Instituut voor Natuur- en Bosonderzoek - Gaverstraat 4 - B-9500 Geraardsbergen - T.: +32 (0)54 43 71 11 - F.: +32 (0)54 43 61 60 - info@inbo.be - www.inbo.be



Second European Forest Soil Condition Report

Volume I: Results of the BioSoil Soil Survey

Bruno De Vos and Nathalie Cools

INBO.R.2011.35

Vlaamse overheid

Authors:
Bruno De Vos and Nathalie Cools
Research Institute for Nature and Forest

The Research Institute for Nature and Forest (INBO) is the Flemish research and knowledge centre for nature and its sustainable management and use. INBO conducts research and provides knowledge to policy advisors, policy makers and all its interested parties.

Establishment:
INBO Geraardsbergen
Gaverstraat 4, 9500 Geraardsbergen
www.inbo.be and fscc.inbo.be

Email:
fscc@inbo.be

Citation:
De Vos, B. and Cools, N. 2011. Second European Forest Soil Condition Report. Volume I: Results of the BioSoil Soil Survey. INBO.R.2011.35. Research Institute for Nature and Forest, Brussel.

D/2011/3241/286
Report N° INBO.R.2011.35
ISSN: 1782-9054

Responsible publisher:
Jurgen Tack

Press:
Management supporting services of the Flemish Government

Cover photo:
Nathalie Cools

This research was financed by the European Commission and the Flemish Government. It was executed within the framework of the EU Life+ project 'Further development and implementation of an EU-Level Forest Monitoring System (FutMon)' in cooperation with the International Cooperative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests), LIFE+07 ENV/D/000218/Action C1-Soil-3(FL).

© 2011, Research Institute for Nature and Forest

Second European Forest Soil Condition Report

Volume I: Results of the BioSoil Soil Survey

Bruno De Vos, Nathalie Cools

INBO.R.2011.35
D/2011/3241/286

LIFE+07 ENV/D/000218/FutMon Report S-Soil-11Soil

Preface

Fourteen years after the release of the first European Forest Soil Condition Report in 1997, the Forest Soil Co-ordinating Centre is proud to present its second report now based on the 2006 - 2009 BioSoil survey data.

This extensive report consists basically of two volumes. The first volume presents a profound description and analysis of the BioSoil^{+} data, gathered on Level I and a subset of Level II ICP-Forests' plots, and is a main deliverable of the Life^{+} FutMon project (report S-Soil-11Soil). The second volume builds further on these BioSoil^{+} data providing thematic evaluations of carbon and nutrient stocks, acidification and nutrient status and contamination levels of European forest soils. The humus classification system and the soil classification according to the World Reference Base for soil resources are reviewed. Finally, temporal changes of forest soil properties compared to the first soil condition survey are investigated.

We are generally concerned with the forest ecosystem and the vital role of the soils herein. Surely, forest soils in good physical and chemical condition are the basis for healthy, productive and sustainable forests offering various ecosystem services. But, what is the actual soil condition? This report describes the contemporary state of forest soils at the European level and provides a benchmark for national and regional evaluations.

Adequate, reliable and up-to-date soil information is a prerequisite for all forest related research and should be freely available within the scientific community and accessible to decision makers and the broad public. Despite the intentions of free availability of environmental data within Europe (proclaimed by the Aarhus convention among other statements), we faced the reality of data protectionism when asking for the validated BioSoil-soil data needed for this Life^{+} evaluation. This was especially astonishing, because of the indispensable support of the FSCC before and during the BioSoil survey. Therefore we are very grateful to all BioSoil countries providing us with their national/regional BioSoil data in order to assemble the BioSoil^{+} database and for their ongoing co-operative support for data cleaning, analysis and evaluation. In this respect, the handling of BioSoil data was similar as all other flows of EC co-financed data within the UN/ECE ICP-Forests community over the last 25 years.

Thanks to the combined efforts of hundreds of people across Europe this task could be accomplished. People involved in field assessment and sampling, for the processing of ten-thousands of samples in the laboratories and for the scientific analyses, evaluation and reporting of the data. We dedicate this work to all of them.

We also fully acknowledge the EC Life^{+} unit for their support and the Life^{+} co-financing of FutMon Action C1-Soil-3(FL), giving us the opportunity to continue our long-term mission in unravelling the nature and evolution of European forest soils. We also express our true appreciation to INBO and the Flemish Government, investing much more in this work than initially foreseen.

The support, enthusiasm and helpful suggestions of the members of the ICP-Forests Expert Panel on Soil and Soil Solution, before, during and after the BioSoil survey, during the FutMon meetings and by email are also greatly acknowledged.

During the FutMon project, we lost our Finnish colleague Dr. John Derome (1947 – 2010), who was the vice-chairman of our Expert Panel and a most dedicated ambassador for forest (soil) monitoring in Europe. This 2nd Forest Soil Condition report is a humble tribute to him.

Table of contents

Preface i
Table of contents ii
1 Introduction 1
1.1 Background 1
1.2 Scope of this report 4
1.3 General objectives 4
1.4 Report outline 5
2 Materials and methods 7
2.1 Plot selection 7
2.1.1 The ICP Forests Level I and Level II network 7
2.1.2 Participating countries 7
2.2 Field surveys 9
2.2.1 General plot description 9
2.2.2 Profile descriptions and sampling of horizons 9
2.2.3 Sampling at fixed depths 10
2.2.4 Sampling for soil bulk density 11
2.3 Laboratory analyses 11
2.3.1 Participating laboratories 11
2.3.2 Analytical procedures for soil characterisation 12
2.3.3 Chemical and physical characterisation of the composite samples 13
2.3.4 Limit of quantification 13
2.4 Data submission and structure of the data 16
2.4.1 Data submission formats 16
2.4.2 General plot information 17
2.4.3 Soil profile description 18
2.4.4 Description of the soil horizons 18
2.4.5 Sampling and analyses at fixed depths 21
2.5 Data validation 23
2.5.1 Compliance checks 23
2.5.1.1 General plot description (PLS) files 23
2.5.1.2 Soil profile description (PRF) file 24
2.5.1.3 Soil horizon description (PFH) file 24
2.5.1.4 Analyses of fixed depth layers (SOM file) 25
2.5.2 Conformity checks 25
2.5.2.1 General plot description (PLS) file 25
2.5.2.2 Soil profile description (PRF) file 26
2.5.2.3 Soil horizon description (PFH) file 27
2.5.2.4 Analysis results of fixed depth layers (SOM file) 27
2.5.3 Uniformity checks 27
2.5.3.1 General plot description (PLS) file 28
2.5.3.2 Soil profile description (PRF) file 29
2.5.3.3 Soil horizon description (PFH) file 32
2.5.3.4 Analysis of fixed depth layers (SOM file) 33
2.6 Data availability 35
2.6.1 General plot information dataset 35
2.6.2 Soil profile description dataset 36
2.6.3 Soil horizon description dataset 40

2.6.4 Sampling and analyses at fixed depths 44
2.6.4.1 Sampled layers 44
2.6.4.2 Particle size distribution 47
2.6.4.3 Organic layer mass 48
2.6.4.4 Bulk density 49
2.6.4.5 Coarse fragments 50
2.6.4.6 Soil reaction 51
2.6.4.7 Carbonates 53
2.6.4.8 Organic Carbon 54
2.6.4.9 Total Nitrogen 55
2.6.4.10 Exchangeable elements 56
2.6.4.11 Aqua regia extractable elements 57
2.6.4.12 Total Elements 72
2.6.4.13 Acid oxalate extractable elements 72
2.7 Use of additional data, geodata and derived data 74
2.7.1 Introduction 74
2.7.2 Forest Soil databases 74
2.7.3 Soil map at EU level 75
2.7.4 Characteristics of Level I and II plots 76
2.7.5 Forest (soil) cover 77
2.7.5.1 Area estimates 77
2.7.5.2 Grid based estimates 78
2.7.6 Corine Land Cover 79
2.7.7 Altitude and climate 79
2.7.8 Biogeographical regions and Ecoregions 80
2.7.9 Natura 2000 areas 81
2.7.10 Solum depth for calculation of stocks 82
2.8 Data exploration and statistical evaluation 84
2.8.1 General statistics 84
2.8.1.1 Statistical software 84
2.8.1.2 Handling missing and left censored data 84
2.8.1.3 Univariate statistics 85
2.8.2 Multivariate analysis 86
2.8.2.1 Principal Components 86
2.8.2.2 Correlation matrix 87
2.8.3 Geographical mapping 88
3 Results and discussion 89
3.1 General plot information 89
3.1.1 Survey period 89
3.1.2 Plot location 90
3.1.2.1 The BioSoil^{+} Level I and II plots 90
3.1.2.2 Distance among ICP Forests plots 94
3.1.3 Altitude 99
3.1.4 Temperature 101
3.1.5 Mean annual precipitation 103
3.1.6 Biogeographical regions and Ecoregions 103
3.1.7 Water availability for tree growth 105
3.1.8 Tree species and tree species group 105
3.1.9 Stand type: broadleaved, coniferous, mixed 107

3.1.10 European Forest type Classification 107
3.1.11 Corine land cover 108
3.1.12 Natura 2000 areas 109
3.2 Soil profile description 110
3.2.1 Soil parent material 110
3.2.2 Humus forms 112
3.2.3 Soil classification 112
3.2.3.1 The Reference Soil Groups (RSGs) 113
3.2.3.2 The qualifier level 115
3.2.4 Type of water table 125
3.2.5 Mean highest, mean lowest groundwater level 125
3.2.6 Rooting depth, rock depth and depth to obstacle 126
3.2.7 Depth for stock calculations 127
3.3 Soil horizon description 128
3.3.1 Thickness of horizons, layers and profile depth 128
3.3.2 Horizon designations 129
3.3.2.1 Master horizon symbol 129
3.3.2.2 Subordinate symbol 129
3.3.3 Soil structure 130
3.3.4 Soil colour 130
3.3.5 Textural class 132
3.3.6 Coarse fragments code 134
3.4 Univariate analysis of the fixed depth samples 136
3.4.1 Particle size distribution 136
3.4.1.1 Mineral layers 136
3.4.1.2 Peat layers 140
3.4.2 Organic layer mass and thickness 141
3.4.2.1 Organic layer mass 141
3.4.2.2 Organic layer thickness 143
3.4.3 Bulk density 145
3.4.3.1 Measured bulk density 145
3.4.3.2 Estimated bulk density 148
3.4.4 Coarse fragments 150
3.4.5 Soil reaction 152
3.4.5.1 pH-$CaCl_2$ 152
3.4.5.2 pH-H_2O 156
3.4.6 Carbonates 159
3.4.7 Organic Carbon 161
3.4.8 Total Nitrogen 165
3.4.9 Exchangeable elements 169
3.4.9.1 Free H^+ 169
3.4.9.2 Exchangeable Acidity 173
3.4.9.3 Exchangeable Potassium 177
3.4.9.4 Exchangeable Calcium 181
3.4.9.5 Exchangeable Magnesium 185
3.4.9.6 Exchangeable Sodium 189
3.4.9.7 Exchangeable Aluminium 193
3.4.9.8 Exchangeable Iron 197
3.4.9.9 Exchangeable Manganese 201

3.4.10 Aqua regia extractable elements 205
3.4.10.1 Extractable Phosphorus 205
3.4.10.2 Extractable Potassium 209
3.4.10.3 Extractable Calcium 213
3.4.10.4 Extractable Magnesium 217
3.4.10.5 Extractable Sulphur 221
3.4.10.6 Extractable Sodium 225
3.4.10.7 Extractable Aluminium 229
3.4.10.8 Extractable Iron 233
3.4.10.9 Extractable Manganese 237
3.4.10.10 Extractable Copper 241
3.4.10.11 Extractable Lead 245
3.4.10.12 Extractable Nickel 249
3.4.10.13 Extractable Chromium 253
3.4.10.14 Extractable Zinc 257
3.4.10.15 Extractable Cadmium 261
3.4.10.16 Extractable Mercury 265
3.4.11 Total Elements 269
3.4.11.1 Total Potassium 269
3.4.11.2 Total Calcium 270
3.4.11.3 Total Magnesium 271
3.4.11.4 Total Sodium 272
3.4.11.5 Total Aluminium 273
3.4.11.6 Total Iron 274
3.4.11.7 Total Manganese 275
3.4.12 Acid Oxalate Extractable elements 276
3.4.12.1 Acid Oxalate Extractable Aluminium 276
3.4.12.2 Acid Oxalate Extractable Iron 280
3.5 Evaluation of quantification limits and plausible ranges 284
3.6 Multivariate analysis 287
3.6.1 Introduction 287
3.6.2 Forest floor samples 287
3.6.2.1 Overall analysis 287
3.6.2.2 Analysis according to variable groups 289
3.6.3 Mineral soil samples 294
3.6.3.1 Overall analysis 294
3.6.3.2 Analysis according to variable groups 296
3.6.4 Peat samples 302
3.6.4.1 Overall analysis 302
3.6.4.2 Analysis according to variable groups 304
3.6.5 Conclusions 307
4 Conclusions 309
5 Recommendations 315
Field assessments 315
Laboratory analysis 315
Database 316
General recommendations 316
List of abbreviations 318
References 320

Annexes 324
Annex I. BioSoil laboratories 324
Annex II. Tables general statistics 328
Annex III. Maps 339

1 Introduction

1.1 Background

This report forms the major product of the Life^{+} FutMon Action C1-Soil-3(FL): "Quality, expertise and evaluations within soil surveys". It evaluates in depth the soil data collected in the Forest Focus demonstration project 'BioSoil' (call 2005 - 2006).

The BioSoil demonstration project was set up in response to the Forest Focus Regulation (EC) No. 2152/2003 of the Directorate-General for the Environment of the European Commission. The aim of this regulation was the development of a scheme for broad-based, harmonised and comprehensive, long-term monitoring of the condition of forests to (i) continue and further develop monitoring of air pollution and air pollution effects and of other agents and factors that have an impact on forests, … and to (ii) assess the requirements for and develop the monitoring of soils, carbon sequestration, climate change effects, biodiversity as well as protective functions of forests. The regulation stated that for the realisation of these objectives the scheme had to be developed by means of studies, experiments, demonstration projects, testing on a pilot basis and establishment of new monitoring activities. In this way, the Forest Focus regulation offered a legal framework to further support the EU countries in meeting the obligations set out in the framework of the United Nations ECE Convention on Long-range Transboundary Air Pollution (CLRTAP) and the International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests).

In response to the call for the 2005 - 2006 period, the chairs of the ICP Forests Expert Panel on Litterfall and Biodiversity and the Forest Soil Co-ordinating Centre (FSCC) launched the proposal for a combined soil – biodiversity demonstration project on the ICP Forests systematic 16 x 16 km grid at the 85th Standing Forestry Committee on October 22nd, 2004. During the following months the project proposal was further developed.

The soil component was scientifically coordinated by the Joint Research Centre of the European Commission (JRC, Ispra, Italy). The member states were responsible for the survey and the analyses in their own country but a subset of samples and parameters were analysed by a central laboratory as suggested by the FSCC. The JRC i) established a new group of soil experts ii) organised and coordinated the soil analyses by a central laboratory by tender and iii) organised and coordinated the data collection, management, evaluation, interpretation and reporting also by tender. The biodiversity data generated by the BioSoil project were integrated in the Forest Focus databases. However, the soil data were integrated in the European Soil Information System (EUSIS) without any link with ICP Forests databases. FSCC ensured the technical support to the project. This was the preparation of the demonstration project (final amendments to the ICP-Forests manual, organisation of training courses, elaboration of supporting studies), the organisation of its 4th FSCC interlaboratory comparison and participation in the coordination meetings organised by the JRC in Ispra.

The newly established group of soil experts met at the JRC, Ispra, 13 - 14 December 2004 to finalise the detailed project proposal. This ad hoc advisory group defined the broad objectives of the BioSoil project. Twenty-two European countries submitted a national BioSoil project proposal to the Commission early 2005. After the agreement was reached, the JRC organised a kickoff-meeting

in Ispra on 16-17 June 2005 for all project partners. In October 2005 a joint BioSoil soil – biodiversity workshop took place and in December 2005 the JRC organised a preparation meeting of the soil component. At these meetings, the project partners reached a number of agreements on the manual to be used, the plots to be samples and the parameters to be analysed.

In contrast to the biodiversity component of the BioSoil project, the soil component had the advantage that it could build on the experience of the Forest Soil Expert Panel of ICP Forests that conducted a first soil condition survey already in the 1990s and since then continued to improve and harmonise the sampling and analytical procedures. The basis for the BioSoil implementation was the most recent version of the manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests (Part IIIa Sampling and Analysis of Soil). At that time, this was the update of June 2003 (Expert Panel on Soil and FSCC 2003). Though, as FSCC was testing and revising this manual in an ongoing Forest Focus study, all participating countries agreed to use the updated soil manual of June 2006 as the working version of the BioSoil project (FSCC 2006). The demonstration project would lead to further improvements of the manual and result in an updated version of 2010 (Cools and De Vos 2010).

The sampling strategy adopted for BioSoil included all sites of the 16 x 16 km Level I network of all Member States participating in the project. The possibility was given to include a limited subset of Level II plots as well. None EU member states though countries that participate in the ICP Forests programme were invited to conduct the soil survey on their Level I and II network on voluntary basis and submit the data to the central BioSoil database.

The measurements and analyses performed on Level I included all parameters (mandatory and optional parameters following the ICP Forests soil manual) for the soil layers 0 - 10 cm, 10 - 20 cm, 20 - 40 cm and 40 - 80 cm according to the revised manual of procedures (FSCC 2006). Analyses had to be performed at national level by laboratories that performed well in the FSCC interlaboratory comparison exercises following the analytical procedures described in the manual. A subset of the samples from benchmark Level I sites (corresponding to ca. 10 % - 15 % of the total sites) was analysed in parallel by a central laboratory selected through open tender by the JRC. The selected central and the national laboratory had to participate in the FSCC interlaboratory comparison exercises. In addition, the central laboratory would perform the same analysis of all mandatory parameters on archived samples from the previous Level I survey provided by the member states for the same benchmark sites (ca. 600 sites).

Following the ICP Forests soil manual, a full soil profile description according to the FAO guidelines and classified according to WRB had to be provided. This pedological information would be centrally stored in a newly developed soil profile database. In case countries had a profile description already available from the previous survey - possibly according to national or regional methods - and providing that this information was sufficient to complete the soil profile database, no new description was required. In the latter case, the already existing information could be submitted to the BioSoil database.

The technical support of the soil module was ensured by the FSCC. FSCC organised a 4th Interlaboratory Comparison (Cools et al. 2006) in 2005, prior to the start of the project, and a 5th Interlaboratory Comparison (Cools et al. 2007) at the time that the laboratories were receiving the first samples of the BioSoil soil survey. Additionally FSCC provided all participating laboratories with

free 'FSCC soil reference material' to be analysed in parallel with the BioSoil soil samples (Cools and De Vos 2008).

The necessary support in training of profile descriptions and classification of forest soils was provided by FSCC in four training courses. A first training course was hosted by the Austrian Federal Research and Training Centre for Forests, Natural Hazards and Landscape (BFW) in Vienna in October 2005 and was co-financed by the JRC. A second training course in Belgium in November 2005 covered the soils of western Europe and a third course on the Mediterranean soils took place in Spain in April 2006. These training courses were attended by members of the IUSS Working Group on WRB. A number of typical problems of classification of forest soils were defined and improvements were suggested. These were taken on board by the IUSS Working Group on WRB in the updated version of 2006. As the countries agreed at the 13th FSEP meeting in Alton (UK) to use the most recent official version of the WRB (as stated in the manual update of June 2006), FSCC needed to guide the member states in the transition between the initially agreed system of 1998 towards the key of 2006. After conducting a desk study on the differences between WRB 1998 and 2006, FSCC organised in March 2007 a training course focussing on the differences between WRB 1998 and WRB 2006.

Other supporting studies by FSCC concerned a variability in C-stocks assessments, guidelines on subsampling and homogenisation of soil samples to be provided to the central laboratory, guidelines on the selection of benchmark sites for analyses by the central laboratory, a literature review on useful pedotransfer functions, comparison of single versus triple $BaCl_2$ extraction methods, a review on the storage of forest soil samples, deduction of the limits of quantification, all published in technical reports.

The analysis of the samples of the benchmark sites was performed by the soil laboratory of INRA in Arras and the data collection, management, evaluation and reporting was done by INRA Orléans (Unité de Service InfoSol) and IFN (Inventaire Forestier National).

At the 14th FSEP in Florence, Italy, in April 2008 the forest soil experts expressed the need for a second forest soil condition report based on the BioSoil data to link the BioSoil dataset with the first forest soil condition survey conducted in the 1990s.

By the end of 2009, the INRA-IFN consortium validated and integrated all BioSoil data in the database and transferred the database to the JRC. A summary of the first results of the preliminary data evaluation was presented to the public during the BioSoil Conference held in Brussels in November 2009 followed by a first report (Hiederer and Durrant 2010). In 2011 Hiederer et al. elaborated a second report on the analysis of the soil data where all validated data submitted by the NFCs (as of 4 January 2010) and the results of the carbon analyses by the central laboratory were included. The report elaborated specifically on the soil carbon stocks and their changes, comparison of the carbon data at national level with the results of the central laboratory and the evaluation of the performance of the WRB soil classification system.

At the 16th FSEP meeting in Brussels (December 2009) the FSEP decided to devote this second forest soil condition report –as a FutMon product - to the contemporary status of forest soils and not their temporal evolution. The FSCC developed a first draft of this report by the end of 2010 which was presented and discussed at the 17th FSEP meeting in Tallinn, March 2011 during the prologation period of the FutMon project. At this forum, the forest soil experts of all participating

members states had the opportunity to express their comments which helped us in improving the quality of this end product in September 2011.

1.2 Scope of this report

The scope of this report is to describe the physical and chemical status of the pan-European forest soil condition as described and sampled in the survey period 2004-2008 on the systematic Level I grid of ICP Forests. The purpose of the soil inventory on Level I is first of all the assessment of basic information on the chemical and physical status and their changes over time and secondly, the assessment of soil properties which determine the forest soil's sensitivity to air pollution (acidification) among other threats. Besides providing soil data for the study of atmospheric deposition, the Level I soil survey serves also other purposes. An important part of Volume II of this report will be devoted to the accounting of forest soil carbon stocks to support climate change studies and the assessment of (available) nutrient stocks as the basis for sustainable forestry.

