed in four forest plots (Buriánek et al., 2013). For example Q102 Březka, Q103 Všeteč, Q215 Luisino údolí and Q341 Litovel are plots with occurrence of *Urtica dioica.*

Most of forest plots show increasing nitrogen leaching and decreasing Bc/Al ratios with exceedances of critical loads of nitrogen. Excees of nitrogen deposition is usually accompanied by decreasing soil C/N ratios. This fact also influence the rate of nitrogen immobilization and export by waters (Oulehle et al., 2008).

Decrease in Bc/Al ratios reflects very well the occurrence of acidification caused by nitrogen deposition. The Bc/Al ratio is important factor for derivation of critical loads of S maximum and than critical loads of N maximum. It should be in accordance to the main vegetation species in ecosystems (Sverdrup, Warfvinge, 1993).

Conclusions

This presentation is focussed into elaboration of exceedances of critical loads of S and N in the Czech forest ecosystems and detailed processing critical loads of forest plots involved in the monitoring of level II. Mesurements of the soil chemistry including soil solution and phytocenological study allow better interpretation of exceedances in more details. Bc/Al ratios in soil solution, N leaching, soil C/N ratios belong to very good indicators supported exceedances of critical loads. Ground vegetation species reflect the changes of soil chemistry caused by atmospheric depositions.

Improvement of the assessment of nitrogen deposition is crucial point in the calculation of critical load exceedances. Exceedances of nitrogen critical loads has been underestimated up to now because of inaccurate nitrogen deposition assessment. The evaluation of dry gaseous deposition of NH_3 is one of steps to better results.

References

Novotný, R., Hůnová, I., Skořepová, I., Zapletal, M., Seidl, V., Buriánek, V., Fadrhonsová, V., Jurkovská, L., Neudertová Hellebrandová, K., Kurfűrst, P., Lachmanová, Z., Ostatnická, J., Schovánková, J., Schreiberová, M., Stoklasová P., Šrámek, V., Vlček, O. (2013): Stav lesních půd jako určující faktor vývoje zdravotního stavu, biodiverzity a naplňování produkčních i mimoprodukčních funkcí lesa Závěrečná zpráva grantu NAZV QI112A168, Výzkumný ústav lesního hospodářství a myslivosti, Zbraslav - Strnady. 65 pp. (Forest soil state as a determining factor of health state development, biodiversity and filling productivity and outside productivity functions of forests. Final Report of the NAZV grant, Forestry and Game Management Research Institute, Zbraslav – Strnady. 65 pp.).

Novotný, R., Buriánek, V., Šrámek, V., Hůnová, I., Skořepová, I., Zapletal, M., Lomský, B. (2015): N deposition and its impact on forest ecosystems in the Czech Republic – change in soil chemistry and ground vegetation. Poster presentation in IUFRO conference, June 1-6, 2015, France, Nice, session 6: Forest ecosystems, atmospheric deposition and water cycle.

Oulehle, F., McDowell, W., H., Aitkenhead-Peterson, J., A., Krám, P., Hruška, J., Navrátil, T., Buzek, F., Fottová, D. (2008): Long-Term Trends in Stream Nitrate Concentrations and Losses Across Watersheds Undergoing Recovery from Acidification in the Czech Republic. Ecosystems (2008) 11: p. 410-425.

Sverdrup, H., Warfvinge, P.(1993): The effect of soil acidification on the growth of trees, grass and herbs as expressed by the (Ca+Mg+K)/Al ratio. Reports in ecology and environmental engineering, Report 2: 1993, Lund University, Sweden. 177 pp.

UBA (2004): Manual on methodologies and criteria for Modelling and Mapping Critical Loads & Levels, Air Pollution Effects, Risks and Trends. UNECE Convention on Long-range Transboundary Air Pollution. Federal Environmental Agency, text 52/04, ISSN 0722-186X, Berlin. http://www.icpmapping.org

References

Boháčová, L., Lomský, B., Šrámek, V. (eds) (2010): Monitoring zdravotního stavu lesa v České republice. Ročenka programu ICP Forests/FutMon data 2008 a 2009. *Forest Condition Monitoring in the Czech Republic. Annual Report ICP Forests/FutMon Programme data 2008 and 2009*. VÚLHM, Strnady – Zbraslav.160 pp.

Bonten, L., Posch, M., Reinds, G.J. (2010): The VSD+ Soil Acidification Model – Model Description and User Manual. Alterra, WUR, Wageningen

Braun-Blanquet, J. (1965): Plant Sociology, the Study of Plant Communities. London, Hafner. p. 439.

Buriánek, V., Novotný, R., Hellebrandová, K., Šrámek, V. (2013): Ground vegetation as an important factor in the biodiversity of forest ecosystems and its evaluation in regard to nitrogen deposition. Journal of Forest Science, 59, 2013(6): p. 238-252.

CLRTAP, 2015. Mapping critical loads for ecosystems, Chapter V of Manual on methodologies and criteria for modelling and mapping critical loads and levels and air pollution effects, risks and trends. UNECE Convention on Long-range Transboundary Air Pollution; accessed [date of consultation] at www.icpmapping.org .

Hůnová, I., Maznová, J., Kurfurst, P. (2014): Trends in atmospheric deposition fluxes of sulphur and nitrogen in Czech forests. Environmental Pollution 184, p. 668-675.

Chytrý, M., Kučera, T., Kočí, M., eds. (2001): Katalog biotopů České republiky. Interpretační příručka k evropským programům Natura2000 a Smaragd. AOPK, Praha ve spolupráci s PřFMU, Brno a BÚ AVČR. ISBN 80-86064-55-7, 1. vydání, Praha. 307 pp.

Clarke N, Zlindra D, Ulrich E, Mosello R, Derome J, Derome K, König N, Lövblad G, Draaijers GPJ, Hansen K, Thimonier A, Waldner P, 2010: Sampling and Analysis of Deposition. 66 pp. Part XIV. In: Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests. UNECE, ICP Forests, Hamburg. ISBN: 978-3-926301-03-1. [http://www.icp-forests.org/Manual.htm]

Draaijers, G. P. J & Erisman, J. W., Van Leeuwen, N. F. M., Römer, F. G., Te Winkel, B. H., Vermeulen, A. T., Wyers, G. P. & Hansen, K. (1995): The contribution of canopy exchange to differences observed between atmospheric deposition and throughfall fluxes. In: Studies in Environmental Sciences 64 : p. 455-456.

Draaijers G.P.J., Erisman J.W., Lövblad G., Spranger T., Vel E. (1998): Quality and uncertainty aspects of forest deposition estimation using throughfall, stemflow and precipitation measurements. TNO-Report TNO-MEP-R 98/093, TNO, The Netherlands, 73 pp.