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Reorganisation of a long-term monitoring network using moss as biomonitor for atmospheric deposition in Germany

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ABSTRACT

The determination of atmospheric deposition in forests can be accomplished using technical sampling devices (bulk samplers, wet only samplers), biomonitors or modelling. In Europe, since 1990 moss sampled every five years at up to 7300 places in up to 35 countries was used as biomonitor. In the moss specimens, heavy metals (HM), nitrogen (N, since 2005) and persistent organic pollutants (POPs, since 2010) were determined. Germany participated in all surveys with the exception of that in 2010. For the moss survey 2015, the biomonitoring network applied in the 2005 campaign should be reorganized. To this end, a complex statistically based methodology including a decision support system was developed and implemented. Its application yielded a network with a reduction of sample points from 726 to 402. By use of the data collected in 2005 the performance of the reorganized network did not reveal significant loss of statistical validity.

1. Background and objectives

1.1. Atmospheric deposition monitoring

Atmospheric deposition is the precipitation of substances (e.g. dust, particulate matter containing heavy metals, polycyclic aromatic hydrocarbons, dioxins, furans, sulphates, nitrates) emitted from natural and anthropogenic sources to surfaces such as soils and vegetation (Amodio et al., 2014). As is true for complex forest ecosystem assessments, the monitoring of atmospheric dry, occult and wet deposition to forests is a challenging objective. This can be achieved by technical samplers collecting either only dry deposition when there is no precipitation, wet deposition during rain, or bulk deposition sampling both wet and dry deposition with subsequent chemical analyses (Amodio et al., 2014; Ferretti and Fischer, 2013; Hansen et al., 2013). This technical approach can be complemented by both, moss and lichens used as biomonitors for an indirect measure of atmospheric deposition, and by dynamic modelling. Thereby, the spatial validity of the measurements is one of the crucial issues. Whilst technical samplers enable a high temporal resolution, monitoring using moss as biological sampler for atmospheric deposition allow for high spatial density of measurements (Amodio et al., 2014; Tørseth et al., 2012). For assessing potential changes of structures and functions of ecosystems, the spatial resolution of deposition data should cope with the spatial variability of the ecosystems pattern covering the area under investigation.

Deposition values calculated by dynamic modelling rely on meteorological data, which are of excellent quality and high spatial resolution, and on emission data which may be of considerable uncertainty (Liang et al., 2015; Pouliot et al., 2012; Rafaj et al., 2014; Reis et al., 2009; Vestreng et al., 2006, 2007; Winiwarter et al., 2009). Such modelling results need validation by deposition measurements derived by technical samplers and/or biomonitors based on harmonized methods applied throughout the area under investigation (Nickel and Schröder, 2016; Schröder et al., 2016). If this requirement could not be met, then the deposition, ecosystems are exposed to, cannot be assessed specifically for single ecosystem types or ecoregions. This might provoke measures which are not appropriate for protecting the respective ecosystems. Therefore, since 1990, a European Moss Survey (EMS) was conducted at high spatial resolution every five years, since 2000 in the framework of the International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops (ICP Vegetation) under the United Nation Economic Commission for Europe (UNECE) Convention on Long-Range Transboundary Air Pollution (CLRTAP).

1.2. European moss survey

Due to the lack of epidermis, cuticle and roots and, therefore, only areal element supply, the same morphology throughout the