The Expert Panel on Soil and Soil Solution and the FSCC have put their shoulders underneath the BioSoil project because of the wealth of new information that would be collected on the existing ICP Forests network. Since the first Forest Soil Condition Report (Vanmechelen et al. 1997) many efforts have been made to improve the quality of forest soil surveys and the resulting databases. When the Programme Coordinating Centre (PCC) of ICP Forests, also coordinating beneficiary of FutMon, was not granted access to the validated BioSoil database, all BioSoil partners were prepared to resubmit all their BioSoil soil datafiles to the PCC and the FSCC. This was required to fulfull the evaluation tasks within the Life^{+} FutMon project and the elaboration of this report.

As it was unclear to what extent the validation of the datafiles was completed by the INRA-IFN consortium and the JRC, it was indispensable to validate the data (again) in order to gain confidence in the correctness of the newly assembled BioSoil data. Later it became apparent that data of a substantial amount of BioSoil plots were not considered by Hiederer and Durrant (2010) or Hiederer et al. (2011), but could be implemented by us. To distinguish between the BioSoil database located at the JRC and the newly assembled database at the FSCC, the latter will be referred to as the **BioSoil^{+}** database. This database is the foundation for this report.

1.3 General objectives

The main objective of this first volume is to describe the status of the pan-European forest soil condition in the survey period 2004 - 2008. More than 10 years after the first Forest Soil Condition Report on the ICP Forests large-scale soil survey (Vanmechelen et al. 1997), this report becomes the 'second Forest Soil Condition Report on the ICP Forests Level I and Level II network'. Besides thematic evaluations, the second volume attempts to describe temporal changes compared to the first inventory, in relation to carbon stocks, soil acidification, forest soil nutrients and heavy metals.

In 1997 different limitations have been defined to the database i) high interlaboratory variability for several parameters, ii) low reliability of calculated nutrient pools and iii) unavailability, for many plots, of parameters that are important in the study of soil changes introduced by atmospheric pollution (such as exchangeable cations in the organic layer). Between 1997 and the start of the BioSoil survey, the FSCC and the Forest Soil Expert Panel have continuously worked to overcome these limitations by updates of the reference soil analytical methods, by conducting interlaboratory

comparisons and by updating the list of mandatory and optional parameters. So the third objective is to evaluate the BioSoil$^+$ database and to verify whether all these efforts have been successful.

This report offers a critical evaluation and will make recommendations towards the future. It will include suggestions for further improvements to the existing quality strategy for European forest soil condition surveys and monitoring (uncertainties, detectability of changes, forest soil classification).

1.4 Report outline

The report consists of two volumes (Figure 1.1). This first volume describes, analyses and synthesises the BioSoil$^+$ soil data. It describes the content of the BioSoil$^+$ database and provides elemental statistics of all described and analysed forest soil parameters. The materials and methods chapter provides information on the plot locations, the conducted field survey and laboratory procedures. It outlines the data submission procedures and the structure of the data. An overview is given of all conducted data validation procedures. Detailed tables show the data availability of all fields contained within the BioSoil$^+$ database. In view of the thematic evaluations, ancillary information has been added at the plot level. Finally the statistical methods and procedures used in this report are explained.

For the results and discussion chapter, the four main datasets are systematically discussed parameter by parameter. The univariate analysis of the samples taken at fixed depth forms the main part of the results in this volume. Subsequently the plausible ranges are evaluated for use in future ring tests and European forest soil surveys. A number of multivariate analyses close this chapter. Conclusions and recommendations concerning the BioSoil$^+$ data resume this volume.

The second volume, released as a separate report, contains selected thematic evaluations. First it concentrates on the status of the European forest soils where the assessment of bulk density and coarse fragments content are evaluated as these factors are critical to the assessment of stocks of carbon and macronutrients dealt with in the following chapters. The soil nutrient availability and soil acidification status is discussed based on the same indicators as used in the first forest soil condition report. Additionally soil contamination by heavy metals is investigated and discussed. After the description of the status, this 2nd volume also looks into the changes observed between the first inventory in 1990s and the BioSoil survey. Temporal changes in bulk density, carbon stocks, soil nutrient availability, soil acidity and soil contamination are considered. Although Hiederer et al. (2011) already evaluated the performance of WRB within the BioSoil survey, the last chapter of the second volume evaluates both the classification of the humus forms and the application of WRB particularly for forest soils and formulates recommendations to the IUSS Working Group on WRB and to the European humus research group.

Second European Forest Soil Condition Report

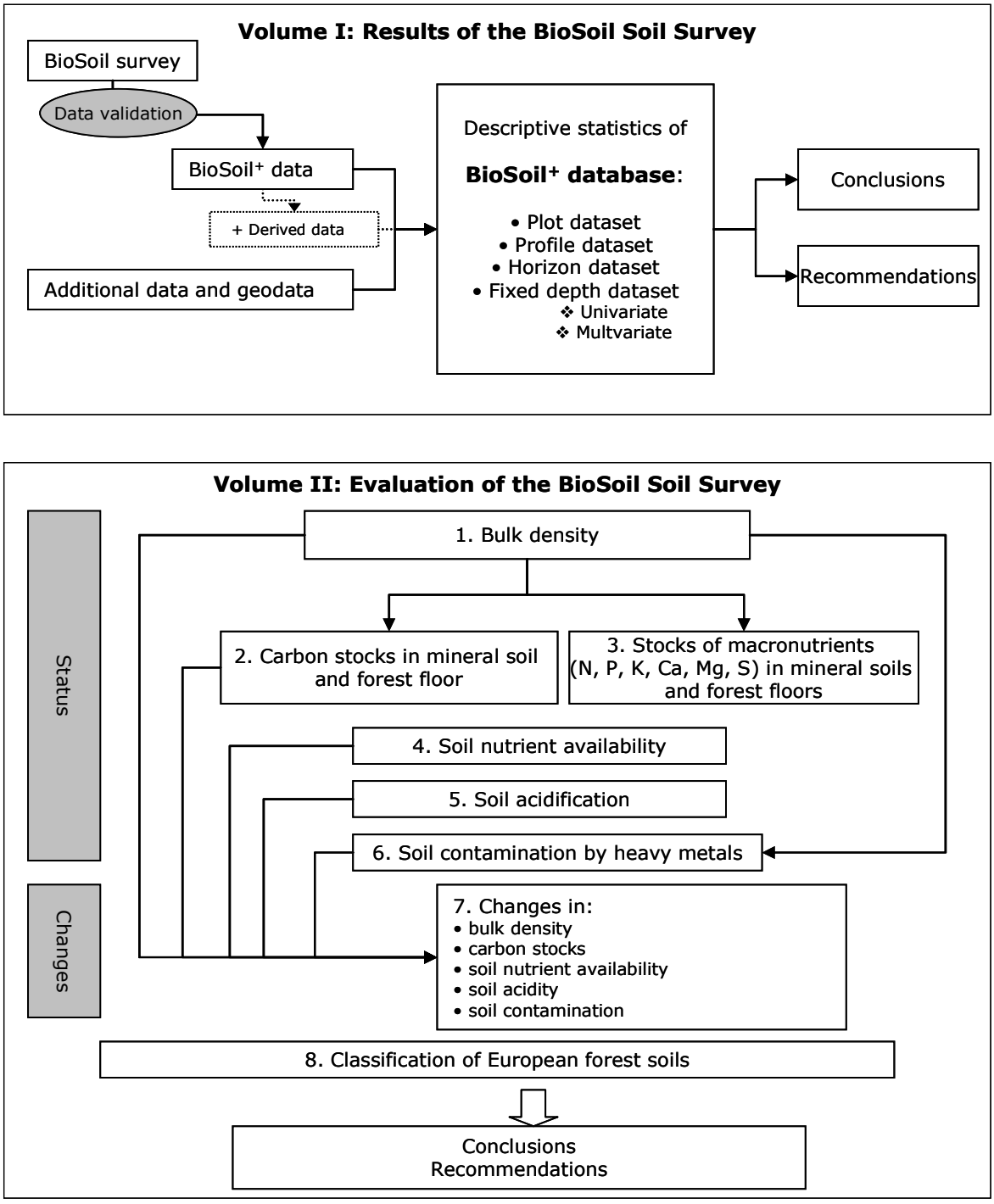


Figure 1.1. Outline of the Second Forest Soil Condition Report

2 Materials and methods

2.1 Plot selection

2.1.1 The ICP Forests Level I and Level II network

ICP Forests was launched in 1985 under the Convention on Long-range Transboundary Air Pollution of the United Nations Economic Commission for Europe (UN/ECE) due to the growing public awareness of possible adverse effects of air pollution on forests. ICP Forests monitors the forest condition in Europe using two different monitoring schemes. The first scheme (called Level I) is based on around 6000 observation plots on a systematic transnational grid of 16 x 16 km throughout Europe. In addition, the intensive monitoring scheme (called Level II) comprises around 500 plots in selected forest ecosystems in Europe. Currently 40 European countries participate in this programme (Table 2.1.1). Further ICP Forests cooperates with the forest health programmes in Canada and the USA.

Large-scale forest condition monitoring on Level I provides an annual pan-European overview on forest condition. Soil condition has been assessed on 5289 plots in the 1990s (Vanmechelen et al. 1997) and also the chemical status of the foliage condition on approximately 1400 plots has been investigated in the 1990s. With the BioSoil demonstration project, 2326 of these plots (44 %) were revisited and received an improved and extended soil assessment.

Concerning Level II, the countries participating in BioSoil selected a total of 127 plots for which they submitted data to the BioSoil^{+} database. The selection criteria of these plots differed amongst the countries. Ninety-five of these BioSoil Level II plots (75 %) have the same plot ID and are – based on the reported coordinates – located within a distance of 2 km of the plots assessed in the 1990s. Table 2.1.1.

2.1.2 Participating countries

Of the 40 European countries participating in the ICP Forests programme, 30 countries made in the 1990s a soil inventory either on their Level I or Level II plots. In the BioSoil demonstration project, 22 countries of the European Union took part in the soil component. Serbia made a soil survey in 2004 on a number of their ICP Forests Level I plots. These data were integrated in the BioSoil^{+} database. The number of plots common to both databases based on plot ID and on a distance of less than 2 km are shown in Table 2.1.1.

While the BioSoil survey at Level I aimed to cover all the plots of the systematic 16 x 16 km grid in the participating countries, BioSoil at Level II covered only a subset of the nearly 500 Level II plots of the permanent ICP Forests monitoring network. In contrast to the reports by Hiederer and Durrant (2010) and Hiederer et al. (2011) this report includes the Level I plots of Poland and all 603 Spanish Level I plots. The BioSoil^{+} database does not contain 4 Hungarian plots while they are included in the BioSoil database at the JRC in Ispra.

Table 2.1.1. Countries and number of plots included in 1) the Forest Soil Condition database and 2) the BioSoil^{+} database and 3) N° plots in common to both databases

ISO code	Country participating in ICP Forests programme	ICP Forests - Forest Soil Condition Survey		BioSoil^{+}		In common based on PlotID and distance < 2 km	
		Level I	Level II	Level I	Level II	Level I	Level II
AL	**Albania**						
AD	**Andorra**						
AT	**Austria**	131	20	135	2	124	2
PT	**Azores (Portugal)**	8					
BY	**Belarus**						
BE	**Belgium**	31	20	10	11	10	11
BU	**Bulgaria**	176	3				
IC	**Canaries (Spain)**	12		13		10	
HR	**Croatia**	87	7				
CY	**Cyprus**			15	4		
CZ	**Czech Republic**	100	11	146	8	107	4
DK	**Denmark**	25	16	26	3	25	2
EE	**Estonia**	91	7	96		71	
FI	**Finland**	442	31	630	32	403	30
FR	**France**	517	100	548	10	482	10
DE	**Germany**	416	87	425	8	156	6
GR	**Greece**	15	4		4		4
HU	**Hungary**	67	14	78		66	
IE	**Ireland**	22	15	36	3	22	2
IT	**Italy**	70	20	239	8	39	5
LV	**Latvia**	76	1	95		65	
LI	**Liechtenstein**						
LT	**Lithuania**	74		62	2		
LX	**Luxembourg**	4	2				
MD	**Moldova**						
ME	**Montenegro**						
NL	**Netherlands**	11	14				
NO	**Norway**	440	17				
PL	**Poland**	122	150	524	6		
PT	**Portugal**	149	4	103		99	
MK	**Republic of Macedonia**						
RS	**Republic of Serbia**			27			
RO	**Romania**	242					
RU	**Russian Federation**		12				
SK	**Slovak Republic**	111	8	112	8	107	6
SI	**Slovenia**	34		45	1	27	
ES	**Spain**	452	53	603	13	441	10
SE	**Sweden**	1249	100	794		59	
CH	**Switzerland**	48	16				
TR	**Turkey**						
UA	**Ukraine**						
GB	**United Kingdom**	67	10	166	4		3
	Total	***5289***	***742***	***4928***	***127***	***2326***	***95***

2.2 Field surveys

The BioSoil soil field survey consisted of two main components which were (i) the profile and horizon description and sampling of the genetic horizons in order to characterise the soil type (if not yet done in a previous inventory) and (ii) the sampling of composite samples taken at fixed depth intervals and subsequent chemical and physical analysis in the laboratory for forest soil monitoring purposes.

2.2.1 General plot description

Of each plot, field coordinates were measured mainly by Global Positioning System (GPS) as recommended by the ICP Forest Manual IIIa on Sampling and Analysis of Soil (FSCC 2006). The plot centre and profile coordinates had to be reported according to the World Geodetic System 1984 (WGS84) using geographical LAT/LONG coordinates in degrees, minutes, seconds (DMS). Also the altitude class was assessed either in the field by use of an altimeter or derived from a topographical map. The date of each field assessment had to be recorded. Further an estimate of the water availability to the trees was recorded following three classes (sufficient, insufficient or excessive). The most representative humus type for the plot was recorded following the guidelines provided in the soil manual (FSCC 2006).

2.2.2 Profile descriptions and sampling of horizons

Following the soil manual (FSCC 2006) a profile characterisation was required to classify the soil following the World Reference Base for Soil Resources (IUSS Working Group WRB 2006, IUSS Working Group WRB 2007). Although guidelines for profile description were available from FAO (1990), FSCC recommended to follow the adapted FSCC Guidelines for Forest Soil Profile Description (Mikkelsen et al. 2006). These guidelines were partly based on a draft version of the the 4th edition of the Guidelines for Soil Profile Description and Classification (FAO 2006) as the latter were not yet published at the onset of the project.

To define the humus forms in a harmonised way, FSCC consulted the experts of the European Humus Research Group Humus (HRG) who were in full preparation of a European morpho-functional classification of humus forms (Zanella et al. 2006, 2011). At the time of the project preparation in 2005, the definitions of the horizons and the humus forms were still preliminary. Table 2.2.1 shows the definitions as provided by the HRG which served as the reference definitions in the BioSoil survey. For the definitions of the subhorizons of the forest floor, we like to refer to the soil manual (FSCC 2006).

For the definition of the parent material, so the geological material in which the soil horizons are formed, the hierarchical classification system of the SGDBE was used (Lambert et al. 2003). Whenever possible, it was recommended to identify the parent material as precisely as possible using a 4 – digit code where the first digit refers to the major class, the second to the group level, the third to the type and the fourth digit to the sub-type.

Table 2.2.1. Definition of the main humus form (Zanella et al. 2006)

Code	Humus form	Description
1	Mull	- No presence of OH and - Presence of Az formed by anecic and endogeic earthworms
2	Moder	- Presence of OH and Ajz/Aze, gradual transition between OH and mineral A or - Presence of OF, OHz if overlying bedrock/coarse debris
3	Mor	- Presence of OH and Ae/E (with sharp transition to OH) and - Soil macro fauna absent, low abundance or absence of mesofauna, Ae never zoogenic
4	Amphi (or Amphihumus)	- Presence of OHz and Az and - Thick holorganic horizon with more or less sharp transition to the below zoogenous Az
5	Anmoor	Presence of a Aa horizon. An Aa horizon contains 8-17% organic carbon, is at least 20 cm thick and is developed under influence of stagnant water or fluctuating groundwater, organic substance highly humified with greasy (smeary) consistence. An Aa horizon may be biomacrostructured (=Aaz) when water table has fallen.
6	Histomull	- Hz dominant with high faunal activity (anecic worms) - Drained eutrophic peat soils with high content of clay (10-30%) or peat with thin subdominant clay cover. - Mostly grasslands, sometimes drained Elder woods - Ectoorganic layers are rare or extremely thin
7	Histomoder	Hs dominant, faunal activity mainly springtails
8	Histomor	- No or nearly no faunal activity - Fibric (Hf) – mesic (Hfs) – sapric forms (Hs)
9	Histoamphi	- Aa or Aaz is dominant - Presence of a Hz arthropod activity and a Aaz horizon

2.2.3 Sampling at fixed depths

Composite samples have been taken from the organic and the mineral soil layers. The terrestrial humus layers of the forest floor are usually built of an OL, OF and OH layer. In the BioSoil project the OL layer was sampled separately but the OF and OH layer could be combined in one sample since discrimination is often difficult. In case the organic layer is water saturated, the constituting layers are defined as Hf, Hfs or Hs. Not all of the organic layers need to be present. In some cases the layers are present but not sufficiently thick to allow proper sampling.

The mineral soil was sampled following the depth intervals 0 – 10 cm (optionally 0 – 5 and 5 – 10 cm), 10 – 20 cm, 20 – 40 cm and 40 – 80 cm. The peat soils followed a peat sampling design. The model behind the arrangement of the sampled layers is shown in Figure 2.2.1. One major difficultly that was not clearly stated in the manual and hence, not properly implemented in the BioSoil survey, is whether the thickness limit of '≥ 40 cm peat' should include all organic layers on top of a mineral soil or only refers to the combined thickness of the Hf, Hfs and Hs layers. This especially causes problems when sampling drained peat soils.

A second difficulty of the applied model is that it is possible to find two 0 cm reference lines in one profile in case a moderately thick peat soil is sampled above the underlying mineral soil. This is overcome by reporting the superior and inferior layer limit of each sampled layer where the M01,…

layers below the peat layer should continue from the depth where the peat layer ended. So the presence of a M01, M12 layer in the lower left corner of Figure 2.2.1 is to be avoided in the future.

The minimum requirements of the sampling design are given in the soil manual (FSCC 2006). The actual sampling design (location of the sampling points in the survey plots, N° of subsamples in the composite) falls under the responsibility of each of the participating countries and differs among the countries.

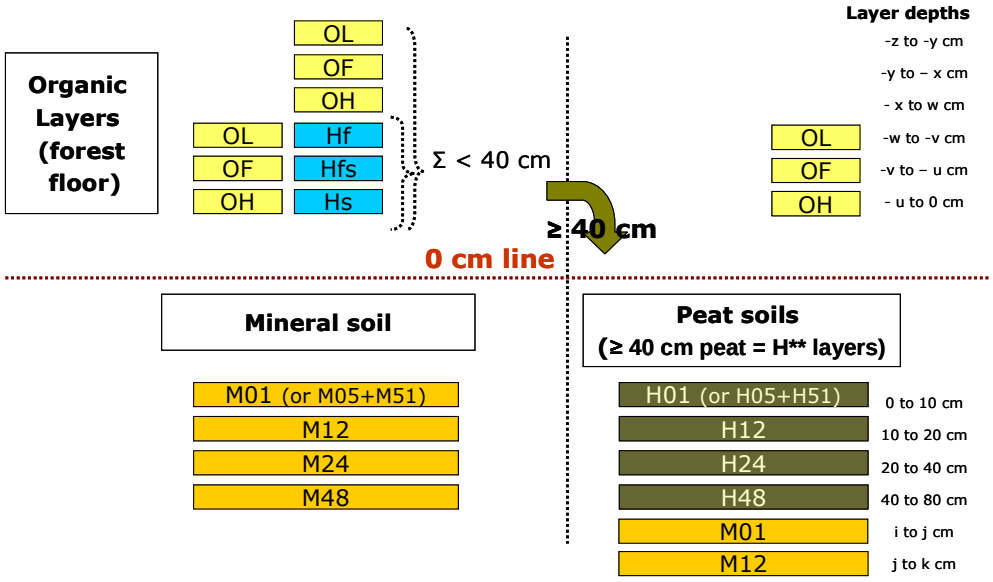


Figure 2.2.1. Diagram of the arrangement of the sampled layers at fixed depth intervals

2.2.4 Sampling for soil bulk density

To measure the soil bulk density in the laboratory, additional undisturbed core samples (minimum 5 replicates per layer) were taken of the mineral soil at the same depth intervals as the composite samples described above [0 – 10 cm layer (or 0 – 5 and 5 – 10 cm), 10 – 20 cm layer, 20 – 40 cm layer and 40 – 80 cm layer]. In order to determine the bulk density of the organic layer, the fresh organic layer mass was measured in the field (preferentially with its thickness) and a subsample was taken to the laboratory in order to determine its dry mass.

In case the mineral soils had a stone content of less than 5 % (and diameter less than 20 mm) and that could be sampled with a core sampler, the core sample could additionally be passed through a 2 mm sieve to measure the stone content. Alternatively the coarse fragment content could be estimated during routine profile description (Mikkelsen et al. 2006) or measured by the 'Finnish method' or 'rod penetration method' (FSCC 2006).

2.3 Laboratory analyses

2.3.1 Participating laboratories

In total 44 laboratories conducted analyses within BioSoil. Most countries had all the analyses done by one main soil laboratory. In some cases, a number of analyses were subcontracted to more specialised laboratories. In Germany, most of the analyses were centralised at the level of the

federal states, with the participation of 13 laboratories in BioSoil. The list of laboratories with their contact information is provided in Annex I.
It was requested that all of these laboratories participated in the FSCC Interlaboratory Comparisons. FSCC organised a 4th FSCC Interlaboratory Comparison in the preparatory stage of the BioSoil survey in 2005, a 5th in 2007 and a 6th in 2009. Three laboratories, mostly subcontractors, however failed to participate in any of these ring tests.

2.3.2 Analytical procedures for soil characterisation

To allow for a proper classification according to WRB (IUSS Working Group WRB 2006, 2007), it was necessary to analyse the genetic horizons by following the *Procedures for soil analysis* (ISRIC and FAO 2002) and the *USDA Soil Survey Laboratory Methods manual* (USDA 2004). These procedures are partly the same as the laboratory analyses outlined in the ICP-Forests Manual IIIa on Sampling and Analysis of Soil (FSCC 2006) but require in some cases additional analyses (Table 2.3.1).

Table 2.3.1. Comparison of analytical methods between the samples taken from the genetic horizon for profile characterisation and taken at fixed depths

Parameter	***Genetic horizons*** ISRIC manual (ISRIC, FAO 2002)	***Fixed depth samples*** ICP-Forests manual (FSCC 2006)
Organic carbon	OC by Walkley-Black * 1.3 OM = 2 * OC by Walkley-Black	Total organic carbon (TOC) OM = 1.72 * TOC
Particle size analysis	Pipette method or Hydrometer method	Pipette method (2-63-2000 µm)
pH	1:2,5 soil:liquid mixture Either H_2O or 1 M KCl	1:5 soil:liquid mixture $CaCl_2$, and or H_2O
Exchangeable bases (including Na, Mg) and CEC	1 M NH_4OAC	Unbuffered $BaCl_2$ method; single extraction
Exchangeable acidity	Unbuffered KCl solution ECEC = sum of bases + exch. Acidity (H+Al)	Titration of unbuffered $BaCl_2$ extract with NaOH
Effective CEC	silver thiourea or NH_4OAc	Unbuffered $BaCl_2$ method; single extraction
Reactive Fe, Al, (Si)	Same method: Acid oxalate extractable Fe, Al	
EC	measured on saturated soil paste at 25°C	not measured
Phosphate retention	Blakemore et al. (1987) p.44	Not measured
Gypsum	Sample shaken with water Precipitated by adding acetone, Ca conc. in precipitate	Not measured
ODOE	Percolation with acid ammonium oxalate extract Absorbance at 430 nm	Not measured
Melanic index	Extraction 0.5 M NaOH Absorbance at 450 and 520 nm	Not measured

2.3.3 Chemical and physical characterisation of the composite samples

All laboratory procedures that needed to be conducted on the composite samples are described in detail in Annex I of the soil manual (FSCC 2006). An overview is given in Table 2.3.2. All results had to be expressed on oven-dry basis. The bulk density was measured on the undisturbed core samples. Not all analyses were required on all composite samples. The reporting requirements varied with parameter and depth (Section 2.4).

Table 2.3.2. Overview of reference methods for the physical and chemical analysis within BioSoil

Physical analysis	**ISO Reference**	**Description**	**Unit**
Particle size distribution (sand, silt, clay)	ISO 11277 (1998)	Pipette method Finger test method (only allowed on Level I)	%
Coarse fragments	ISO 11464 (1994)	Laboratory measurement	vol %
		Field estimate during soil profile description	
Bulk density	ISO 11272 (1993)	Oven drying at 105°C	kg m^{-3}
Volume dry mass of organic layer	ISO 11465 (1993)	Field measurement of total fresh mass Field measurement of the horizon thickness Determination of moisture content in the laboratory	kg m^{-2} cm mass %

Chemical analysis	**ISO**	**Extractant**	**Measurement**			**Unit**
pH-$CaCl_2$	ISO 10390 (1994)	0.01 M $CaCl_2$	pH-electrode			
pH-H_2O		H2O	pH-electrode			
Total Nitrogen	ISO 13878 (1998)	-	Dry Combustion			g kg^{-1}
	ISO 11261 (1995)	-	Modified Kjeldahl			
Total Organic Carbon	ISO 10694 (1995)	-	Dry Combustion at ≥ 900 °C			
Carbonates	ISO 10693 (1994)	HCl	Calcimeter			
P	ISO 11466 (1995)	Aqua Regia by reflux digestion	ICP	Colorimetry		mg kg^{-1}
K, Ca, Mg, Mn				AAS		
Heavy metals: Cu, Cd, Pb, Zn						
Other: Al, Fe, Cr, Ni, Na						
Hg			ICP	Cold vapour AAS		
S			ICP			
		CNS - analyser				
Exchangeable acidity (or sum of AC) and free H^+	ISO 11254 (1994) modified	0.1 M $BaCl_2$	titration to pH 7.8 or 'German' method			$cmol_+$ kg^{-1}
Exchangeable Cations: Al, Fe, Mn	ISO 11260 (1994) modified	0.1 M $BaCl_2$	ICP	AAS	-	
Exchangeable Cations: Ca, K, Mg, Na					FES	
Reactive Fe and Al	ISRIC and FAO (2002)	Acid ammonium oxalate	AAS	ICP		mg kg^{-1}
Total Elements: Ca, Mg, Na, K, Al, Fe, Mn	ISO 14869-1 (2001)	HF or $LiBO_2$	AAS	ICP		mg kg^{-1}

2.3.4 Limit of quantification

Detection and quantification capabilities are fundamental performance characteristics of any chemical measurement process (Currie 1999). Knowledge of them is crucial for proper interpretation of chemical datasets. The limit of detection (LOD) is commonly defined as the smallest measure that can be detected with reasonable certainty for a given analytical procedure. It is the concentration at which we can decide whether an element is present or not. The limit of quantification (LOQ) is the concentration at which an element may be quantified reliably, for instance with a relative standard deviation (RSD) of repeated measures equal to 10 % of the mean. According to IUPAC recommendations, the LOQ is 3.3 times LOD. More information and

methods to assess LOD and LOQ are described in the ICP Forests Manual Part XVI on Quality Assurance and Control in Laboratories (König et al. 2010). In ICP-Forests, method/matrix quantification limits are considered instead of instrument LOQs since they are based on real-life (soil) samples. Consequently, they are more meaningful for environmental research than instrument limits.

Based on the last three FSCC soil ring tests, one prior to BioSoil (4th FSCC Interlaboratory Comparison 2005, Cools et al. 2006), one during BioSoil (5th FSCC Interlaboratory Comparison 2007, Cools et al. 2007) and one during the Life+ FutMon project (6th FSCC Interlaboratory Comparison 2009; Cools et al. 2010), laboratory proficiency data including LOQ information was gathered by FSCC. Empirical LODs and LOQs for most parameters were published in a supporting BioSoil report (De Vos 2008). During BioSoil, countries submitted also LOD/LOQ values to INRA, but this information was not available to us. However, since definitions were not clear which limits (detection or quantification) were requested, we assume that these INRA/JRC data have limited value.

A first attempt for listing average LOQ values of ICP Forests laboratories (n = 48 - 52) based on the 4th and the 5th FSCC interlaboratory comparisons was compiled in Clarke et al. (2008, 2009) and published in the ICP Forests QAQC manual (König et al. 2010). Initially, a distinction was made between organic (forest floor, peat layers) and mineral soil matrices as presented in Table 2.3.4.

Careful analysis during FutMon, based on added data from the 6th FSCC interlaboratory comparison, expert judgement and the use of median values instead of average LOQ data from the labs, led to an improved set of LOQ values for all parameters. Except for total N, it was found that the differences between the median LOQ values for organic and mineral matrices were in fact negligible, justifying one LOQ value for both matrices for most parameters (Table 2.3.4).

The latter LOQ list was used throughout this report to indicate the ability of at least 50 % of the BioSoil laboratories to quantify low levels with sufficient accuracy. Reported data below LOQ ($x < LOQ$) are considered not reliably quantifiable and are further treated as left censored data using appropriate statistical tools (Section 2.8).

In BioSoil, values below LOQ were reported as '-1'. Since the individual LOQ values from each lab are unknown to us, they were replaced by the median LOQ value of all labs to enable statistical processing.

Table 2.3.4. Quantification limits (LOQ) for soil parameters taken from the ICP Forests Manual Part XVI for organic (Org.) and mineral (Min.) forest soils and an improved set based on median values for both organic and mineral soil (Org./Min.). LOQs in bold are used in this report.

Parameter	Extract	Method	Unit	Deci-mals	LOQ in QAQC Manual		LOQ
					Org.	Min.	Org./ Min.
Moisture content (of air-dry sample)	-	Oven-drying	%	1	0.1	0.1	**0.1**
Particle size: clay	-	Pipette method	%	1	-	0.6	**0.5**
Particle size: silt	-	Pipette method	%	1	-	0.4	**0.5**
Particle size: sand	-	Sieve method	%	1	-	0.6	**0.5**
pH-$CaCl_2$	$CaCl_2$	pH-electrode	-	1	-	-	-
pH-H_2O	H_2O	pH-electrode	-	1	-	-	-
$CaCO_3$	HCl	Calcimeter	g kg^{-1}	0	3	3	**3**
Organic carbon	-	Dry combustion (> 900 °C)	g kg^{-1}	1	-	1.2	**1.2**
Total N	-	Dry combustion/ Modified Kjeldahl	g kg^{-1}	1	0.5	0.1	**0.5/ 0.1***
Free H^+	$BaCl_2$	Titration or German	$cmol_+$ kg^{-1}	2	0.25	0.21	**0.1**
Exchangeable acidity	$BaCl_2$	Calculation method	$cmol_+$ kg^{-1}	2	0.23	0.21	**0.1**
Exchangeable K	$BaCl_2$	ICP / AAS / FES	$cmol_+$ kg^{-1}	2	0.23	0.23	**0.03**
Exchangeable Ca	$BaCl_2$	ICP / AAS / FES	$cmol_+$ kg^{-1}	2	0.25	0.22	**0.03**
Exchangeable Mg	$BaCl_2$	ICP / AAS / FES	$cmol_+$ kg^{-1}	2	0.19	0.18	**0.03**
Exchangeable Na	$BaCl_2$	ICP / AAS / FES	$cmol_+$ kg^{-1}	2	0.18	0.17	**0.03**
Exchangeable Al	$BaCl_2$	ICP / AAS	$cmol_+$ kg^{-1}	2	0.22	0.2	**0.02**
Exchangeable Fe	$BaCl_2$	ICP / AAS	$cmol_+$ kg^{-1}	2	0.05	0.04	**0.02**
Exchangeable Mn	$BaCl_2$	ICP / AAS	$cmol_+$ kg^{-1}	2	0.03	0.03	**0.02**
Extractable P	Aqua regia	ICP /colorimetry	mg kg^{-1}	1	32.8	35.2	**35**
Extractable K	Aqua regia	ICP / AAS / FES	mg kg^{-1}	1	74.2	81.4	**80**
Extractable Ca	Aqua regia	ICP / AAS / FES	mg kg^{-1}	1	45.9	50	**50**
Extractable Mg	Aqua regia	ICP / AAS	mg kg^{-1}	1	33.3	38.5	**35**
Extractable S	Aqua regia	ICP / AAS /CNS	mg kg^{-1}	1	128.6	134.6	**20**
Extractable Na	Aqua regia	ICP / AAS	mg kg^{-1}	1	20.6	21.1	**20**
Extractable Al	Aqua regia	ICP / AAS	mg kg^{-1}	1	76.1	77.1	**10**
Extractable Fe	Aqua regia	ICP / AAS	mg kg^{-1}	1	75.5	82.6	**10**
Extractable Mn	Aqua regia	ICP / AAS	mg kg^{-1}	1	7.2	7.8	**2**
Extractable Cu	Aqua regia	ICP / AAS	mg kg^{-1}	1	1.9	2	**1**
Extractable Pb	Aqua regia	ICP / AAS	mg kg^{-1}	1	2.4	2.4	**2.5**
Extractable Ni	Aqua regia	ICP / AAS	mg kg^{-1}	1	1.5	1.6	**1**
Extractable Cr	Aqua regia	ICP / AAS	mg kg^{-1}	1	3.3	3.3	**1**
Extractable Zn	Aqua regia	ICP / AAS	mg kg^{-1}	1	2	2.1	**2**
Extractable Cd	Aqua regia	ICP / AAS	mg kg^{-1}	1	0.5	0.5	**0.5**
Extractable Hg	Aqua regia	Cold vapour AAS	mg kg^{-1}	1	0.3	0.3	**0.03**
Total K	HF or $LiBO_2$	ICP / AAS / FES	mg kg^{-1}	1	50	50	**80**
Total Ca	HF or $LiBO_2$	ICP / AAS / FES	mg kg^{-1}	1	20	20	**50**
Total Mg	HF or $LiBO_2$	ICP / AAS / FES	mg kg^{-1}	1	5	5	**35**
Total Na	HF or $LiBO_2$	ICP / AAS / FES	mg kg^{-1}	1	20	20	**20**
Total Al	HF or $LiBO_2$	ICP / AAS / FES	mg kg^{-1}	1	40	40	**10**
Total Fe	HF or $LiBO_2$	ICP / AAS / FES	mg kg^{-1}	1	3.5	3.5	**10**
Total Mn	HF or $LiBO_2$	ICP / AAS / FES	mg kg^{-1}	1	0.5	0.5	**2**
Reactive Fe	Acid ammonium oxalate	ICP / AAS	mg kg^{-1}	1	44.6	44.6	**50**
Reactive Al		ICP / AAS	mg kg^{-1}	1	48.4	48.4	**50**

2.4 Data submission and structure of the data

2.4.1 Data submission formats

To organise the data submission to the BioSoil database, INRA-IFN developed a set of documents with the reporting requirements for the parameters. The "file format specification" documents used as basis for the database were:

- Plot sampling (PLS file), validated document of 20/07/2007 version 2.2
- Soil profile description (PRF file), validated document of 16/10/2007 version 2.4
- Soil profile horizons (PFH file), validated document of 16/10/2007 version 2.5
- Composite sample analysis (SOM file), validated document of 16/10/2007 version 2.4

Besides these file format specifications, a 'list of mandatory parameters' (14/06/2007, version 1.0) was distributed to the national focal centres for further comments in June 2007. That list corresponded closely to the list of mandatory parameters as defined in the ICP Forest soil manual (Expert Panel on Soil and FSCC 2003; FSCC 2006) for Level I and Level II but was less demanding than the above mentioned file format specifications. In the file format specifications it was for example agreed that all mandatory and optional parameters on the Level I plots described in the ICP Forest Manual would become mandatory in the BioSoil survey. To the knowledge of FSCC, there was no update and/or final validation of the 'list of mandatory parameters' (14/06/2007, version 1.0) and so no further reference will be made to this list. It is however possible that this draft list was confusing for the national focal centres which might explain the deviations between what is specified in the file format specifications and what they actually submitted to the database.

In the file format specification, four types of parameters/variables were distinguished:

1. **Mandatory parameters (M):** if they were not present for all records of the files, the files were rejected and so could not be submitted to the database
2. **Requested parameters (R):** if they were not present, the files were not rejected but a warning message was given and the country had to report why this parameter was missing
3. **Optional parameters (O):** if they were not present, files were not rejected and no warning error was given.
4. **Not asked (NA):** the parameter for the layer/horizon under consideration was not asked but could be reported on a voluntary basis

For each of the four datasets an overview of the requested data fields is provided below. it also provides the priority of reporting. Each NFC along with the responsible persons had to submit 4 data files for the Level I and/or 4 data files for the Level II plots. The structure of the files on Level I and II are exactly the same.

Information on the laboratory methods and the limits of detection/quantification was submitted using an on-line form, separately for Level I and Level II. A data accompanying report and pictures could be uploaded optionally. These data and the data of the Biodiversity component of the BioSoil project were occasionally reported to the FSCC and PCC Hamburg. They were used for validation and cross checks but not included in the BioSoil^{+} database.

2.4.2 General plot information

The PLS files contain the general plot information. The data reporting requirements were the same for Level I and Level II plots. Countries reported the coordinates of the plot in +/- DD.MM.SS (degrees, minutes, seconds). FSCC conducted necessary transformations (see further) on this data. Note that for privacy protection reasons, some countries submitted their coordinates only up to the minute level.

To allow the linkage with the existing country codes in the databases of the first inventory, FSCC added an additional field with the ICP Forests country codes (following the ICP Forests Manual) (Table 2.4.1). In the working database, two more identifying fields were added, namely the PLOTID = CODECOUNTY_CODEPLOT and BPLOTID = BIOSOILCOUNTRY_CODEPLOT. Throughout the text of this report, plots are identified by their BPLOTID (e.g. 401_259), except when explicitly stated otherwise.

Table 2.4.1. The INRA-IFN field name, BioSoil$^+$ field name, unit, N° of decimals, format, priority and description of the parameters reported in the General Plot information (PLS) dataset

INRA-IFN field name	BioSoil$^+$ field name	Unit	Deci-mals	Format	Prio-rity	Description
	CODECOUNTRY			Numeric	A	ICP Forests country code
CODE_COUNTRY	BIOSOILCOUNTRY			Numeric	M	BioSoil country code
CODE_PLOT	CODEPLOT			Numeric	M	Identification number of the plot
DATE_ASSESSMENT	DATEASSESS	YYYY-MM-DD		Date	M	Sampling data of the plot
LAYER_ANALYSIS_ LABORATORY	LAYANALLAB			Character	M	Identifier of the laboratory responsible for the analysis of the fixed-depth layer composite samples
HORIZON_ANALYSIS _LABORATORY	HORANALLAB			Character	M	Identifier of the laboratory responsible for the analysis of the pedogenetic horizon samples
LATITUDE	LAT	+/-DD MM SS	0	Character	M	Latitude of the plot in geographical coordinates (degrees, sexagecimal minutes, sexagesimal seconds; datum is WGS84; no projection)
LONGITUDE	LONG	+/-DD MM SS	0	Character	M	Longitude of the plot in geographical coordinates (degrees, sexagecimal minutes, sexagesimal seconds; datum is WGS84)
	DDLAT	DD.xxxxx	5	Numeric	A	Latitude of the plot in decimal degrees (datum is WGS84)
	DDLONG	(-)DD.xxxxx	5	Numeric	A	Longitude of the plot in decimal degrees (datum is WGS84)
	ETRS89.X	metres	0	Numeric	A	Longitude of the plot following the European Terrestrial Reference System 1989 LAEA
	ETRS89.Y	metres	0	Numeric	A	Latitude of the plot following the European Terrestrial Reference System 1989 LAEA
CODE_ELEVATION	CODEELEV			Numeric	R	Altitude (in 50 metres classes from 1 to 51)
CODE_WATER	CODEWATER			Numeric	R	Water availability (1 = insufficient, 2 = sufficient, 3 = excessive)
CODE_HUMUS	CODEHUMUS			Numeric	R	Humus type (1 = Mull, 2 = Moder, etc…)
OBSERVATION	OBSERVATION			Character	O	Other observations

Legend: A = added by FSCC; M = Mandatory; O = Optional; R = requested;

2.4.3 Soil profile description

Although the latitude and the longitude of the profile pit was asked, most countries reported in PLS and PRF files identical coordinates. In depth quality checks were performed on the plot coordinates reported in the general plot information dataset and so it was decided to remove the unvalidated profile coordinates from the BioSoil^{+} database. Concerning the soil classification, up to six qualifiers with their respective specifier code could be reported though it was mandatory to report at least one qualifier. Besides the WRB 2006 (or 2007) classification name, the opportunity to report the diagnostic horizons, properties and materials was given to allow future reclassifications in case changes would be made to the WRB classification system (Table 2.4.2).

2.4.4 Description of the soil horizons

The file format of this dataset, shown in Table 2.4.3, finds it origin partly in the Soil Geographical Database for Eurasia and the Mediterranean: Instruction Guide for the Elaboration at the scale 1:1,000,000, version 4.0 (Lambert et al. 2003). This explains why the units of certain parameters are different in the soil horizon description dataset compared to the dataset containing the analyse of the composite samples taken at fixed depths (e.g. OC, TON, BD, BDEST). In the data submission specification of the Life^{+} FutMon project and in the ICP Forests forms from 2011 onwards this has been harmonised. As Ireland reported seven additional chemical analyses (exchangeable acidity, Al, Fe, Mn, free H^{+}, reactive Fe and Al) on some of their plots, the columns in the PFH file do not match any longer the column headings of the INRA-IFN files. Seven additional columns were added behind the observation field.

Table 2.4.2. The INRA-IFN field name, BioSoil+ field name, unit, N° of decimals, format, priority and description of the parameters of the Soil Profile Description (PRF) dataset

INRA-IFN field name	BioSoil+ field name	Unit	Decimals	Format	Priority	Description
	CODECOUNTRY			Numeric	A	ICP Forests country code
CODE_COUNTRY	BIOSOILCOUNTRY			Numeric	M	Country code in the BioSoil project
CODE_PLOT	CODEPLOT			Numeric	M	Identification number of the plot
CODE_PROFILE	CODEPROF			Numeric	M	Identification number of the profile
DATE_DESCRIPTION	DATEDESCR	YYYY-MM-DD		Date	M	Date of description of the soil profile
LATITUDE		+/-DD.MM.SS		Character	M	Latitude of the soil profile (datum WGS84, no map projection)
LONGITUDE		+/-DD.MM.SS		Character	M	Longitude of the soil profile (datum WGS84, no map projection)
ELEVATION	ELEV	metres	0	Numeric	O	Elevation in metres above the mean sea level
CODE_ELEVATION	CODEELEV			Numeric	R	Elevation (in 50 metre classes from 1 tot 51)
WRB_GROUP	RSG			Character	R	World Reference Soil Group (WRB 2006) of the plot
WRB_QUALIFIER_1	QUAL1			Character	O	First adjective describing the reference soil group
WRB_SPECIFIER_1	SPEC1			Character	O	Specifier for the adjective 1
WRB_QUALIFIER_2	QUAL2			Character	O	Second adjective describing the reference soil group
WRB_SPECIFIER_2	SPEC2			Character	O	Specifier for the adjective 2
WRB_QUALIFIER_3	QUAL3			Character	O	Third adjective describing the reference soil group
WRB_SPECIFIER_3	SPEC3			Character	O	Specifier for the adjective 3
WRB_QUALIFIER_4	QUAL4			Character	O	Fourth adjective describing the reference soil group
WRB_SPECIFIER_4	SPEC4			Character	O	Specifier for the adjective 4
WRB_QUALIFIER_5	QUAL5			Character	O	Fifth adjective describing the reference soil group
WRB_SPECIFIER_5	SPEC5			Character	O	Specifier for the adjective 5
WRB_QUALIFIER_6	QUAL6			Character	O	Sixth adjective describing the reference soil group
WRB_SPECIFIER_6	SPEC6			Character	O	Specifier for the adjective 6
DIAGNOSTIC_1	DIAG1			Character	O	Code of the 1st diagnostic horizon, property or material
DEPTH_DIAGNOSTIC_1	DDIAG1	cm	0	Numeric	O	Depth of appearance of the first diagnostic horizon, property or material
DIAGNOSTIC_2	DIAG2			Character	O	Code of the 2nd diagnostic horizon, property or material
DEPTH_DIAGNOSTIC_2	DDIAG2	cm	0	Numeric	O	Depth of appearance of the 2nd diagnostic horizon, property or material
DIAGNOSTIC_3	DIAG3			Character	O	Code of the 3rd diagnostic horizon, property or material
DEPTH_DIAGNOSTIC_3	DDIAG3	cm	0	Numeric	O	Depth of appearance of the 3rd diagnostic horizon, property or material
DIAGNOSTIC_4	DIAG4			Character	O	Code of the 4th diagnostic horizon, property or material
DEPTH_DIAGNOSTIC_4	DDIAG4	cm	0	Numeric	O	Depth of appearance of the 4th diagnostic horizon, property or material
DIAGNOSTIC_5	DIAG5			Character	O	Code of the 5th diagnostic horizon, property or material
DEPTH_DIAGNOSTIC_5	DDIAG5	cm	0	Numeric	O	Depth of appearance of the 5th diagnostic horizon, property or material
DIAGNOSTIC_6	DIAG6			Character	O	Code of the 6th diagnostic horizon, property or material
DEPTH_DIAGNOSTIC_6	DDIAG6	cm	0	Numeric	O	Depth of appearance of the 6th diagnostic horizon, property or material
DIAGNOSTIC_7	DIAG7			Character	O	Code of the 7th diagnostic horizon, property or material
DEPTH_DIAGNOSTIC_7	DDIAG7	cm	0	Numeric	O	Depth of appearance of the 7th diagnostic horizon, property or material
DIAGNOSTIC_8	DIAG8			Character	O	Code of the 8th diagnostic horizon, property or material
DEPTH_DIAGNOSTIC_8	DDIAG8	cm	0	Numeric	O	Depth of appearance of the 8th diagnostic horizon, property or material
DIAGNOSTIC_9	DIAG9			Character	O	Code of the 9th diagnostic horizon, property or material
DEPTH_DIAGNOSTIC_9	DDIAG9	cm	0	Numeric	O	Depth of appearance of the 9th diagnostic horizon, property or material
DIAGNOSTIC_10	DIAG10			Character	O	Code of the 10th diagnostic horizon, property or material
DEPTH_DIAGNOSTIC_10	DDIAG10	cm	0	Numeric	O	Depth of appearance of the 10th diagnostic horizon, property or material
USE	USE			Numeric	R	Land use type of the soil profile
PARENT_MATERIAL_CODE	PMAT			Numeric	R	Code for the parent material of the plot
HGWL	HGWL			Numeric	R	Mean highest groundwater depth (in depth classes)
LGWL	LGWL			Numeric	R	Mean lowest groundwater depth (in depth classes)
TWT	TWT			Numeric	R	Type of water table (0 = no water table; 1 = perched; 2 = permanent)
ROOT	ROOT	cm	0	Numeric	R	Root depth of the soil profile
ROCK	ROCK	cm	0	Numeric	R	Rock depth of the soil profile
OBSTACLE	OBSTACLE	cm	0	Numeric	R	Obstacle depth of the soil profile
OBSERVATION	OBSERVATION			Character	O	Observations about the soil profile