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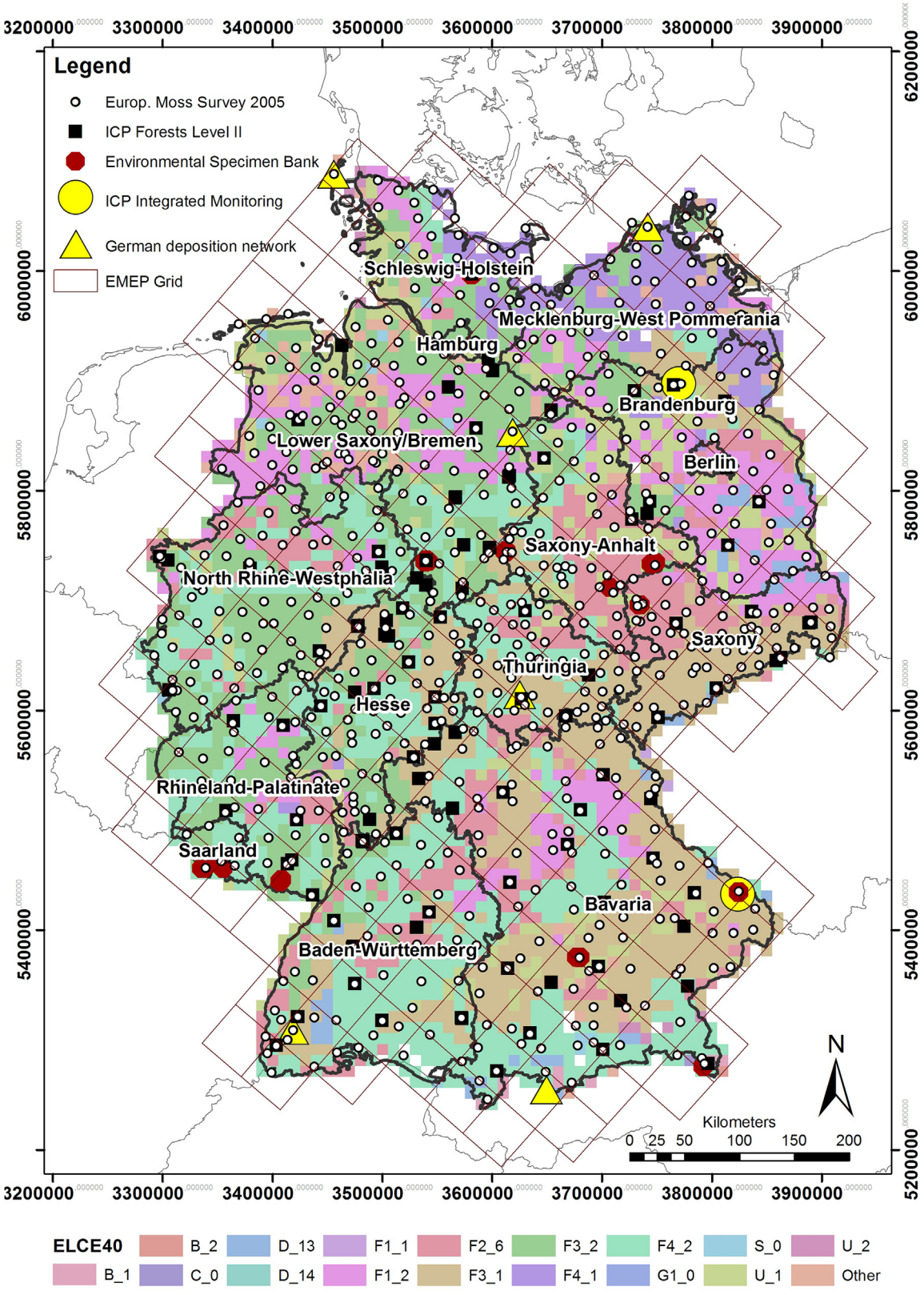

Fig. 1. Spatial distribution of sampling sites from the European Moss Survey 2005, other environmental monitoring networks, Federal states and Ecological land classes ELCE40.

seasons, high surface area to mass ratio and high efficiency in element accumulation, ubiquitous occurrence and ease of sampling, ectohydric mosses allow long-term monitoring the atmospheric deposition of several elements in the same matrix collected at many sampling sites covering large areas (Amodio et al., 2014). They accumulate dry, occult and wet deposition and by that enable the determination of elements far beyond their analytical detection and quantification limits (Frahm, 1998). *Pleurozium schreberi* (BRID.)