Legend: A = added by FSCC; M = Mandatory; O = Optional; R = requested;

Table 2.4.3. The INRA-IFN field name, BioSoil^{+} field name, unit, N° of decimals (Dec.), format, priority and description of the parameters of the Soil Profile Horizon (PFH) dataset

IFN-INRA field name	BioSoil^{+} field name	Unit	Dec.	Format	Priority	Description
	CODECOUNTRY			Numeric	A	ICP Forests country code
CODE_COUNTRY	BIOSOILCOUNTRY			Numeric	M	BioSoil country code
CODE_PLOT	CODEPLOT			Numeric	M	Identification number of the plot
CODE_PROFILE	CODEPROF			Numeric	M	Identification number of the profile
CODE_HORIZON	CODEHOR			Numeric	M	Identification number of the horizon
DATE_ANALYSIS	DATEANAL			Date	M	Date of the laboratory analysis
HORIZON_DISCONTINUITY	HORDISC			Numeric	M (if exists)	Number to indicate a discontinuity in the horizon designation
HORIZON_MASTER	HORMAST			Character	M	Symbol of the master part of the horizon designation
HORIZON_SUBORDINATE	HORSUBORD			Character	M (if exists)	Symbol of the subordinate characteristics of the horizon designation
HORIZON_VERTICAL	HORVERT			Numeric	M (if exists)	Order number of the vertical subdivision in the horizon designation
HORIZON_LIMIT_SUP	HORTOP	cm	0	Numeric	M	The upper limit of the horizon depth
HORIZON_LIMIT_INF	HORBOT	cm	0	Numeric	M	The lower limit of the horizon depth
STRUCTURE	STRUCT			Numeric	R (min.)	Type of the soil structure
MOIST_COLOUR	COLOURM			Character	R (min.)	Moist colour of the soil matrix (Munsell soil colour charts)
DRY_COLOUR	COLOURD			Character	R (min.)	Moist colour of the soil matrix (Munsell soil colour charts)
TEXTURE_CLASS	TEXCLASS			Character	R (min.)	Horizon textural class
CLAY	CLAY	%	1	Numeric	R (min.)	First particle size fraction corresponding to clay
SILT1	SILT1	%	1	Numeric	R (min.)	Second particle size fraction corresponding to a silt fraction
SILT2	SILT2	%	1	Numeric	O	Third particle size fraction corresponding to a silt fraction
SAND1	SAND1	%	1	Numeric	R (min.)	Fourth particle size fraction corresponding to a sand fraction
SAND2	SAND2	%	1	Numeric	O	Fifth particle size fraction corresponding to a sand fraction
SAND3	SAND3	%	1	Numeric	O	Sixth particle size fraction corresponding to a sand fraction
CODE_COARSE_FRAG	CFCODE			Numeric	R (min.)	Code volume class of coarse fragments (stones & gravel with diameter > 2 mm)
COARSE_FRAG	CFMASS	Mass %	0	Numeric	O	Mass of coarse fragments (stones and graval with a diameter > 2 mm)
HORIZON_ORGANIC_CARBON	OC	%	1	Numeric	R	Organic carbon content
TOTAL_NITROGEN	TON	%	1	Numeric	R	Total nitrogen content
TOTAL_CALCIUM_CARBONATE	CARBONATES	%	0	Numeric	R (if present)	Total calcium carbonate ($CaCO_3$) content
GYPSUM_CONTENT	GYPSUM	%	0	Numeric	O	Gypsum content ($CaSO_4.2H_2O$)
PH	PH			Numeric	R	pH value of the soil horizon
ELECTRICAL_CONDUCTIVITY	EC	dS m^{-1}	0	Numeric	O	Electrical conductivity of the horizon
SODIUM_ADSORPTION_RATIO	SAR		0	Numeric	O	Sodium absorption ratio of the horizon
EXCHANGEABLE_SODIUM_PERCENTAGE	ESP	%	0	Numeric	O	Exchangeable sodium percentage of the horizon (expressed as % of CEC)
EXCHANGEABLE_CA	EXCHCA	$cmol_+ kg^{-1}$	2	Numeric	O	Exchangeable calcium of the horizon
EXCHANGEABLE_MG	EXCHMG	$cmol_+ kg^{-1}$	2	Numeric	O	Exchangeable magnesium of the horizon
EXCHANGEABLE_K	EXCHK	$cmol_+ kg^{-1}$	2	Numeric	O	Exchangeable potassium of the horizon
EXCHANGEABLE_NA	EXCHNA	$cmol_+ kg^{-1}$	2	Numeric	O	Exchangeable sodium of the horizon
CATION_EXCHANGE_CAPACITY	CEC	$cmol_+ kg^{-1}$	1	Numeric	R* (min.)	Cation exchange capacity (CEC) of the horizon
BASE_SATURATION	BS	%	0	Numeric	R* (min.)	Base saturation of the horizon [(exchangeable Ca+Mg+K+Na)/CEC * 100]
WATER_RETENTION_1	SWC1	Vol %	0	Numeric	O	First value of water retention of the horizon
WATER_RETENTION_2	SWC2	Vol %	0	Numeric	O	Second value of water retention of the horizon
WATER_RETENTION_3	SWC3	Vol %	0	Numeric	O	Third value of water retention of the horizon
WATER_RETENTION_4	SWC4	Vol %	0	Numeric	O	Fourth value of water retention of the horizon
WATER_RETENTION_FC	SWCFC	Vol %	0	Numeric	O	Fifth value of water retention corresponding to field capacity of the horizon
CODE_POROSITY	CODEPOROS			Numeric	R (min.)	Class of total porosity
POROSITY	POROSITY	Vol %	0	Numeric	O	Total porosity of the horizon
MEASURED_BULK_DENSITY	BD	g cm^{-3}	2	Numeric	R (min.)	Measured bulk density of the horizon
ESTIMATED_BULK_DENSITY	BDEST	g cm^{-3}	0	Numeric	R (min.)	Estimated bulk density of the fine earth if no measured bulk density exists
OBSERVATION	OBSERVATION			Character	O	Observation about the horizon
	EXCHACID	$cmol_+ kg^{-1}$	2	Numeric	NA	Exchangeable acidity of the horizon
	EXCHAL	$cmol_+ kg^{-1}$	2	Numeric	NA	Exchangeable aluminium of the horizon
	EXCHFE	$cmol_+ kg^{-1}$	2	Numeric	NA	Exchangeable iron of the horizon
	EXCHMN	$cmol_+ kg^{-1}$	2	Numeric	NA	Exchangeable manganese of the horizon
	FREEH	$cmol_+ kg^{-1}$	2	Numeric	NA	Free H^+ of the horizon
	REACAL	ppm	1	Numeric	NA	Acid oxalate extractable aluminium content of the horizon
	REACFE	ppm	1	Numeric	NA	Acid oxalate extractable iron content of the horizon

Legend: A = added by FSCC; M = Mandatory; O = Optional; R = requested; min. = Mineral soil horizons; NA = Not asked, R* = either the measured, either estimated value should be reported

2.4.5 Sampling and analyses at fixed depths

This dataset contains the laboratory analytical results of the composite samples taken at fixed depths. Table 2.4.4 shows the reporting requirements. Table 2.4.5 lists the INRA-IFN field name, the BioSoil^{+} field name, the unit, the number of decimals, the format and description of the parameters of the Composite Sample Analysis (SOM) dataset.

Table 2.4.4. Reporting requirements of the parameters of the Composite Sample Analysis (SOM) dataset.

Parameter	Level I					Level II				
	OL	OF, OH, OFH, H	0-10 cm	10-20 cm	20-40 /40-80 cm	OL	OF, OH, OFH, H	0-10 cm	10-20 cm	20-40 /40-80 cm
BIOSOILCOUNTRY, CODEPLOT, CODELAYER, REPETITION,			M					M		
Depth of upper and lower boundary of layer			R					R		
N° of subsamples, data of analysis			M					M		
Moisture content			R					R		
CLAY, SILT, SAND fraction, texture class	NA	NA	R	R	R	NA	NA	R	R	R
Bulk density	NA	NA	R*	R*	R*	NA	NA	R	O	O
Estimated bulk density	NA	NA	R*	R*	R*	NA	NA	O	O	O
Coarse fragments	NA	NA	R	R	R	NA	NA	R	O	O
Organic layer weigth	R	R	NA	NA	NA	O	R	NA	NA	NA
pH-$CaCl_2$	NA	R	R	R	R	NA	R	R	R	R
pH-H_2O	NA	R	R	R	R	NA	O	O	O	O
OC, TON	NA	R	R	R	R	NA	R	R	R	O
Carbonates	NA	R	R	R	R	NA	R	R	R	O
Exchangeable Al, Fe, Mn, Ca, K, Mg, Na, free H^+ and exchangeable acidity	NA	R	R	R	R	NA	R	R	R	R
Aqua regia extractable Al, Cr, Fe, Na, Ni and S	R	R	R	NA	NA	O	O	O	NA	NA
Aqua regia extractable Ca, K, Mg, Mn, P	R	R	R	R	R	O	R	O	O	NA
Aqua regia extractable Cd, Cu, Pb and Zn	R	R	R	NA	NA	O	R	R	NA	NA
Extractable Hg	O	O	O	NA	NA	O	O	O	NA	NA
Acid oxalate extractable Fe and Al	NA	R	R	R	R	NA	O	R	R	R
Total elements: Ca, Mg, Na, K, Al, Fe, Mn	NA	NA	NA	NA	NA	NA	NA	O	O	O
Observation	O	O	O	O	O	O	O	O	O	O

Legend: M = Mandatory; NA = not asked; O = Optional; R = requested

* either estimated or measured bulk density had to be reported

Table 2.4.5. The INRA-IFN field name, BioSoil$^+$ field name, unit, N° of decimals (Dec.), format, priority and description of the parameters of the Composite Sample Analysis (SOM) dataset

INRA-IFN field name	BioSoil$^+$ field name	Unit	Dec.	Format	Description
	CODECOUNTRY			Numeric	ICP Forests country code
CODE_COUNTRY	BIOSOILCOUNTRY			Numeric	BioSoil country code
CODE_PLOT	CODEPLOT			Numeric	Identification number of the plot
CODE_LAYER	CODELAYER			Character	The code of the layer
REPETITION	REPETITION			Numeric	Order number of the composite when several composites are analysed of the same layer on one plot
LAYER_LIMIT_SUP	LAYTOP	cm	0	Numeric	The upper limit of the layer depth
LAYER_LIMIT_INF	LAYBOT	cm	0	Numeric	The lower limit of the layer depth
SUBSAMPLES	SUBSAMPLES			Numeric	Number of subsamples used in the composite
DATE_ANALYSIS	DATEANAL			Date	Date of the laboratory analysis (date of last analysis performed on the sample)
MOISTURE_CONTENT	MOISTURE	g $100g^{-1}$	1	Numeric	Moisture content of the sample
CLAY	CLAY	g $100g^{-1}$	1	Numeric	Mass fraction of clay (0 - 2 µm)
SILT	SILT	g $100g^{-1}$	1	Numeric	Mass fraction of silt (2 - 63 µm)
SAND	SAND	g $100g^{-1}$	1	Numeric	Mass fraction of sand (63 - 2000 µm)
TEXTURE_CLASS	TEXCLASS			Numeric	USDA texture class
MEAN_BULK_DENSITY	BD	kg m^{-3}	0	Numeric	Mean bulk density of the fine earth (average from the different measurements)
ESTIMATED_BULK_DENSITY	BDEST	kg m^{-3}	0	Numeric	Estimated bulk density of the fine earth
MASS_COARSE_FRAG	CFMASS	g $100g^{-1}$	0	Numeric	Mass of coarse fragments (stones and gravel with diameter > 2 mm
VOLUME_COARSE_FRAG	CFVOL	Vol %	0	Numeric	Volume of coarse fragments (stones and gravel with diameter > 2 mm
ORGANIC_LAYER_WEIGHT	ORGLAY	kg m^{-2}	2	Numeric	Total dry mass of the organic layer
PH(CACL2)	PHCACL2		1	Numeric	pH measured in $CaCl_2$
PH(H2O)	PHH2O		1	Numeric	pH measured in water
ORGANIC_CARBON	OC	g kg^{-1}	1	Numeric	Organic carbon content
TOTAL_N	TON	g kg^{-1}	1	Numeric	Total nitrogen content
CARBONATES	CARBONATES	g kg^{-1}	0	Numeric	Carbonate content
EXCHANGEABLE_ACIDITY	EXCHACID	$cmol_+$ kg^{-1}	2	Numeric	Total exchangeable acidity
EXCHANGEABLE_AL	EXCHAL	$cmol_+$ kg^{-1}	2	Numeric	Exchangeable Al
EXCHANGEABLE_CA	EXCHCA	$cmol_+$ kg^{-1}	2	Numeric	Exchangeable Ca
EXCHANGEABLE_FE	EXCHFE	$cmol_+$ kg^{-1}	2	Numeric	Exchangeable Fe
EXCHANGEABLE_K	EXCHK	$cmol_+$ kg^{-1}	2	Numeric	Exchangeable K
EXCHANGEABLE_MG	EXCHMG	$cmol_+$ kg^{-1}	2	Numeric	Exchangeable Mg
EXCHANGEABLE_MN	EXCHMN	$cmol_+$ kg^{-1}	2	Numeric	Exchangeable Mn
EXCHANGEABLE_NA	EXCHNA	$cmol_+$ kg^{-1}	2	Numeric	Exchangeable Na
FREE_H+_ACIDITY	FREEH	$cmol_+$ kg^{-1}	2	Numeric	Free H^+ acidity
EXTRACTABLE_AL	EXTRAL	mg kg^{-1}	1	Numeric	Aqua regia extractant determination for Al
EXTRACTABLE_CA	EXTRCA	mg kg^{-1}	1	Numeric	Aqua regia extractant determination for Ca
EXTRACTABLE_CD	EXTRCD	mg kg^{-1}	1	Numeric	Aqua regia extractant determination for Cd
EXTRACTABLE_CR	EXTRCR	mg kg^{-1}	1	Numeric	Aqua regia extractant determination for Cr
EXTRACTABLE_CU	EXTRCU	mg kg^{-1}	1	Numeric	Aqua regia extractant determination for Cu
EXTRACTABLE_FE	EXTRFE	mg kg^{-1}	1	Numeric	Aqua regia extractant determination for Fe
EXTRACTABLE_HG	EXTRHG	mg kg^{-1}	1	Numeric	Aqua regia extractant determination for Hg
EXTRACTABLE_K	EXTRK	mg kg^{-1}	1	Numeric	Aqua regia extractant determination for K
EXTRACTABLE_MG	EXTRMG	mg kg^{-1}	1	Numeric	Aqua regia extractant determination for Mg
EXTRACTABLE_MN	EXTRMN	mg kg^{-1}	1	Numeric	Aqua regia extractant determination for Mn
EXTRACTABLE_NA	EXTRNA	mg kg^{-1}	1	Numeric	Aqua regia extractant determination for Na
EXTRACTABLE_NI	EXTRNI	mg kg^{-1}	1	Numeric	Aqua regia extractant determination for Ni
EXTRACTABLE_P	EXTRP	mg kg^{-1}	1	Numeric	Aqua regia extractant determination for P
EXTRACTABLE_PB	EXTRPB	mg kg^{-1}	1	Numeric	Aqua regia extractant determination for Pb
EXTRACTABLE_S	EXTRS	mg kg^{-1}	1	Numeric	Aqua regia extractant determination for S
EXTRACTABLE_ZN	EXTRZN	mg kg^{-1}	1	Numeric	Aqua regia extractant determination for Zn
TOTAL_AL	TOTAL	mg kg^{-1}	1	Numeric	Total Al content
TOTAL_CA	TOTCA	mg kg^{-1}	1	Numeric	Total Ca content
TOTAL_FE	TOTFE	mg kg^{-1}	1	Numeric	Total Fe content
TOTAL_K	TOTK	mg kg^{-1}	1	Numeric	Total K content
TOTAL_MG	TOTMG	mg kg^{-1}	1	Numeric	Total Mg content
TOTAL_MN	TOTMN	mg kg^{-1}	1	Numeric	Total Mn content
TOTAL_NA	TOTNA	mg kg^{-1}	1	Numeric	Total Na content
REACTIVE_AL	REACAL	mg kg^{-1}	1	Numeric	Acid oxalate extractable Al
REACTIVE_FE	REACFE	mg kg^{-1}	1	Numeric	Acid oxalate extractable Fe
OBSERVATION	OBSERVATION			Character	

2.5 Data validation

Although the data submitted by the NFCs were subject to a validation by a posteriori procedures for quality assurance by INRA-IFN (Hiederer and Durrant 2010; Hiederer et al. 2011), it was unclear to what extent this validation was completed for the national datasets sent to FSCC. Hiederer and Durrant (2010) reported that the BioSoil uniformity check reports were sent rather late in the project so that NFCs were unable to correct their data and resubmit them in time. Therefore, following compilation of the national datasets, it was indispensable to run validation checks (again) in order to gain confidence in the correctness of the newly assembled BioSoil data. The followed procedures may deviate from the ones performed by INRA-IFN. Three main types of validation checks have subsequently been carried out: compliance, conformity and uniformity checks. As the data validation progresses the degree of automatisation decreases and the need for expert knowledge increases.

2.5.1 Compliance checks

These checks verify if the format (syntax) of the submitted information is according to the required specifications stipulated in the file format specification documents (see Section 2.4). These do not test if the content (value) of a parameter is valid. Data ranges are not verified, only syntactic checks are applied.

All data had to be submitted as fixed format ASCII files with ';' comma separated values. Though, not all the countries submitted the data as *.csv files. Some reported MS Excel or MS Access (DE, Saxony 413) files along with different formats for certain fields, which could be read for instance, as a text instead of a numeric field. In text fields, empty space before the start of the text have been deleted/removed.

2.5.1.1 General plot description (PLS) files

Completeness

The plot information file from Cyprus (PLS) on its 4 Level II plots did not contain any data. The country and PLOTIDs, coordinates and altitude class were taken from the profile information dataset.

Dates

The format in which the dates were reported (YYYY-MM-DD) was checked and if necessary corrected.

Coordinates

The coordinate syntax was checked for both Level I and II plots: (i) the presence of a +/- sign in front of the coordinate and (ii) the length of the coordinate variable which should be 9 characters (including the +/- sign and a dot separated format of two characters for degrees, minutes and seconds). A number of countries did not report the '+' sign (Sweden, the German federal states of Mecklenburg-Vorpommern, Rheinland-Pfalz, Saarland and Thüringen) where it was added. Estonia reported in the format DDMMSS. In some plots (e.g. 10_17) spaces were preceding the PLOTID,

which were removed. At locations where degrees were zero, prefix minus or plus signs were lost. In that case, the right sign was added.
No compliance errors were found on the level II data.

2.5.1.2 Soil profile description (PRF) file

Dates

The format in which the dates were reported (YYYY-MM-DD) was checked and if necessary corrected.

Rooting depth, rock depth and depth to obstacle

These fields should contain an integer value. Estonia reported 'N/A' for the rock depth and obstacle depth of all profiles. These values were removed to make the fields numeric.

2.5.1.3 Soil horizon description (PFH) file

Dates

The format in which the dates were reported (YYYY-MM-DD) was checked and if necessary corrected.

Horizon designations

The horizon master symbols should comply with the FAO guidelines for soil profile description (FAO 2006). In some cases none existing horizon symbols according to the FAO nomenclature have been used like for example P, M (once), G (5 times), OO (8 times). The subordinate symbols should be also a character that is listed in the FAO guidelines and the subordinate field should not contain a capital letter as this refers to a master horizon. In case the subordinate symbol was a number, it was removed (e.g. in Spain). In two records, the subordinate symbol was used twice. The duplicated 's' was removed (plot 5_600 in Italy).

Depth of horizons

The 0 cm line (reference) should be at the interface of the forest floor and the mineral soil. Organic O and H layers should therefore have negative depth unless the organic layer is thicker than 40 cm and is described as a peat soil. Corrections have been made accordingly.

MOIST_COLOUR and DRY_COLOUR

This field contains non numeric code. Some countries used parentheses unlike others. All parentheses were removed. The code of the hue had to be written with a decimal point. In case a comma was used, it was replaced.

Laboratory analysis of soil samples

Values below the detection limit should have been attributed the value '-1'. All non numeric notations as for example '<LOQ value' were replaced accordingly. When numeric fields contained 'NA' or other indications of missing values, they were removed.

2.5.1.4 Analyses of fixed depth layers (SOM file)

Dates

The format in which the dates were reported (YYYY-MM-DD) was checked and if necessary corrected.

Code of the layer

Unnecessary leading spaces were removed, for example ' OL' was corrected into 'OL'.

Laboratory analysis results

Values below the quantification limit should have received the value '-1'. All non numeric notations as for example '<LOQ value' were replaced accordingly. Decimals had to be separated by a point. In case they were separated by a comma, the content of the fields were considered as text fields. In numeric fields containing 'NA', the 'NA' was removed.

2.5.2 Conformity checks

These checks evaluate if the submitted data (value or observation) is plausible (realistic). It includes plausible range tests of quantitative variables, evaluations of attributed classes and qualitative descriptions. Single observations are checked individually, not compared with observations within the profile or the plot, nor with observations of other plots.

During the BioSoil validation period, INRA-IFN asked the NFCs to verify the generated error reports. Sometimes these reports were very extensive lists and it is unclear to what extent data has been screened and corrected in the files that were submitted to FSCC. We ran conformity checks again, contacted the NFCs if necessary and corrected the data accordingly.

2.5.2.1 General plot description (PLS) file

Country codes

The file format specifications of the BioSoil survey adapted the existing ICP Forests country codes after modifications. All German federal states and the two Belgian regions received a separate code. Both the mainland of Portugal and the Azores received a new code (101 and 102) though Portugal used the code '100' for all its plots on the mainland.

In order to improve the comparability of the BioSoil^{+} database with the data contained in the first Forest Soil Condition inventory, the countries, federal states and regions received two types of country codes: an ICP Forest country code (CODECOUNTRY) and a BioSoil^{+} country code (BIOSOILCOUNTRY) which may deviate from the country codes stored in the original BioSoil database hosted by the JRC.

We maintained the ICP Forest country code of the Canaries (95) and the Azores (96). The mainland of Portugal kept the country code '10' as CODECOUNTRY. For the Belgian regions and the German federal states, the country codes defined in the file format specifications of the BioSoil survey were adopted.

Coordinates

As the coordinates had to be reported in the sexagesimal system, seconds and minutes had to be an integer ranging from 0 till 59. This was not the case for (some) plots in United Kingdom, Lithuania, Portugal, Finland, Germany and Italy. Occasionally this was due to typing errors. In total 62 Level I plot coordinates in the PLS file were corrected thanks to input from national experts. Subsequently boundary checks of the coordinates were conducted by mapping them. Three German federal states switched latitude and longitude coordinates and could easily be corrected.

Codes for elevation, water, humus

It was checked whether the codes of the elevation, water availability and humus were integers in the predefined range. No violations were met.

2.5.2.2 Soil profile description (PRF) file

Soil classification

It was checked whether the correct codes of the WRB Reference Soil Groups (RSG), qualifiers and specifiers were used. The reference list of codes is the one published in Annex 2 of IUSS Working Group WRB (2006) with the exception that the code for 'Hyperalbic' is 'hb'. The code 'ha' should be used for 'Haplic' (personal communication with Michéli, 2006).

Spain reported '0' codes for the code of the first qualifier. These '0' codes, which had no meaning, were removed. Further Spain reported on two plots 'g' instead of 'gl' (11_1744 and 11_1781) and twice 'iv' instead of 'lv' (11_1570 and 11_886). Corrections were based on the national report of the first soil inventory (Moreno et al. 1997).

Concerning the specifier codes, Austria used qualifier and specifier codes that existed in WRB 1998 (FAO, ISRIC and ISSS 1998) but no longer in WRB 2006. Table 2.5.1 shows how this was corrected in the BioSoil^{+} database.

Table 2.5.1. Examples of conversion of codes between WRB 1998 and WRB 2006

Plot	RSG	Qualifier	Specifier	Correction
14_228	LV	oh	h	ho
14_197	LV	oh	h	ho
14_230	RG	hu	m	fo mo UM
14_167	RG	hu	u	fo
14_273	GL	hu	u	fo
14_129	RG	hu	m	mo UM
14_325	RG	hu	m	fo mo UM

The corrections made were related to the priority ranking of the qualifiers and whether a certain qualifier could be combined with the concerning RSG.

Land use

In the data field "USE" it was asked to report either one of the three codes '311' = broad-leaved forests; '312' = coniferous forest and '313' = mixed forests. Austria and Finland used codes that were given in a draft document on the specification for the data submission and reported according to a different coding system. So the land use code did not pass the conformity check on 765 plots.

As this data could be derived from ancillary data sources, the missing codes were added by FSCC in a new data field 'USEu' ('u' referring to update).

Parent material

Unlike the codes of the other soil profile parameters, it was possible to report the code '0000' for 'no information'. This code was used on 145 of the 4924 Level I plots. On the other hand, there were also a number of empty fields which had exactly the same meaning. So it was decided to remove this code from the data field giving equal importance to the fact that no information was reported or that it was reported that there was no information.

2.5.2.3 Soil horizon description (PFH) file

Verification of the data units

Special attention was given to the parameters which were asked in both the profile data and in the data of the samples taken at fixed depths but with different units (e.g. the data on the bulk density of the fine earth, the organic carbon, total nitrogen content, carbonates). Also differences in conventions in national databases and the ICP Forests manual was an important source of reporting mistakes (e.g. Austria reported aqua regia extractable macronutrients in g kg^{-1} instead of mg kg^{-1}). Mistakes concerning the $CaCO_3$ content were in Latvia related to the fact that the C–element content in the carbonates (g kg^{-1}) had been reported instead of the $CaCO_3$ content as a whole (in g kg^{-1}).

2.5.2.4 Analysis results of fixed depth layers (SOM file)

Repetition

The numeric field 'REPETITION' should be at least 1. Missing values (NA) or zero's are replaced by 1 as for all Latvian plots. This field is often required for routines aggregating data at plot level.

Layer Thickness

The difference between the top and bottom of a layer (i.e. the thickness) was checked. Inconsistencies were found (e.g. OFH of plot 6_140) and corrected based on profile description information.

Aqua regia extractable elements

Plausibility ranges were checked and NFCs were contacted in case of strong outliers. For example, by applying this check it appeared that Czech republic swapped the results of the parameters Fe and Na on a few plots.

2.5.3 Uniformity checks

This type of checks is comparative in nature. Data values or qualitative observations (e.g. horizon designations) are compared with spatially or temporally related values or observations. This way, data of adjacent layers are compared, samples within and between plots, etc. Expert judgment is crucial for these checks.
Mapping of classified variables is used to detect lack of spatial uniformities (see dot maps in Annex III). Data is also compared with previous surveys to detect strong temporal changes.

2.5.3.1 General plot description (PLS) file

PLOTID

When linking BioSoil^{+} data with ICP-Forest data by PLOTIDs, we soon found identical plot codes in the German federal states: 401 (Baden-Württemberg), 410 (Nordrhein-Westfalen) and 414 (Sachsen-Anhalt). For instance, plot code 267 is present in the three federal states (BPLOTIDs = 401_267, 410_267 and 414_267) but conforms to 4_267 as PLOTID when only the country is considered. Duplicates are found in Germany for 13 other plot codes (i.e. 267, 283, 286, 287, 288, 300, 306, 307, 259, 260, 266, 267, 284, 285 and care should be taken when linking soil data with plot or species information using the former PLOTIDs.

Coordinates

A check for duplicate coordinates was run. For BioSoil^{+} Level I, 4 duplicate coordinates were found (i.e. 15_2569 and 15_2572, 15_3718 and 15_3723, 15_3683 and 15_3684 and 15_3701 and 15_3708). All these were Finish plots. Feedback on this from Finland resulted in corrected coordinates. For Level II, no duplicates were present.

The reported coordinates of 15 % of the Level II plots differed between PLS and PRF file. For instance. Finland truncated the seconds to minute level in PRF. Seconds were added from the PLS file. Slovakia had wrong PRF coordinates for Level II plots 54_204 and 54_206. Czech republic apparently reversed LAT and LONG coordinates for 8 Level II plots. Four plots from the United Kingdom had incorrect coordinates, one of them was located in the North sea. With the help of the NFCs, all these coordinates were properly corrected.

Various uniformity checks were conducted comparing the plot coordinates of BioSoil^{+} with those of the Forest Soil Condition Database (FSCDB) and the PCC Database. When the location of identical plots (based on PLOTID) were deviating more than 2 km, NFCs were contacted to verify the correctness of their coordinates. This way, 24 Latitude and 26 Longitude coordinates were corrected in the PLS file. Since over 94 coordinates were erroneous in the PRF file, all coordinates were discarded from this file.

Elevation

The code of the elevation was cross checked with the elevation in metres and it was checked whether the elevation codes in the PLS file was the same as in the PRF file. In case inconsistencies were met, the plot location was checked with Google Earth images which also provide elevation information. Based on this information, a best estimate of the elevation class was made.

Humus form

The reported humus form (CODEHUMUS) was checked using thickness, organic mass and carbon stock in the total forest floor. Inconsistencies were found especially for Mull types. On 73 plots (65 in Sweden, 6 in UK, one in Germany and one in France) the Mull forest floors were more than 5 cm thick and stored over 50 t C ha^{-1}, which is very unlikely. Some of these 'Mulls' had also OH or thick OFH layers indicating misclassification. An updated HUMUSTYPEu field was created where the unreliable classified Mulls were discarded.

Observation

Some countries entered 'no observation', 'not observation', 'no', 'no observations',… This content was added purely to be able to export the record into a correctly formatted *.csv file but has no real meaning. All these contents were removed from the data file since it did not add additional information.

2.5.3.2 Soil profile description (PRF) file

Reference Soil Groups

The correctness of the classification of the soil profiles according to the World Reference Base for Soil Resources (IUSS Working Group WRB 2006 and 2007) was checked based on information reported on the profile and horizon description and the composite samples taken at fixed depths. As it is at this stage hard to say whether the classification is either correct or wrong, each classification name was attributed to one of the classes shown in Table 2.5.2.

Table 2.5.2. Definition of the 'reliability classes' used in the uniformity checks of the reference soil groups

Reliability class	Description	N° profiles Level I/II	% of profiles
1	Based on the available information the classification seems correct	3017/78	62/63
2	Essential information is lacking but based on the available information, the classification can be correct	1534/27	31/22
3	Essential information is lacking but based on the available information, the classification seems incorrect.	69/10	1.4/8
4	The classification and the available information contradict each other.	132/9	2.7/7.3
5	Classification is lacking	172/0	3.5/0
Total		4924/124	

In each reference soil group a selection was made of diagnostic criteria which were checked based on the available information from the horizon descriptions. Table 2.5.3 shows for each reference soil group, the checked criteria.

Table 2.5.3. Criteria used in the validation of the Reference Soil Groups (RSG)

RSG	Criterion
HISTOSOLS	Thickness of organic layer ≥ 40 cm
ANTHROSOLS	
TECHNOSOLS	
LEPTOSOLS	Continuous rock within 25 cm of soil surface
VERTISOLS	Clay ≥ 30%
FLUVISOLS	Organic carbon ≥ 0.2% till 1 m
GLEYSOLS	reducing conditions/gleyic colour pattern (mentioned as diagnostic)
ANDOSOLS	Presence of andic/vitric properties: * Bulk density ≤ 900 $kg.m^{-3}$ (andic) * Al_{ox} + 0.5 Fe_{ox} ≥ 2.0% (andic), ≥ 0.4 % (vitric) * OC content < 25%
PODZOLS	*Presence of Spodic B horizon:* * OC content > 0.5% * pH < 5.9 * colour requirements
PLANOSOLS	abrupt textural change
STAGNOSOLS	reducing conditions/ stagnic colour pattern or albic horizon
CHERNOZEMS **KASTANOZEMS** **PHAEOZEMS**	*Presence of Mollic horizon:* * OC ≥ 0.6% * Colour requirements * base saturation ≥ 50%
GYPSISOLS	Presence of gypsum
CALCISOLS	*Presence of Calcic horizon:* $CaCO_3$ ≥ 15%; Secondary $CaCO_3$ enrichment
ALBELUVISOLS **ALISOLS** **ACRISOLS** **LUVISOLS** **LIXISOLS**	*Presence of Argic horizon:* * Texture LS or finer; clay ≥ 8% * clay illuviation: overlying horizon < 15% clay => clay in Argic + 3% overlying horizon ≥ 15% and < 40 % => clay Argic > 20 % relative increase overlying horizon > 40% clay => clay in Argic + 8%
UMBRISOLS	*Presence of Mollic or Umbric horizon*
ARENOSOLS	Soil texture till 100 cm: LS or coarser
CAMBISOLS	
REGOSOLS	

Qualifiers and specifiers

The use of the qualifier follows certain rules. First of all, there are priority rules which make that the first qualifier should always be a prefix qualifier. In case none of the prefix qualifiers apply, the qualifier *Haplic* should be used. This priority rule has been validated and corrected:

1) In some cases no or insufficient attention was given to the priority ranking but the problem could be solved by re-arranging the qualifiers without adding or deleting any of the reported qualifiers.

2) In case none of the prefix qualifiers applied and when a suffix qualifier was given as first qualifier, the qualifier *Haplic* has been added and the concerning qualifier moved to the field of a lower order qualifier (done for approximately 326 profiles).

3) In case the *Haplic* qualifier was given as a lower order qualifier, *Haplic* was removed as it contains in this case no information. The priority of the other qualifiers was adjusted according to the rules outlined in IUSS Working Group WRB (2006; 2007). This was done for 7 profiles.

4) In the validation procedure, also first order prefix qualifiers could be found at lower ranking positions. They were upgraded accordingly. It could happen that the original *Haplic* qualifier in the first position was replaced by the appropriate prefix qualifier.

Secondly, the Folic qualifier is a qualifier that received in WRB 2006 (update 2007) more attention compared to WRB 2006. As this is a typical qualifier for forest soils and can easily be checked, the Folic qualifier was added during the data validation procedure (N° of profiles = 144).

After this validation process, the first qualifier of more than 800 profiles changed, this is 17 % of the profiles for which a first order qualifier was reported.

According to the guidelines outlined in IUSS WG on WRB (2006), certain qualifier – specifier combinations receive a separate two-letter code instead of the classical combination of a two-letter code for the qualifier complemented by a one-letter code for the specifier. In order to harmonise the dataset, all such special qualifier – specifier combinations were converted in the two-letter code. This was stored into a new qualifier field. The concerning combinations are given in Table 2.5.4.

Table 2.5.4. Recoding of qualifier-specifier combinations into a two-letter specifier code. The number shows the frequency as observed in the BioSoil$^+$ database.

Qualifier	Specifier	N°	New code	Qualifier	Specifier	N°	New code
Albic (ab)	Hyper (h)	1	hb	**Gypsic (gy)**	Hyper (h)	0	hp
Alic (al)	Hyper (h)	0	hl		Hypo (w)	0	wg
Andic (an)	Thapto (b)	0	ba	**Leptic (le)**	Endo (n)	68	nl
Calcic (cc)	Hyper (h)	0	hc		Epi (p)	17	el
	Hypo (w)	1	wc	**Luvic (lv)**	Hypo (w)	0	wl
Duric (du)	Endo (n)	0	nd	**Ochric (-)**	Hyper (h)	2	ho
Dystric (dy)	Endo (n)	0	ny	**Salic (sz)**	Endo (n)	0	ns
	Epi (e)	84	ed		Epi (p)	0	ea
	Hyper (h)	94	hd		Hyper (h)	0	hs
Eutric (eu)	Endo (n)	42	ne		Hypo (w)	0	ws
	Epi (e)	7	ee	**Sodic (so)**	Hypo (w)	3	wn
	Hyper (h)	96	he	**Skeletic (sk)**	Hyper (sk)	21	hk
Fluvic (fv)	Endo (n)	0	nf	**Vitric (vi)**	Thapto (b)	0	bv
Gleyic (gl)	Endo (n)	27	ng				

Subsequently it was checked whether the described qualifiers can occur in combination with the concerning RSG. To help the user, all qualifiers that can be used with a specifier RSG are listed in IUSS WG on WRB 2006 (update 2007). On the other hand however, this system is not fully waterproof and it could be possible that a user describes a qualifier which fits perfectly well with the concerning RSG but is not listed in the WRB guidelines. FSCC will report this to the IUSS Working Group on WRB.

There are several reasons why a certain qualifier cannot be used in combination with a RSG.

1) A first reason is data redundancy. Depending on the RSG where they are used, some qualifiers give redundant information, for example *Dystric* in Podzols or *Histic or Haplic* in Histosols. These redundant qualifiers have been removed.
2) A second reason is that certain qualifiers have especially defined to be used in combination with only one reference soil group. For example, the *Spolic* qualifier (abbreviated as 'sp') typically associated with Technosols. By checking, it appeared that the qualifier *Spodic* was

sometimes wrongly abbreviated as 'sp' while it should have been 'sd'. Based on the data in PFH dataset this could easily be corrected.

3) The qualifier *Gleyic* can in certain RSGs (Planosols, Stagnosols) only occur when the gleyic properties are described below 50 cm of the surface, so when it is *Endogleyic*. As it was not mandatory to report the specifier code and when no depth was given of these gleyic properties, it could not be checked and the qualifier stayed as such in the dataset.
4) In France, 44 profiles received the *Vetic* qualifier in combination with Lixisols and Acrisols. This is however a qualifier typically used in highly weathered tropical soils. The NFC was contacted and the soil were checked and reclassified. The RSG turned out not to be Lixisols or Acrisols, but rather Cambisols and Luvisols and also the *Vetic* qualifier was no longer applicable. Also in Poland a small number of Acrisols and Lixisols have been described. They have not yet been corrected so far.

Mean highest and mean lowest ground water level

The class of the mean lowest ground water level had to be lower or equal to the mean highest level of the ground water table. If this was not the case, the two values were switched except in the case where one of both values belonged to the class 'no water table'. This was the case for 16 Latvian plots.

Rooting depth (ROOT), rock depth (ROCK) and depth to obstacle (OBSTACLE)

These tree fields should contain an integer between 0 and 200 – 300 cm as they described a depth in cm measured from the top of the mineral soil. When a 0 value was reported, it was checked whether this was a real value i.e. in case the soil profile consists of an organic layer of less than 40 cm thick directly overlying continuous rock. In case the ROCK field contained a 0 value but a higher rooting depth or obstacle depth was observed the 0 values in ROCK field were removed (19 ROCK fields in Sachsen, a higher number of ROCK field values in Latvia). Also the 17 zero values in Mecklenburg-Vorpommern for ROOT were removed and all 19 OBSTACLE fields in Sachsen.
Further, each of the three fields often contained default values such as 80, 90, 99, 100, 101 cm. The limits of 80 and 90 cm resemble very well with the lower sampling depth of the deepest horizon, and the number 99, 100 and 101 seem to be default values for 'roots observed till at least 100 cm', or 'no rock or obstacle observed within 100 cm'. So an important problem here was that these data fields were poorly defined. One needs to take into account that only information can be given on rooting, rock or obstacle depth within the limits of the profile pit that has been studied.
To overcome the problem of fragmentary data on these three variables, a new data field 'DEPTHSTOCK' was derived based on the information contained in these three fields and based on the lower limit of deepest described horizon in the PFH dataset (see further in Chapter 2.7 Use of additional data).

2.5.3.3 Soil horizon description (PFH) file

Textural classes

The textural class is an important parameter in the classification of soils and often used in modelling work. An important prerequisite for determining the textural class, is that the sum of the particle size classes of the fine earth: clay (0-2 µm), silt (2- 63 µm) and sand (63 – 2000 µm) equals 100.0 %. In these uniformity checks this rule was checked and corrections were made on

the largest class (in %). Subsequently the textural classes were calculated (using Excel add in Texture Autolookup ver 2.8, Sung 1995). In case the textural class was missing or wrong, the right textural class was added to the dataset.

2.5.3.4 Analysis of fixed depth layers (SOM file)

Upper and lower boundary of the fixed depth layers

In theory all fixed depth layers should correspond with following upper and lower limits of the layers (Table 2.5.5).

Table 2.5.5. Upper and lower limits of the fixed depth layers

CODE_LAYER	LAYER_LIMIT_SUP	LAYER_LIMIT_INF
M05, H05	0 cm	5 cm
M51, H05	5 cm	10 cm
M01, H01	0 cm	10 cm
M12, H12	10 cm	20 cm
M24, H24	20 cm	40 cm
M48, H48	40 cm	80 cm

An important exception is in peat soils where a mineral soil layer M0* may be described below the peat layers at fixed depths (a second 0 cm reference line in one profile should be avoided in future databases). When the lower limit of a fixed soil layer is not reached when the soil is laying above shallow, continuous rock, this can be indicated by adjusting the LAYER_LIMIT_INF accordingly.

Some countries reported depths deviating from the ones in Table 2.5.5. In case it concerned layers deeper than 80 cm of depth, layer designations were recoded as 'Mxx' in mineral soils and 'Hxx' in peat soils. This was the case for 4 plots in Sweden and one in Estonia for Level I, whereas it did not occur on Level II. Organic rich M-layers – generally with more than 20 % OC - have been recoded into H-layers. It mainly concerned M-layers on Swedish and British plots. Negative depths were reserved for the forest floor layers (OL, OF, OH, OFH, Hf, Hfs, Hs), so for the organic material on top of the mineral soil or peat layer. Exceptions on this rule are possible when a profile holds buried organic layers below peat or mineral soil.

These rules were checked and corrected accordingly. Although these corrections have large implications (e.g. for Estonia, Sweden), it improves the comparability of the soil database a lot. These corrections were very important regarding further use of the data as in calculation of stocks and stock changes according to organic/mineral soil layers and comparative soil depths.

Some plots had forest floors or mineral layers with overlapping depths. Four Finish plots had identical depths for M01 and H01 layers, which were corrected with the help of a national forest soil expert.

Exactly 27 layers from Level I and 15 layers from Level II plots were corrected for their depth limits because (i) these limits did not correspond with the limits of the adjacent layer or (ii) the depth of the lower and upper limit were erroneously reversed. In the first case, the deviance was less than one cm (rounding errors) or just few cm, but for stock calculation based on depths it is important that the layer depths were matching.

Combined layers

On 19 Level I plots (none in Level II), a combined occurrence of terrestric and semiterrestric forest floor layers was found. In such a case, aerated layers are expected on top of the hydromorphic layers. In one plot (13_2533) the horizon boundaries of Hfs and OF overlapped completely, which was corrected by putting the OF layer on top with half of the reported thickness.

On 58 Level I plots (none in Level II) both H and M layers occurred together. The thicknesses of these layers were thoroughly checked for inconsistencies. Overlap of H and M horizons was found on plots 15_3140, 15_2386, 15_2056, 15_1620 and 13_1221. The depths were corrected using the profile description data and/or feedback from national experts.

Textural classes

The textural classes were validated and corrected in the same manner as for soil horizon description (PFH) file. See above.

Bulk density

Both measured and estimated bulk density values were checked if they were exceeding the plausible range. For instance, an unrealistic value of 6808 kg m^{-3} was reported for M24 layer on plot 53_1001523 and changed into 1808 kg m^{-3} in line with the magnitude of BD of the adjacent layers.

Carbon and Nitrogen concentration

A comparison check for OC and TON was conducted by computing the C:N ratio for all layers in the SOM files. Ratios exceeding 100 were carefully checked. By doing so, we found that Czech Republic reported the nitrogen concentration in percent instead of g N kg^{-1} for about 330 layers. These values were corrected. Other occurrences of C:N > 100 were found mostly in M48 layers, but are left unchanged.

Exchangeable elements

The sum of the acid exchangeable cations (Al, Fe and Mn) and the free H^+ should approximate the exchangeable acidity. By applying this check, it appeared that France calculated the exchangeable acidity as the sum of all cations. After contacting the NFC, the exchangeable acidity was replaced by the sum of Al and free H^+ as this is the method that France used in the first inventory.

Niedersachsen calculated the exchangeable acidity as the sum of free H^+, Al, Fe and Mn. This was indeed correct on most of their reported records though there was factor 10 difference in the mineral layers of 19 plots, probably due to the fact that in national databases in Germany many exchangeable elements are expressed in mmol kg^{-1}, while the BioSoil database uses cmol kg^{-1}. Corrections were made accordingly.

2.6 Data availability

This chapter shows for all parameters in the BioSoil^{+} database the data availability for each country at the time of the writing of this report. This data availability deviates from the data availability in the BioSoil database at the JRC (for already before mentioned reasons) but also because the FSCC made some corrections and small additions – with or without contacting the NFCs – between the data submission at the end of 2009 and the publication of this report (September 2011).

2.6.1 General plot information dataset

The general plot information dataset (PLS) contains information on 4928 Level I plots in 23 countries and 127 Level II plots in 17 countries (Table 2.6.1). On Level I, four plots lack the sampling date (DATEASSESS) as no sampling was performed in the BioSoil survey: two of them were felled (7_188, 402_1540); on one plot the soil was completely disturbed (8_103) and one plot was not accessible (402_1714). One additional plot in Niedersachsen in Germany (409_526) was not sampled as it was not accessible due flooding.

Table 2.6.1. Data availability in the general plot information dataset. The number before the slash refers to the number of Level I plots. The number behind to Level II.

Country	N° plots	DATEASSESS	ANALLAB	COORDINATES	CODEELEV	CODEWATER	CODEHUMUS
AT	135/2	135/2	135/2	135/2	135/2	135/2	135/2
BE	10/11	10/11	10/11	10/11	10/11	10/11	10/11
CY	15/4	15/-	15/-	15/4	15/4	15/-	15/-
CZ	146/8	146/8	146/8	146/8	146/8	145/8	146/8
DE	425/8	423/8	425/8	425/8	425/8	425/8	423/8
DK	26/3	26/3	25/3	26/3	26/3	-/-	-/-
EE	96/-	96/-	96/-	96/-	96/-	96/-	96/-
ES	603/13	603/13	603/13	603/13	603/13	603/13	603/8
FI	630/32	630/32	630/32	630/32	630/32	630/32	629/32
FR	548/10	548/10	548/10	548/10	548/10	548/10	540/10
GB	166/4	166/4	166/4	166/4	166/4	166/4	166/4
GR	-/4	-/4	-/4	-/4	-/4	-/4	-/4
HU	78/-	78/-	78/-	78/-	78*/-	67/-	18/-
IC	13/-	13/-	13/-	13/-	13/-	13/-	13/-
IE	36/3	35/3	35/3	36/3	36/3	36/3	22/3
IT	239/8	239/8	239/8	239/8	239/8	239/8	239/8
LI	62/2	62/2	62/2	62/2	62/2	62/2	62/2
LV	95/-	95/-	95/-	95/-	95/-	-/-	-/-
PL	524/6	524/6	524/6	524/6	524/6	524/6	524/6
PT	103/-	103/-	103/-	103/-	103/-	103/-	103/-
RS	27/-	27/-	27/-	27/-	27/-	27/-	8/-
SE	794/-	794/-	794/-	794/-	794/-	794/-	784/-
SI	45/1	45/1	45/1	45/1	45/1	45/1	45/1
SK	112/8	112/8	112/8	112/8	112/8	112/8	112/8
Total	**4928/127**	**4925/123**	**4926/123**	**4928/127**	**4928/127**	**4795/120**	**4693/115**

The field 'ANALLAB' provides the ID of the laboratory that performed the analyses. This could be specified separately for the analysis performed on the horizons and on the fixed depth samples but is only mentioned once in this table as the data availability in these two fields is very similar.

Except for 31 Hungarian plots, the elevation class (CODEELEV) in 50 metre intervals was reported on all the Level I plots. On 26 Hungarian plots, the elevation class was reported in the first inventory and so the values were copied in the BioSoil^{+} database. On the remaining 5 plots, the class was derived from the information on the altitude in the stratifier dataset (WORLDCLIM geodatabase version 1.3, 2009). CODEWATER was available for 97 % and the humus type (CODEHUMUS) for 95 % of the Level I plots. The latter data is lacking for all Latvian and Danish plots and on the majority of the Hungarian and Serbian plots.

On Level II, most of the mandatory fields in the general plot information dataset are available. Though, there was no information on the 4 Cypriote plots as the submitted data file did not contain any data. The coordinates and elevation were taken from the soil profile description dataset. Furthermore, humus type (CODEHUMUS) and water availability (CODEWATER) is missing for the Danish plots. Additionally, five of the 13 Spanish plots lack information on the humus type.

2.6.2 Soil profile description dataset

Table 2.6.2. shows that the strict mandatory information (country code, identification numbers of plot and profile, date of description, coordinates) was available for all 4924 Level I and 127 Level II plots.

Table 2.6.2. Data availability in the soil profile description dataset. The number before the slash refers to the number of Level I plots. The number behind to Level II.

Coun-try	N° profiles	CODEPROF	DATEDESCR	ELEV	CODEELEV	USE	USEu	HGWL	LGWL	TWT
AT	135/2	135/2	135/2	-/-	135/2	135/2	135/2	135/2	135/2	135/2
BE	10/11	10/11	10/11	10/11	10/11	10/11	10/11	10/11	10/11	10/11
CY	15/4	15/4	15/4	15/4	15/4	15/4	15/4	15/4	15/4	15/4
CZ	146/8	146/8	146/8	146/8	146/8	146/8	146/8	146/8	146/8	146/8
DE	422/8	422/8	422/8	372/6	422/8	422/8	422/8	422/8	422/8	396/8
DK	25/3	25/3	25/3	-/-	25/3	25/3	25/3	25/3	-/-	25/3
EE	96/-	96/-	96/-	-/-	96/-	96/-	96/-	96/-	96/-	96/-
ES	603/13	603/13	603/13	-/13	603/13	-/13	603/13	-/-	-/-	-/-
FI	630/32	630/32	630/32	630/32	630/32	630/32	605/32	630/32	630/32	630/32
FR	548/20	548/20	548/20	543/-	548/20	548/20	548/20	397/20	475/20	548/20
GB	166/4	166/4	166/4	-/-	166/4	166/4	166/4	146/-	146/-	154/-
GR	-/4	-/4	-/4	-/4	-/4	-/4	-/4	-/4	-/4	-/4
HU	78/-	78/-	78/-	43/-	78*/-	78/-	78/-	76/-	76/-	77/-
IC	13/-	13/-	13/-	-/-	13/-	-/-	13/-	-/-	-/-	-/-
IE	36/3	36/3	36/3	36/3	36/3	-/3	36/3	35/3	35/3	35/3
IT	239/8	239/8	239/8	171/8	239/8	239/8	239/8	239/8	239/8	239/8
LT	62/2	62/2	62/2	-/2	62/2	62/2	62/2	62/2	62/2	62/2
LV	95/-	95/-	95/-	-/-	95/-	95/-	95/-	95/-	95/-	95/-
PL	524/6	524/6	524/6	524/-	524/6	524/6	524/6	524/6	524/6	524/6
PT	103/-	103/-	103/-	103/-	103/-	103/-	103/-	103/-	103/-	103/-
RS	27/-	27/-	27/-	-/-	27/-	-/-	27/-	-/-	-/-	-/-
SE	794/-	794/-	794/-	792/-	794/-	794/-	794/-	598/-	598/-	598/-
SI	45/1	45/1	45/1	45/1	45/1	45/1	45/1	45/1	45/1	45/1
SK	112/8	112/8	112/8	112/8	112/8	112/8	112/8	112/8	112/8	112/8
Total	**4924/ 137**	**4924/ 137**	**4924/ 137**	**3542/ 100**	**4924/ 137**	**4245/ 137**	**4924/ 137**	**3911/ 120**	**3964/ 117**	**4045/ 120**

On each of the 10 French Level II plots, two profiles were described and classified. Therefore the Tables 2.6.2 till 2.6.4 provide the N° of profiles for which the concerning information is available. So the total number of profiles described at Level II is 137.

Again, the elevation codes (CODEELEV) on the Hungarian plots were missing on 31 plots. It was decided to copy the CODEELEV from the completed PLS file. The (ELEV) elevation in metres above sea level was not completed with secondary information as we assume that secondary information is less accurate.

In Ireland the profile on the felled plot was not described and classified although Ireland included it in the soil profile description dataset. On the other hand, the three German plots and one Danish plot, mentioned above, were not reported. The data field USE refers to whether the stand is broadleaved, coniferous or mixed. As Austria and Finland use a different coding system, the information was derived from the additional data contained in the ICP Forests database at the PCC in Hamburg. Unfortunately the class coniferous/broadleaved refers to the main tree species and not necessarily to the whole stand. In order to keep the originally reported information, a new data field 'USEu' was created with the combined information: reported by the countries and complemented with the information from the ICP Forests database or obtained by directly contacting the NFCs.

Information on the parent material was available for 4053 of the 5061 profiles in the soil profile description datasets (80 %). Spain did not report the parent material for its 616 plots (12 % of total N° of plots). In Sweden the parent material was missing on 25 % of its plots, in Latvia on 19 %, in Great Britain on 17 %, in France on 15 % and in Bayern on 12 % of the reported plots. However, during the first forest soil condition inventory in the 90s the soil parent material was reported on a number of the plots where the information was lacking in the BioSoil inventory. Unfortunately the classification system was different. Though, for a number of plots the translation between the two parent material classification systems was possible. So the parent material on these plots were complemented with the data from the first inventory (till 4422 plots on Level I).

Concerning the soil classification (Table 2.6.3), the WRB reference soil group (RSG) is available for 97 % of the plots. On Level I, it is lacking for a number of Spanish (including 3 plots on the Canaries) and on a number of Swedish plots. All other information related to the WRB soil classification - as qualifiers and specifiers - was optional. At least one WRB qualifier was reported on 92 % of the plots. A few countries/federal states did not report this qualifier (Spain, Canary Islands, Hessen, Lower-Saxony, Saxony-Anhalt, Great Britain and Latvia) on a high proportion of their plots. On less than 4 % of the plots, six qualifiers or more were reported.

Also the reporting of the diagnostic properties, materials and horizons (together with their depth within the profile) was optional (Table 2.6.4). These diagnostics were asked for 1) data validation and 2) cross references with other (future) classification systems. A number of countries, altogether responsible for 1302 plots, decided not to report the diagnostics of the profiles (Austria, Cyprus, Czech Republic, Spain, Great Britain, Canary Islands, Slovenia, Slovak Republic, Serbia). For the countries that did report diagnostics, it is often restricted to a limited number of plots. Additionally, it is possible that a soil profile does not show any diagnostics (e.g. in certain Regosols). Overall, at least one diagnostic has been reported on 45 % of the plots.

During the data validation, a number of corrections have been made to the list of qualifiers. In order not to loose the originally reported classification names, new data fields have been added

Table 2.6.3. Data availability in the soil profile description dataset. Parent material, WRB soil classification and depth of limiting layers. The number before the slash refers to the number of Level I plots. The number behind to Level II.

Country	N° profiles	PMAT	RSG	QUAL1	SPEC1	QUAL2	SPEC2	QUAL3	SPEC3	QUAL4	SPEC4	QUAL5	SPEC5	QUAL6	SPEC6	ROOT	ROCK	OBSTACLE
AT	135/2	135/2	135/2	135/-	56/-	113/-	65/-	66/-	38/-	2/-	2/-	-/-	-/-	-/-	-/-	129/2	113/2	1/-
BE	10/11	10/11	10/11	10/11	1/2	10/11	4/4	10/11	7/7	6/8	4/1	3/8	-/3	3/5	1/1	10/11	-/-	-/-
CY	15/4	15/4	15/4	15/4	-/-	15/4	-/-	15/4	0/-	15/3	-/-	14/1	-/-	-/-	-/-	15/4	15/4	-/-
CZ	146/8	142/8	146/8	146/8	3/1	125/4	50/3	57/1	24/1	8/-	1/-	-/-	-/-	-/-	-/-	146/8	1/-	-/-
DE	422/8	411/8	422/8	330/8	31/2	323/8	27/3	236/4	72/3	170/4	66/3	102/1	28/1	49/-	11/-	381/7	193/1	174/1
DK	25/3	25/3	25/3	25/3	-/-	24/2	-/-	20/1	-/-	8/-	-/-	3/-	-/-	1/-	-/-	10/-	-/-	-/-
EE	96/-	96/-	96/-	96/-	8/-	95/-	12/-	78/-	9/-	54/-	7/-	20/-	3/-	7/-	4/-	96/-	3/-	18/-
ES	603/13	-/-	443/-	433/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
FI	630/32	630/32	630/32	630/32	-/-	263/11	-/-	12/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	630/32	630/32	630/32
FR	548/20	465/20	548/20	548/20	20/8	534/16	22/-	470/12	63/6	288/9	46/3	126/-	24/-	32/-	2/-	232/17	262/7	519/15
GB	166/4	138/-	166/4	122/4	14/-	72/3	20/1	23/-	6/-	2/-	-/-	-/-	-/-	-/-	-/-	166/-	-/-	-/-
GR	-/4	-/4	-/4	-/4	-/-	-/4	-/-	-/4	-/-	-/3	-/-	-/-	-/-	-/-	-/-	-/4	-/4	-/-
HU	78/-	76/-	78/-	78/-	11/-	78/-	17/-	62/-	18/-	35/-	13/-	10/-	4/-	4/-	-/-	69/-	37/-	33/-
IC	13/-	-/-	10/-	10/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
IE	36/3	35/3	35/3	35/3	2/-	35/3	-/-	27/3	-/-	-/-	-/-	-/-	-/-	-/-	-/-	35/3	6/1	-/-
IT	239/8	238/8	239/8	239/8	11/-	233/8	14/-	178/6	7/-	106/3	11/-	42/1	3/1	8/-	-/-	239/1	86/1	121/3
LT	62/2	62/2	62/2	62/2	15/-	60/2	28/2	25/-	10/-	10/-	6/-	2/-	-/-	-/-	-/-	62/2	-/2	62/2
LV	95/-	77/-	95/-	36/-	-/-	32/-	-/-	28/-	-/-	19/-	1/-	3/-	-/-	1/-	-/-	95/-	95/-	95/-
PL	524/6	524/6	524/6	524/6	7/1	121/3	-/-	18/-	-/-	1/-	-/-	-/-	-/-	-/-	-/-	524/6	52/-	-/-
PT	103/-	103/-	103/-	103/-	86/-	103/-	81/-	100/-	78/-	93/-	80/-	79/-	77/-	73/-	72/-	103/-	103/-	103/-
RS	27/-	-/-	27/-	27/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
SE	794/-	594/-	786/-	777/-	-/-	103/-	-/-	7/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	80/-	763/-	3/-
SI	45/1	45/1	45/1	45/1	-/-	45/1	2/-	44/1	2/-	39/1	13/-	17/1	8/1	3/-	2/-	45/1	5/-	45/1
SK	112/8	112/8	112/8	112/8	10/-	109/8	17/1	77/4	30/2	50/3	25/1	18/3	2/1	1/-	-/-	70/8	6/-	7/-
Total	**4924/ 137**	**3933/ 120**	**4752/ 124**	**4538/ 122**	**275/ 14**	**2493/ 88**	**359/ 14**	**1553/ 51**	**364/ 19**	**906/ 34**	**275/ 8**	**439/ 15**	**149/ 7**	**182/ 5**	**92/ 1**	**3137/ 106**	**2370/ 54**	**1811/ 54**

Table 2.6.4. Data availability in the soil profile description dataset. Reported diagnostic horizons, materials and properties. The number before the slash refers to the number of Level I plots. The number behind to Level II.

Country	N° profiles	DIAG1	Depth DIAG1	DIAG2	Depth DIAG2	DIAG3	Depth DIAG3	DIAG4	Depth DIAG4	DIAG5	Depth DIAG5	DIAG6 +depth	DIAG7 +depth	DIAG8 + depth	DIAG9 + depth	DIAG10 + depth
AT	135/2	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
BE	10/11	9/11	9/11	9/11	9/11	9/11	9/11	8/8	8/8	7/6	7/6	4/4	4/3	3/1	2/1	1/-
CY	15/4	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
CZ	146/8	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
DE	422/8	104/5	49/5	65/4	41/4	46/2	33/2	15/1	14/1	10/1	10/1	3/-	3/-	1/-	-/-	-/-
DK	25/3	25/3	25/3	25/3	25/3	24/3	24/3	23/2	23/2	18/1	18/1	16/-	11/-	4/-	2/-	-/-
EE	96/-	96/-	96/-	95/-	95/-	80/-	80/-	53/-	53/-	35/-	35/-	16/-	3/-	1/-	-/-	-/-
ES	603/13	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
FI	630/32	405/22	405/22	151/8	151/8	26/-	26/-	1/-	1/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
FR	548/20	516/17	58/15	325/12	137/12	148/1	36/1	26/-	8/-	4/-	2/-	-/-	-/-	-/-	-/-	-/-
GB	166/4	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
GR	-/4	-/4	-/4	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
HU	78/-	68/-	68/-	42/-	42/-	13/-	13/-	4/-	4/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
IC	13/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
IE	36/3	33/3	35/3	13/2	16/2	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
IT	239/8	100/8	100/8	21/5	21/5	2/2	2/2	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
LT	62/2	49/2	49/2	38/2	38/2	32/2	32/2	9/-	9/-	1/-	1/-	1/-	-/-	-/-	-/-	-/-
LV	95/-	36/-	36/-	17/-	17/-	8/-	8/-	2/-	2/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
PL	524/6	312/3	312/3	170/-	170/-	71/-	71/-	23/-	23/-	5/-	5/-	-/-	-/-	-/-	-/-	-/-
PT	103/-	94/-	94/-	72/-	33/-	72/-	72/-	72/-	3/-	72/-	72/-	-/-	-/-	-/-	-/-	-/-
RS	27/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
SE	794/-	424/-	423/-	233/-	230/-	48/-	48/-	5/-	5/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
SI	45/1	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
SK	112/8	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
Total	**4924/137**	**2271/78**	**1759/76**	**1276/47**	**1025/47**	**579/21**	**454/21**	**241/11**	**153/11**	**152/8**	**150/8**	**40/4**	**21/3**	**9/1**	**4/1**	**1/0**

with the updated name of the RSG (RSGu) and of the qualifiers and specifiers (QUA1u, SPEC1u, QUAL2u, SPEC2u,…). Their availability is shown in Table 2.6.5. The rooting depth (ROOT) was available for 3243 Level I and Level II profiles. Spain, including the Canary Islands, and Serbia did not report any rooting depth, rock depth (ROCK) or obstacle depth (OBSTACLE). A number of countries reported only one or two of these three variables.

ROCK and OBSTACLE is missing in Belgium, Denmark and Great Britain and only for a few plots in Czech Republic and Slovakia. A problem with these two variables is that it was not possible to report that no continuous rock or another obstacle of any kind was observed within the studied profile limits as these two data fields asked for numeric data. One option was to leave the field blank in case of no rock or obstacle within the observed depth. This is probably what many countries decided to do. So part of the data gaps in these three fields are rather due to a poor definition, description and coding of these tree fields.

Table 2.6.5. Data availability on the soil classification of the profiles by country after validation, corrections and updates

Coun -try	RSGu	QUAL 1u	SPEC 1u	QUAL 2u	SPEC 2u	QUAL 3u	SPEC 3u	QUAL 4u	SPEC 4u	QUAL 5u	SPEC 5u	QUAL 6u	SPEC 6u
AT	135/2	135/-	9/-	127/-	43/-	81/-	39/-	24/-	10/-	1/-	1/-	0/-	0/-
BE	10/11	10/11	1/2	10/11	4/4	10/11	7/6	6/8	4/1	3/8	0/3	3/5	1/1
CY	15/4	15/4	0/-	15/4	0/-	14/4	0/-	9/3	0/-	6/1	0/-	0/-	0/-
CZ	146/8	146/8	1/1	126/5	1/3	58/1	11/1	7/-	1/-	0/-	0/-	0/-	0/-
DE	422/8	331/8	4/2	324/8	13/2	238/4	24/3	172/4	16/2	103/1	20/1	48/-	11/-
DK	25/3	25/3	0/-	24/2	0/-	20/1	0/-	9/-	0/-	3/-	0/-	1/-	0/-
EE	96/-	96/-	6/-	94/-	9/-	78/-	4/-	53/-	3/-	17/-	1/-	7/-	3/-
ES	443/-	429/-	0/-	202/-	0/-	0/-	0/-	0/-	0/-	0/-	0/-	0/-	0/-
FI	630/32	630/32	0/-	255/12	0/-	12/-	0/-	0/-	0/-	0/-	0/-	0/-	0/-
FR	548/20	548/20	26/4	535/20	25/2	469/12	64/4	275/11	50/3	115/-	19/-	27/-	3/-
GB	166/4	137/4	2/-	97/3	23/-	37/-	11/-	3/-	0/-	0/-	0/-	0/-	0/-
GR	-/4	-/4	-/-	-/4	-/-	-/4	-/-	-/3	-/-	-/-	-/-	-/-	-/-
HU	78/-	78/-	7/-	78/-	10/-	62/-	16/-	35/-	11/-	10/-	3/-	4/-	0/-
IC	10/-	10/-	0/-	4/-	0/-	0/-	0/-	0/-	0/-	0/-	0/-	0/-	0/-
IE	35/3	35/3	1/-	35/3	0/-	25/3	0/-	0/1	0/-	0/-	0/-	0/-	0/-
IT	239/8	239/8	10/-	234/8	14/-	178/6	7/-	104/3	10/-	42/1	3/1	8/-	0/-
LT	62/2	62/2	11/-	59/2	15/1	25/-	4/-	10/-	3/-	2/-	0/-	0/-	0/-
LV	95/-	40/-	0/-	33/-	0/-	28/-	0/-	19/-	0/-	3/-	0/-	1/-	0/-
PL	524/6	524/6	7/1	157/6	0/-	34/-	0/-	1/-	0/-	0/-	0/-	0/-	0/-
PT	103/-	103/-	1/-	102/-	9/-	86/-	4/-	55/-	7/-	22/-	6/-	1/-	0/-
RS	27/-	27/-	0/-	22/-	0/-	0/-	0/-	0/-	0/-	0/-	0/-	0/-	0/-
SE	786/-	767/-	0/-	116/-	0/-	7/-	0/-	0/-	0/-	0/-	0/-	0/-	0/-
SI	45/1	45/1	0/-	45/1	1/-	45/1	3/-	39/1	13/-	17/1	8/1	3/-	2/-
SK	112/8	112/8	1/-	109/8	6/-	80/4	13/1	51/3	21/1	17/3	2/1	1/-	0/-
Total	**4752/ 124**	**4544/ 122**	**87/ 10**	**2803/ 97**	**173/ 12**	**1587/ 51**	**207/ 15**	**872/ 37**	**149/ 7**	**361/ 15**	**63/ 7**	**104/ 5**	**20/ 1**

2.6.3 Soil horizon description dataset

Table 2.6.6 shows the number of described and reported horizons on both Level I and Level II. The BioSoil^{+} database contains soil horizon descriptions of 23618 Level I horizons on 4738 plots while the profile description dataset contains information on 4924 plots. The difference is due to a lack of information on the 27 Serbian plots, 1 Irish, 155 Spanish and on 3 plots on the Canary Islands.

On Level II, soil horizon description information is available for 852 horizons on 114 plots (124 profiles) while the profile description dataset contained data on 127 plots (137 profiles). The difference is due to the lack of information on the 13 Spanish Level II plots where no detailed profile description or classification was reported.

The number of horizons includes both the organic and the mineral soil horizons. The level of detail of describing the horizons is substantially different among the countries. For example Table 2.6.6 shows that Sweden (SE) and Cyprus (CY) did not report any subordinate symbols in the horizon designation. Belgium (Flanders) described the highest number of horizons per profile. Latvia, Poland and Slovenia described the profile till nearly 2 m depth. Sweden, Cyprus, Spain and the Canary Islands described only till a depth of 30 – 40 cm.

Table 2.6.6 shows that Spain, including the Canary Islands, did not report a single colour measurement. France, Ireland, Portugal and Austria only reported the moist colour. Information on the particle size distribution (textural class) is available on about 80 % of the mineral soil samples. The majority of the textural class determinations are based on particle size analysis of the sand, silt and clay fractions although some countries most probably provided estimated values (e.g. France on all their samples and Germany, Portugal, Hungary, Italy and Ireland on a number of their samples).

The code of the abundance class of the coarse fragments is available for most mineral horizons expect for Spain and Ireland. A few countries provided additional information on the coarse fragments by an estimation of the mass %.

The database holds less analytical results of the samples taken from the genetic horizons compared to the analytical results of the samples taken at fixed depth intervals as shown in Table 2.6.4. Spain (including Canary Islands) did not provide any analytical results; Hungary reported only few results. Most countries reported analytical results on a selection of plots and horizons, sufficient to allow a reliable classification following the World Reference Base for Soil Resources (IUSS Working Group WRB 2006). pH and organic carbon is available on 68 % and total nitrogen on 60 % of the horizons; CEC on 57 %, BS on 55 % and the individual basic cations on 38 % of the horizons. A number of countries reported CEC and BS but not the individual exchangeable elements (Czech Republic, Slovak Republic, Latvia, Lithuania, Italy). On the opposite, Ireland analysed and reported acid exchangeable cations and reactive Al and Fe (not shown here).

Information on the soil water retention characteristics is available for 483 horizons in 4 countries (Belgium, Denmark, Germany and Sweden) on 190 plots. Data on the bulk density is lacking for Austria, Spain (including Canary Islands), Hungary, Ireland and Latvia. The other countries provided either measured or estimated bulk density values on the majority of the described horizons.

Table 2.6.6. Data availability in dataset containing the description of the soil horizons (PFH). The number before the slash refers to the number of Level I horizons. The number behind to Level II.

Country	N° horizons	DATEANAL	HORDISC	HORMAST	HORSUBORD	HORVERT	HORTOP	HORBOT	STRUCT	COLOURM	COLOURD	TEXCLASS	CLAY	SILT	SAND
AT	863/14	863/14	2/-	863/14	266/6	133/4	863/14	729/12	451/9	863/10	-/-	396/8	396/11	396/9	396/11
BE	108/122	108/122	16/17	108/122	52/61	28/39	108/122	108/122	82/91	98/92	82/26	82/74	82/74	82/74	82/74
CY	54/18	54/18	-/-	54/18	-/-	54/18	54/18	49/17	38/14	38/14	38/14	35/14	35/14	35/14	35/14
CZ	795/38	795/38	-/-	795/38	420/21	127/4	795/38	784/35	646/30	708/30	643/30	640/30	640/30	640/30	640/30
DE	3030/45	2746/45	651/2	3030/45	1670/24	410/4	3028/45	3023/45	1998/34	2154/34	1647/34	2004/34	1811/34	1819/34	1819/34
DK	146/18	146/18	2/-	146/18	83/7	29/4	146/18	146/18	109/-	128/-	1/-	116/4	113/4	113/4	113/4
EE	550/-	550/-	40/-	550/-	185/-	53/-	550/-	547/-	326/-	326/-	326/-	327/-	325/-	326/-	326/-
ES	1632/-	1632/-	41/-	1632/-	784/-	164/-	1632/-	1209/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
FI	2653/146	2653/146	9/-	2653/146	618/36	250/11	2653/146	2653/146	24/-	2653/146	1084/-	1922/28	1917/28	1922/28	1922/28
FR	2802/198	2802/198	71/16	2802/198	528/50	412/89	2802/172	2802/170	1930/114	1900/128	-/-	1861/-	-/-	-/-	-/-
GB	937/27	937/-	66/-	937/27	297/12	53/4	937/27	935/26	680/8	120/18	700/-	517/15	517/14	517/14	517/14
GR	-/26	-/26	-/-	-/26	-/9	-/9	-/26	-/26	-/18	-/22	-/22	-/18	-/18	-/18	-/18
HU	464/-	464/-	99/-	444/-	254/-	89/-	456/-	437/-	413/-	418/-	70/-	207/-	182/-	182/-	182/-
IC	38/-	38/-	-/-	38/-	1/-	7/-	38/-	28/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
IE	244/22	244/22	-/-	244/22	69/4	89/4	244/21	243/21	100/4	201/19	-/-	100/8	23/8	23/8	23/8
IT	1421/46	1421/46	61/3	1421/46	415/13	262/6	1421/46	1421/46	922/31	789/32	452/21	892/23	540/23	541/23	540/23
LT	442/18	442/18	5/-	442/18	169/3	144/11	442/18	442/18	313/14	313/14	313/14	313/14	313/14	313/14	313/14
LV	725/-	725/-	27/-	725/-	420/-	264/-	725/-	711/-	690/-	725/-	725/-	566/-	560/-	566/-	566/-
PL	3096/45	3096/45	195/8	3096/45	877/12	-/-	3096/45	3096/45	2149/31	2149/31	2149/31	2149/31	2102/31	2149/31	2149/31
PT	502/-	502/-	21/-	502/-	204/-	125/-	502/-	502/-	281/-	302/-	-/-	309/-	167/-	167/-	167/-
SE	2105/-	2105/-	-/-	2103/-	-/-	237/-	2010/-	2007/-	27/-	1065/-	1065/-	177/-	151/-	177/-	177/-
SI	300/9	300/9	18/2	300/9	117/7	99/3	300/9	300/9	206/7	205/7	186/7	176/7	176/7	176/7	176/7
SK	710/60	443/41	15/-	710/60	278/23	119/12	708/60	677/59	460/41	458/41	360/26	431/39	431/39	431/39	431/39
Total	**23617/ 852**	**23066/ 806**	**1339/ 48**	**23595/ 852**	**7717/ 288**	**3148/ 222**	**23510/ 825**	**22849/ 815**	**11845/ 446**	**15126/ 638**	**9840/ 225**	**13220/ 347**	**10481/ 349**	**10575/ 347**	**10574/ 349**

Table 2.6.6 (continued). Data availability in dataset containing the description of the soil horizons (PFH). The number before the slash refers to the number of Level I plots. The number behind to Level II.

Country	CFCODE	CFMASS	OC	TON	CARBO-NATES	GYP-SUM	PH	EC	ESP	EXCHCA	EXCHMG	EXCHK	EXCHNA	CEC	BS
AT	477/9	-/-	474/11	474/11	474/11	-/-	474/11	-/-	-/-	474/11	474/11	474/11	474/11	472/11	472/11
BE	82/91	83/91	108/86	64/82	4/-	-/-	99/120	99/112	38/49	79/59	79/59	79/59	79/59	79/60	37/54
CY	39/18	-/-	50/18	50/18	42/11	-/-	50/18	-/-	-/-	50/18	50/18	50/18	50/8	50/18	50/18
CZ	650/30	-/-	795/38	795/38	-/-	-/-	795/38	-/-	-/-	-/-	-/-	-/-	-/-	794/30	794/30
DE	2272/40	1268/6	1602/28	1602/28	1320/2	-/-	1601/28	-/-	892/-	1289/13	1289/13	1289/13	1289/13	1445/13	1412/13
DK	139/-	-/-	114/4	50/4	114/3	-/-	118/4	-/-	-/-	64/4	64/3	64/4	60/4	60/3	60/-
EE	326/-	173/-	547/-	547/-	120/-	-/-	547/-	-/-	-/-	460/-	460/-	460/-	460/-	460/-	460/-
ES	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
FI	1922/145	1922/-	2653/146	1429/146	-/-	-/-	2653/146	-/-	-/-	2653/146	2653/146	2653/146	2653/146	2653/146	2653/146
FR	2265/-	-/-	1214/-	1109/-	645/-	-/-	732/-	-/-	-/-	604/-	604/-	604/-	-/-	604/-	523/-
GB	936/23	-/-	703/22	703/22	-/-	-/-	683/22	-/21	-/15	705/15	705/15	705/15	705/15	705/15	705/15
GR	-/18	-/-	-/26	-/26	-/1	-/-	-/22	-/-	-/-	-/22	-/22	-/22	-/22	-/22	-/22
HU	343/-	-/-	109/-	-/-	84/-	-/-	183/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
IC	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
IE	-/-	-/-	-/-	-/-	2/-	-/-	85/17	-/-	-/-	79/17	80/17	85/17	85/17	73/17	73/-
IT	921/30	-/-	347/42	155/-	320/-	5/-	850/41	-/-	48/27	48/27	48/27	48/27	48/27	200/27	187/27
LT	313/14	-/-	442/18	442/18	335/-	-/-	442/18	-/-	-/-	-/-	-/-	-/-	-/-	318/14	318/14
LV	587/-	-/-	725/-	725/-	169/-	-/-	725/-	-/-	-/-	-/-	-/-	-/-	-/-	599/-	599/-
PL	2162/31	-/-	3096/45	3096/45	256/3	3/-	3096/39	-/-	-/-	-/-	-/-	-/-	-/-	2163/31	2163/31
PT	310/-	310/-	502/-	333/-	5/-	-/-	310/-	-/-	-/-	310/-	310/-	310/-	310/-	295/-	295/-
SE	903/-	882/-	1664/-	1666/-	37/-	-/-	1662/-	1662/-	-/-	1784/-	1784/-	1784/-	1784/-	1784/-	1693/-
SI	263/9	-/-	300/9	300/9	70/5	-/-	270/8	-/-	-/-	256/8	256/8	256/8	256/8	257/8	257/8
SK	468/41	-/4	650/59	650/59	125/4	-/-	649/59	-/-	-/-	-/-	-/-	-/-	-/-	369/34	367/33
Total	**15378/ 499**	**4638/ 101**	**16095/ 552**	**14190/ 506**	**4122/ 40**	**8/ 0**	**16024/ 591**	**1761/ 133**	**978/ 91**	**8855/ 340**	**8856/ 339**	**8861/ 340**	**8253/ 330**	**13380/ 449**	**13118/ 422**

Table 2.6.6 (continued). Data availability in dataset containing the description of the soil horizons (PFH). The number before the slash refers to the number of Level I plots. The number behind to Level II.

Country	SWC1	SWC2	SWC3	SWC4	SWCFC	CODEPOROS	POROSITY	BD	BDEST
AT	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
BE	37/-	37/-	37/-	37/-	37/-	82/90	82/90	54/81	28/9
CY	-/-	-/-	-/-	-/-	-/-	37/18	-/-	33/6	-/-
CZ	-/-	-/-	-/-	-/-	-/-	646/30	-/-	-/-	652/30
DE	-/-	-/-	-/-	-/-	176/-	1125/36	809/6	1301/20	852/12
DK	95/-	32/-	95/-	82/-	95/-	-/-	91/-	89/4	-/-
EE	-/-	-/-	-/-	-/-	-/-	323/-	323/-	323/-	-/-
ES	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
FI	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	2653/105
FR	-/-	-/-	-/-	-/-	-/-	1818/-	-/-	293/-	1485/-
GB	-/-	-/-	-/-	-/-	-/-	719/-	-/-	562/19	-/2
GR	-/	-/	-/	-/	-/	-/18	-/18	-/18	-/-
HU	-/-	-/-	-/-	-/-	-/-	393/-	-/-	-/-	-/-
IC	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
IE	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
IT	-/-	-/-	-/-	-/-	-/-	343/-	-/-	335/25	455/-
LT	-/-	-/-	-/-	-/-	-/-	313/14	-/-	57/14	256/-
LV	-/-	-/-	-/-	-/-	-/-	593/-	-/-	-/-	-/-
PL	-/-	-/-	-/-	-/-	-/-	2154/31	-/-	-/-	2149/31
PT	-/-	-/-	-/-	-/-	-/-	310/-	310/-	274/-	36/-
SE	175/-	175/-	175/-	-/-	175/-	177/-	-/-	368/-	1299/-
SI	-/-	-/-	-/-	-/-	-/-	201/7	-/-	121/4	68/3
SK	-/-	-/-	-/-	-/-	-/-	455/39	-/-	-/-	427/39
Total	**307/-**	**244/-**	**307/-**	**119/-**	**483/-**	**9689/283**	**1615/114**	**3810/191**	**10360/231**

2.6.4 Sampling and analyses at fixed depths

2.6.4.1 Sampled layers

The SOM dataset contains analytical laboratory data on 4914 Level I plots and 114 Level II plots. In France, Cyprus, Spain and Sweden a number of plots were lacking. They were not sampled for unknown reasons. The next tables provide for each country the number of plots that have been sampled and analysed for the concerning parameter(s). So replicate analyses within one plot on one layer have only been counted once. Each table gives an overview on the completeness of the database at the level of the countries. A number of layers have been aggregated in the Tables 2.6.8 till 34 in case of the following:

1) It was optional to sample the 0 – 5 cm and the 5 – 10 cm separately while it was mandatory to take one sample in the 0 – 10 cm layer. To improve the comparability of data availability among the countries, the two optional layers were considered together. This was done both for the mineral soil layers (M05, M51) and the peat layers (H05, H51).
2) In the BioSoil survey, it was allowed to sample the organic layers OF and OH together. So the data availability has been shown for the OFH layers as a whole. The same was done for the Hf, Hfs and Hs layer which were aggregated in the layer called 'H'.

3) In the rare cases that information was only available for one of the sublayers, it was considered as existing for the whole mandatory layer.

Occasionally, soils below the required depth of 80 cm have been sampled (for example in case of overlying peat soils with a thickness of less than 80 cm). These few layers are not shown in the following tables. Table 2.6.7 shows by colour coding how the individual layers were aggregated.

Most countries sampled the M01 layers mainly as a whole (58 % of the plots), others mainly as two separate layers (M05 and M51) (41 % of the plots). In Sweden and Cyprus both sampling designs have been used depending on the plot. Although it was requested to sample till a depth of 80 cm, the data availability decreases gradually with depth. The 0 – 10 cm layer was sampled on 97 % of the plots, the 10 – 20 cm on 99.8 %, the 20 – 40 cm on 73 % and the 40 – 80 cm layer on 65 % of the plots. This is for a part logical as not all forest soils reach a rootable depth of 80 cm. In Sweden however, it seemed on most plots not feasible to sample below a depth of 20 cm. Further, there are 144 Swedish plots where only the forest floor was sampled (OL, OF, OH, OFH or Hf, Hfs, Hs).

Although requested in the BioSoil survey, the OL layer was not sampled on the Level I plots in a number of countries (France, Sweden, Finland and Latvia). Most countries combined the OF and OH layer except Estonia and the Canary Islands. A water saturated organic layer (Hf, Hfs or Hs) has been described in four northern European countries (Finland, Sweden, Poland and Estonia).

Peat layers have been described and sampled in twelve – mainly northern- countries although one peat soil was described in Austria and one in Italy. From the moment peat soils had a peat layer with a thickness of ≥ 40 cm, the samples taken at fixed depth received separate codes (H01 (or H05/H51), H12, H24 and H48). Whenever the peat layers were shallower, the peat was considered as an organic H layer (Hf, Hfs or Hs). Although this system was well applied on the real thick peat soils, surveyors seemed to have problems in describing the peat layers of more than 40 cm following this system. Examples:

- In Austria and Ireland, some plots (14_136, 7_254) were classified as Histosols, but had only 20 cm peat (H01, H12) which is not sufficient according to WRB to be classified as a peat soil. An a posteriori correction is very difficult as the H01, H12 should become part of the organic layers with negative sampling depths. The 0 cm line of the profile moves downwards and so the depth intervals of the fixed depth layers change.
- In Germany, one plot (404_8162) which had a thickness of the peat layer of 20 cm, was classified as a Histic Gleysol but sampled in a way similar to the Austrian and Irish plots.
- In Finland and Sweden, peat soils were often only sampled till a depth of 20 cm (15_3138) and classified as a Histosol. This can be correct in case the peat layer is directly overlying continuous rock. The classification can also be correct in case the peat is thicker than 40 cm though in the latter case the sampling did not follow the rules of the BioSoil survey. In Slovenia one peat soil was only sampled till 10 cm, no deeper layers were sampled though the root limiting layer was reported at 57 cm.

On the other hand, it also happened that peat layers with a thickness of ≥ 40 cm were sampled according to the rules of the mineral soils layer sampling. FSCC decided to rename these layers into H01, H12,… for those layers that, mainly based on the organic carbon content, were clearly organic in nature.

Table 2.6.7. Number of sampled plots and layers by country as reported in the SOM file of Level I and II. The columns M01a, H01a, OFHa and Ha aggregate information of the individual composing layers [OFH (OF, OH, OFH), Ha (Hf, Hfs, Hs), M01a (M05, M51, M01) and H01a (H05, H51, H01)]. The number before the slash refers to the number of Level I plots. The number behind to Level II.

Country	N° plots	OL	OF	OFH	OH	Hf	Hfs	Hs	M01	M05	M51	M12	M24	M48	H01	H05	H51	H12	H24	H48	OFHa	Ha	M01a	H01a
AT	135/2	135/2	-/-	134/2	-/-	-/-	-/-	-/-	-/-	134/2	134/2	134/2	135/2	135/2	-/-	1/-	1/-	1/-	-/-	-/-	134/2	-/-	134/2	1/-
BE	10/11	10/10	-/3	9/8	-/3	-/-	-/-	-/-	-/-	10/11	10/11	10/11	10/11	10/11	-/-	-/-	-/-	-/-	-/-	-/-	9/11	-/-	10/11	-/-
CY	15/2	15/2	-/-	15/2	-/-	-/-	-/-	-/-	15/2	-/-	-/-	15/2	14/2	9/2	-/-	-/-	-/-	-/-	-/-	-/-	15/2	-/-	15/2	-/-
CZ	146/8	146/8	-/-	145/8	-/-	-/-	-/-	-/-	146/8	-/-	-/-	146/8	146/8	145/8	-/-	-/-	-/-	-/-	-/-	-/-	145/8	-/-	146/8	-/-
DE	422/8	228/8	294/7	146/1	126/6	-/-	-/-	-/-	222/4	193/4	193/4	414/8	415/8	402/8	5/-	2/-	2/-	7/-	5/-	5/-	391/7	-/-	415/8	7/-
DK	25/3	25/3	-/-	25/3	-/-	-/-	-/-	-/-	25/-	-/3	-/3	25/3	25/3	25/3	-/-	-/-	-/-	-/-	-/-	-/-	25/3	-/-	25/3	-/-
EE	96/-	88/-	62/-	-/-	26/-	3/-	7/-	13/-	-/-	83/-	83/-	83/-	82/-	79/-	13/-	-/-	-/-	13/-	13/-	13/-	62/-	14/-	83/-	13/-
ES	598/2	577/2	502/2	54/-	346/2	-/-	-/-	-/-	156/2	598/2	594/2	586/2	-/2	-/2	-/-	-/-	-/-	-/-	-/-	-/-	557/2	-/-	598/2	-/-
FI	630/32	-/32	-/-	493/32	-/-	51/-	34/-	17/-	567/-	-/28	-/28	554/28	531/28	504/16	63/-	-/4	-/4	63/4	62/4	-/-	493/32	61/-	567/28	63/4
FR	545/10	-/10	-/8	133/-	-/4	-/-	-/-	-/-	543/10	-/-	-/-	530/10	496/10	393/-	-/-	-/-	-/-	-/-	-/-	-/-	133/8	-/-	543/10	-/-
GB	166/4	164/4	-/2	163/2	-/2	-/-	-/-	-/-	-/4	123/-	129/-	138/4	145/4	154/4	-/-	43/-	37/-	28/-	21/-	12/-	163/4	-/-	129/4	43/-
GR	/4	/4	/-	/4	/-	/-	/-	/-	/4	/-	/-	/4	/4	/4	/-	/-	/-	/-	/-	/-	/4	/-	/4	/-
HU	78/-	71/-	7/-	20/-	11/-	-/-	-/-	-/-	-/-	78/-	78/-	78/-	78/-	76/-	-/-	-/-	-/-	-/-	-/-	-/-	34/-	-/-	78/-	-/-
IC	13/-	13/-	12/-	-/-	11/-	-/-	-/-	-/-	3/-	13/-	13/-	13/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	12/-	-/-	13/-	-/-
IE	35/3	29/3	5/1	24/2	4/-	-/-	-/-	-/-	11/2	-/-	-/-	15/2	22/2	29/2	24/1	-/-	-/-	20/1	13/1	6/1	29/3	-/-	11/2	24/1
IT	239/8	235/7	37/-	112/8	16/-	-/-	-/-	-/-	238/8	-/-	-/-	237/8	227/8	160/8	1/-	-/-	-/-	1/-	1/-	-/-	165/8	-/-	238/8	1/-
LT	62/2	62/2	9/-	37/2	8/-	-/-	-/-	-/-	57/-	-/2	-/2	57/2	57/2	58/2	5/-	-/-	-/-	5/-	5/-	4/-	48/2	-/-	57/2	5/-
LV	95/-	-/-	-/-	70/-	-/-	-/-	-/-	-/-	77/-	-/-	-/-	82/-	85/-	85/-	18/-	-/-	-/-	13/-	10/-	10/-	70/-	-/-	77/-	18/-
PL	524/6	470/6	1/-	382/6	-/-	7/-	1/-	-/-	-/-	499/6	501/6	504/6	509/6	511/6	-/-	25/-	23/-	20/-	14/-	12/-	383/6	7/-	501/6	25/-
PT	103/-	103/-	-/-	89/-	-/-	-/-	-/-	-/-	103/-	-/-	-/-	103/-	101/-	86/-	-/-	-/-	-/-	-/-	-/-	-/-	89/-	-/-	103/-	-/-
SE	793/-	-/-	312/-	294/-	84/-	18/-	12/-	3/-	553/-	7/-	6/-	411/-	111/-	97/-	88/-	-/-	-/-	81/-	68/-	44/-	675/-	33/-	560/-	88/-
SI	45/1	45/1	43/1	2/-	29/-	-/-	-/-	-/-	-/-	43/1	43/1	41/1	40/1	36/1	-/-	2/-	2/-	1/-	1/-	1/-	45/1	-/-	43/1	2/-
SK	112/8	104/8	28/7	66/3	4/2	-/-	-/-	-/-	112/8	-/-	-/-	111/8	109/8	100/8	-/-	-/-	-/-	-/-	-/-	-/-	94/8	-/-	112/8	-/-
SR	27/-	27/-	-/-	27/-	-/-	-/-	-/-	-/-	-/-	27/-	27/-	27/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	27/-	-/-	27/-	-/-
Total	4914/114	2547/112	1312/31	2440/83	665/19	79/-	54/-	33/-	2828/52	1808/59	1811/59	4314/109	3338/109	3094/87	217/1	73/4	65/4	253/5	213/5	107/1	3798/111	115/-	4485/109	290/5

Another bug in the data is that on a number of plots in Sweden and Finland two 0 – 10 cm layers occurred, namely the 0 – 10 cm layer in the peat profile (H01) and the 0 – 10 cm mineral soil (M01) if the peat soil was relatively shallow and the mineral soil was sampled as well. Corrections have been made by FSCC a posteriori though this problem should be avoided in the future by allowing only one 0 cm line in the description of each profile.

2.6.4.2 Particle size distribution

As the soil texture was not reported in the first survey, it was requested to determine the soil textural class based on the relative proportions of the clay (0 – 2 µm), silt (2 – 63 µm) and sand fractions (63 – 2000 µm) in the fine earth of the mineral soil samples till the depth of 80 cm. The proportions of sand, silt and clay had to be reported too. Some countries did even report the texture of a number of peat or OFH samples. These results are not included in Table 2.6.8 which shows the data availability on the textural classes.

Table 2.6.8. Data availability of the particle size distribution by country and by layer. The number before the slash refers to the number of Level I plots. The number behind to Level II.

Country	N° plots	M01	M12	M24	M48
AT	135/2	-/-	118/2	117/2	114/2
BE	10/11	10/11	10/11	10/11	10/11
CY	15/2	15/2	15/2	14/2	9/2
CZ	146/8	146/8	146/8	146/8	145/8
DE	422/8	382/8	382/8	384/8	375/8
DK	25/3	-/-	-/-	-/-	-/-
EE	96/-	83/-	83/-	82/-	79/-
ES	598/2	562/2	578/2	-/2	-/2
FI	630/32	567/-	554/-	531/28	504/-
FR	545/10	543/10	530/10	496/10	393/-
GB	166/4	128/4	137/4	144/4	143/4
GR	-/4	-/4	-/4	-/4	-/4
HU	78/-	76/-	76/-	77/-	76/-
IC	13/-	13/-	13/-	-/-	-/-
IE	35/3	9/2	12/2	20/2	27/2
IT	239/8	238/8	237/8	226/8	160/8
LT	62/2	57/2	57/2	57/2	58/2
LV	95/-	76/-	82/-	85/-	85/-
PL	524/6	501/6	504/6	509/6	511/6
PT	103/-	103/-	103/-	101/-	86/-
RS	27/-	-/-	-/-	-/-	-/-
SE	793/-	30/-	31/-	60/-	51/-
SI	45/1	43/1	41/1	40/1	36/1
SK	112/8	112/8	111/8	109/8	98/8
Total	**4914/114**	**3694/76**	**3820/78**	**3208/106**	**2960/68**

On Level I, Denmark and Serbia did not report any textural analysis. Austria did not report the texture of the 0 – 10 cm layer and Spain (including the Canary Islands) only analysed till the depth of 20 cm. Sweden analysed the soil texture on less than 8 % of the plots. Most other countries fulfilled the reporting requirements although the data availability decreases with soil depth.

On Level II nearly all the required analyses were done. Ireland had one and Finland had four peat soils where texture analysis was not required according to the soil manual (FSCC, 2006). Also on Level II, Austria did not analyse the 0 – 10 cm layer.

2.6.4.3 Organic layer mass

The organic layer mass (in kg m^{-2}) was available for at least one of the organic layers on 4094 Level I plots and 112 Level II plots. On Level I, the organic layer mass was reported for 5 mineral topsoil layers (3 in Sweden, 1 in Poland and 1 in Hungary). Possibly it concerns soil where the delineation of the boundary between organic and mineral soil was rather difficult in the field and that a renaming of the sampled layers followed after laboratory analysis. This means that an organic layer mass is missing on 821 plots (Table 2.6.9). It is lacking on all Austrian and Cypriote plots and on a relatively high number of French, Hungarian, Latvian and Swedish plots. Either there was no organic layer present, either it was present but not sampled, either it was present, sampled but no organic layer mass was measured and/or reported.

On Level II, the organic layer mass was reported for 1 mineral topsoil layer in Italy (5_10). No organic layer mass values were reported for the peat layers. In Belgium, the OL layer on one plot was partially decomposed at the time of the sampling in summer. In Cyprus, two Level II plots were sampled. According to the profile description, these two plots have an OH layer though no organic layer mass has been reported.

Table 2.6.9. Data availability of the organic layer mass by country and by layer. The number before the slash refers to the number of Level I plots. The number behind to Level II.

Country	N° plots	OL	OFH	H	H01	H12	H24	H48
AT	135/2	-/2	-/2	-/-	-/-	-/-	-/-	-/-
BE	10/11	10/10	9/11	-/-	-/-	-/-	-/-	-/-
CY	15/2	-/-	-/-	-/-	-/-	-/-	-/-	-/-
CZ	146/8	146/8	145/8	-/-	-/-	-/-	-/-	-/-
DE	422/8	185/8	362/7	-/-	1/-	1/-	-/-	-/-
DK	25/3	25/3	25/3	-/-	-/-	-/-	-/-	-/-
EE	96/-	88/-	62/-	14/-	12/-	13/-	13/-	13/-
ES	598/2	574/2	553/2	-/-	-/-	-/-	-/-	-/-
FI	630/32	-/32	493/32	61/-	63/-	63/-	62/-	-/-
FR	545/10	-/10	133/8	-/-	-/-	-/-	-/-	-/-
GB	166/4	137/4	111/4	-/-	-/-	-/-	-/-	-/-
GR	/4	/4	/4	/-	/-	/-	/-	/-
HU	78/-	27/-	16/-	-/-	-/-	-/-	-/-	-/-
IC	13/-	13/-	9/-	-/-	-/-	-/-	-/-	-/-
IE	35/3	29/3	29/3	-/-	-/-	-/-	-/-	-/-
IT	239/8	235/7	165/8	-/-	-/-	-/-	-/-	-/-
LT	62/2	62/2	48/2	-/-	-/-	-/-	-/-	-/-
LV	95/-	-/-	70/-	-/-	-/-	-/-	-/-	-/-
PL	524/6	470/6	383/6	7/-	-/-	-/-	-/-	-/-
PT	103/-	103/-	89/-	-/-	-/-	-/-	-/-	-/-
RS	27/-	-/-	27/-	-/-	-/-	-/-	-/-	-/-
SE	793/-	-/-	618/-	33/-	69/-	40/-	38/-	38/-
SI	45/1	45/1	45/1	-/-	-/-	-/-	-/-	-/-
SK	112/8	104/8	94/8	-/-	-/-	-/-	-/-	-/-
Total	**4914/114**	**2253/110**	**3486/109**	**115/-**	**145/-**	**117/-**	**113/-**	**51/-**

2.6.4.4 Bulk density

The bulk density of the fine earth could be measured or estimated (Table 2.6.10). Complementary to the mass of the organic layer, some countries reported bulk density values for the organic layers. Concerning peat soils, the manual asked for the organic layer mass. Alternatively, the bulk density of the peat layer multiplied by the layer thickness, provides the same information. This latter approach has been followed by a number of countries (DE, GB, IE, IT, LV, PL, SE, SI). Conversely, the organic layer mass divided by the organic layer thickness provides the bulk density of the organic layer.

Table 2.6.10. Data availability of the bulk density (either measured or estimated) by country and by layer. The number before the slash refers to the number of Level I plots. The number behind to Level II.

Country	N° plots	OL	OFH	M01	M12	M24	M48	H01	H12	H24	H48
AT	135/2	-/-	-/-	103/2	102/2	91/2	85/2	-/-	-/-	-/-	-/-
BE	10/11	-/-	-/-	10/11	10/10	10/10	10/10	-/-	-/-	-/-	-/-
CY	15/2	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
CZ	146/8	-/-	-/-	146/8	146/8	146/8	145/8	-/-	-/-	-/-	-/-
DE	422/8	-/-	95/-	414/8	412/8	413/8	400/8	7/-	7/-	5/-	4/-
DK	25/3	-/-	-/-	25/3	25/3	25/3	25/3	-/-	-/-	-/-	-/-
EE	96/-	-/-	-/-	83/-	83/-	82/-	79/-	-/-	-/-	-/-	-/-
ES	598/2	-/-	-/-	551/2	551/2	-/2	-/1	-/-	-/-	-/-	-/-
FI	630/32	-/-	-/-	567/16	554/16	531/16	504/16	-/-	-/-	-/-	-/-
FR	545/10	-/-	-/-	543/10	530/10	496/10	393/-	-/-	-/-	-/-	-/-
GB	166/4	-/-	-/-	129/4	138/4	141/4	130/4	41/-	26/-	19/-	11/-
GR	-/4	-/-	-/-	-/4	-/-	-/-	-/-	-/-	-/-	-/-	-/-
HU	78/-	-/-	-/-	59/-	58/-	64/-	62/-	-/-	-/-	-/-	-/-
IC	13/-	-/-	-/-	13/-	13/-	-/-	-/-	-/-	-/-	-/-	-/-
IE	35/3	-/-	-/-	9/2	13/2	20/2	26/2	24/1	20/1	13/1	5/1
IT	239/8	-/-	-/-	238/8	237/8	226/8	160/8	1/-	1/-	1/-	-/-
LT	62/2	-/-	-/-	57/2	57/2	57/2	58/2	-/-	-/-	-/-	-/-
LV	95/-	-/-	69/-	77/-	82/-	85/-	85/-	18/-	13/-	10/-	10/-
PL	524/6	1/-	-/-	501/6	504/6	509/6	511/6	3/-	1/-	-/-	-/-
PT	103/-	-/-	-/-	103/-	103/-	90/-	72/-	-/-	-/-	-/-	-/-
RS	27/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
SE	793/-	-/-	23/-	368/-	378/-	75/-	69/-	4/-	2/-	-/-	1/-
SI	45/1	-/-	-/-	43/1	41/1	40/1	36/1	2/-	1/-	1/-	1/-
SK	112/8	-/-	-/-	112/8	111/8	109/8	98/8	-/-	-/-	-/-	-/-
Total	**4914/ 114**	**1/ -**	**187/ -**	**4151/ 95**	**4148/ 90**	**3210/ 90**	**2948/ 79**	**100/ 1**	**71/ 1**	**49/ 1**	**32/ 1**

Bulk density data are missing on all plots and layers in Cyprus and Serbia and on a relatively high number and layers of the Swedish plots. Greece limited the bulk density analysis to the upper 10 cm and Spain (including the Canary Islands) to the upper 20 cm of the mineral soil. Overall, on Level I, bulk density data are available for 87 % of the total number of plots in the 0 -10 cm layer, for 86 % in the 10 – 20 cm layer, for 66 % in the 20 – 40 cm layer and for 61 % in the 40 – 80 cm layer. On Level II, it is available for the respective layers in 84 %, 80 %, 80 % and 71 % of the plots. Hence data availability decreases with depth. As forest soils do not always reach a rootable depth of 80 cm, this is in line with the expectations.

2.6.4.5 Coarse fragments

Coarse fragments could be reported by volume % or mass % and was only requested for the mineral soil layers, till 80 cm on the Level I plots and till 40 cm on the Level II plots. As a soil can be free of stones, the content can be 0 % and 0 values in the database are considered as real values. On the other hand, Table 2.6.11 shows that there were also a high number of missing values.

Table 2.6.11. Data availability of the coarse fragments (either mass % or volume %) by country and by layer. The number before the slash refers to the number of Level I plots. The number behind to Level II.

Country	N° plots	OL	OFH	H	M01	M12	M24	M48	H01	H12	H24	H48
AT	135/2	-/-	-/-	-/-	133/-	131/-	125/-	116/-	1/-	1/-	-/-	-/-
BE	10/11	-/-	-/-	-/-	10/11	10/11	10/11	10/11	-/-	-/-	-/-	-/-
CY	15/2	15/2	15/2	-/-	15/2	15/2	14/2	9/2	-/-	-/-	-/-	-/-
CZ	146/8	-/-	-/-	-/-	146/8	146/8	146/8	145/8	-/-	-/-	-/-	-/-
DE	422/8	-/-	95/-	-/-	414/8	413/6	414/6	401/6	7/-	7/-	5/-	5/-
DK	25/3	-/-	-/-	-/-	25/3	25/3	25/3	25/3	-/-	-/-	-/-	-/-
EE	96/-	-/-	-/-	-/-	82/-	83/-	82/-	79/-	-/-	-/-	-/-	-/-
ES	598/2	-/-	-/-	-/-	598/2	586/2	-/1	-/1	-/-	-/-	-/-	-/-
FI	630/32	-/-	-/-	-/-	567/28	554/28	531/28	504/-	-/-	-/-	-/-	-/-
FR	545/10	-/-	-/-	-/-	543/10	530/10	496/10	393/-	-/-	-/-	-/-	-/-
GB	166/4	-/-	-/-	-/-	129/4	138/4	141/4	130/4	41/-	26/-	19/-	11/-
GR	-/4	-/-	-/-	-/-	-/4	-/-	-/-	-/-	-/-	-/-	-/-	-/-
HU	78/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
IC	13/-	-/-	-/-	-/-	13/-	13/-	-/-	-/-	-/-	-/-	-/-	-/-
IE	35/3	-/-	-/-	-/-	9/2	13/2	20/2	26/2	24/1	20/1	13/1	5/1
IT	239/8	-/1	3/-	-/-	238/8	237/8	226/8	160/8	1/-	1/-	1/-	-/-
LT	62/2	-/-	-/-	-/-	57/2	57/2	57/2	58/2	-/-	-/-	-/-	-/-
LV	95/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
PL	524/6	-/-	-/-	-/-	501/6	504/6	509/6	511/6	11/-	6/-	2/-	2/-
PT	103/-	-/-	-/-	-/-	103/-	103/-	101/-	86/-	-/-	-/-	-/-	-/-
RS	27/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
SE	793/-	-/-	25/-	-/-	366/-	378/-	75/-	10/-	2/-	1/-	-/-	1/-
SI	45/1	-/-	-/-	-/-	43/1	41/1	40/1	36/1	2/-	1/-	1/-	1/-
SK	112/8	-/-	-/-	-/-	112/8	111/6	109/5	100/5	-/-	-/-	-/-	-/-
Total	**4914/ 114**	**16/ 3**	**138/ 2**	**-/ -**	**4104/ 107**	**4088/ 99**	**3121/ 97**	**2799/ 59**	**89/ 1**	**63/ 1**	**41/ 1**	**25/ 1**

On Level I, data on the coarse fragments in the M01 is covered for 85 % and in M12 layer for 84 %. It is completely lacking for Hungary, Latvia and Serbia. Below 20 cm, the coverage is worse: 64 % in the 20 – 40 cm layer and 57 % in the 40 – 80 cm layer. On Level II the coverage in the upper 40 cm of the soil is a bit better: 95 % in the 0 – 10 cm, 88 % in the 10 – 20 cm, 86 % in the 20 – 40 cm but only 53 % in the 40 – 80 cm layer.

2.6.4.6 Soil reaction

Following the manual this soil characteristic was measured both in H_2O and in $CaCl_2$ on all fixed depth layers till 80 cm. Additionally the soil pH has been measured on the samples taken by genetic horizons in the profile pits made for profile description.

Table 2.6.12. Data availability of pH-$CaCl_2$ by country and by layer. The number before the slash refers to the number of Level I plots. The number behind to Level II.

Country	N° plots	OL	OFH	H	M01	M12	M24	M48	H01	H12	H24	H48
AT	135/2	4/1	128/2	-/-	134/2	134/2	133/2	126/2	1/-	1/-	-/-	-/-
BE	10/11	-/1	9/11	-/-	10/11	10/11	10/11	10/11	-/-	-/-	-/-	-/-
CY	15/2	-/-	15/2	-/-	15/2	15/2	14/2	9/2	-/-	-/-	-/-	-/-
CZ	146/8	-/-	145/8	-/-	146/8	146/8	146/8	145/8	-/-	-/-	-/-	-/-
DE	422/8	117/7	391/7	-/-	415/8	414/8	415/8	402/8	7/-	7/-	5/-	5/-
DK	25/3	25/3	25/3	-/-	25/3	25/3	25/3	25/3	-/-	-/-	-/-	-/-
EE	96/-	69/-	62/-	14/-	83/-	83/-	82/-	79/-	13/-	13/-	13/-	13/-
ES	598/2	-/-	538/2	-/-	598/2	586/2	-/1	-/1	-/-	-/-	-/-	-/-
FI	630/32	-/-	493/32	61/-	567/28	554/28	531/28	504/-	63/4	63/4	62/4	-/-
FR	545/10	-/-	132/8	-/-	543/10	530/10	496/10	393/-	-/-	-/-	-/-	-/-
GB	166/4	1/-	115/4	-/-	129/4	138/4	144/4	143/4	43/-	28/-	21/-	12/-
GR	-/4	-/-	-/4	-/-	-/4	-/4	-/4	-/4	-/-	-/-	-/-	-/-
HU	78/-	70/-	34/-	-/-	76/-	76/-	77/-	76/-	-/-	-/-	-/-	-/-
IC	13/-	-/-	11/-	-/-	13/-	13/-	-/-	-/-	-/-	-/-	-/-	-/-
IE	35/3	29/3	29/3	-/-	11/2	15/2	22/2	29/2	24/1	20/1	13/1	6/1
IT	239/8	1/-	165/8	-/-	238/8	237/8	226/8	160/8	1/-	1/-	1/-	-/-
LT	62/2	62/2	48/2	-/-	57/2	57/2	57/2	58/2	5/-	5/-	5/-	4/-
LV	95/-	-/-	70/-	-/-	77/-	82/-	85/-	85/-	18/-	13/-	10/-	10/-
PL	524/6	1/-	383/6	7/-	501/6	504/6	509/6	511/6	25/-	20/-	14/-	12/-
PT	103/-	13/-	89/-	-/-	103/-	103/-	101/-	86/-	-/-	-/-	-/-	-/-
RS	27/-	-/-	27/-	-/-	27/-	27/-	-/-	-/-	-/-	-/-	-/-	-/-
SE	793/-	-/-	464/-	27/-	370/-	378/-	75/-	69/-	73/-	66/-	32/-	30/-
SI	45/1	1/-	44/1	-/-	43/1	41/1	40/1	36/1	2/-	1/-	1/-	1/-
SK	112/8	104/8	94/8	-/-	112/8	111/8	109/8	98/8	-/-	-/-	-/-	-/-
Total	**4914/ 114**	**497/ 25**	**3511/ 111**	**109/ -**	**4293/ 109**	**4279/ 109**	**3297 /108**	**3044/ 70**	**275/ 5**	**238/ 5**	**177/ 5**	**93/ 1**

Although the pH-$CaCl_2$ on the OL layer was not a requested parameter, 14 countries (for a total of 10 % of the plots) reported the pH-$CaCl_2$ of the OL layer on at least one plot (Table 2.6.12). The data on the OFH layer include the plots where the pH-$CaCl_2$ was reported separately for the OF and OH layers. So the pH-$CaCl_2$ of the main part of the forest floor is available for 72 % of the plots. The H-layer, which includes the Hs, Hfs and Hf layers, has been analysed for pH-$CaCl_2$ on Level I plots in four northern countries. In the mineral soil and peat layers on the Level I plots, the pH-$CaCl_2$ data availability decrease gradually with depth: 93 % in the 0 – 10 cm layer, 92 % in the 10-20 cm layer over 71 % in the 20 -40 cm layer to 63 % in the 40-80 cm layer. On Level II plots, pH-$CaCl_2$ is available for all sampled plots in BioSoil for the 0 -10 and 10 – 20 cm layer, for 99 % in the 20 – 40 cm layer and for 62 % in the 40 – 80 cm layer.

Table 2.6.13. Data availability of pH-H_2O by country and by layer. The number before the slash refers to the number of Level I plots. The number behind to Level II.

Country	N° plots	OL	OFH	H	M01	M12	M24	M48	H01	H12	H24	H48
AT	135/2	3/1	128/2	-/-	134/2	134/2	133/2	126/2	1/-	1/-	-/-	-/-
BE	10/11	-/1	9/11	-/-	10/11	10/11	10/11	10/11	-/-	-/-	-/-	-/-
CY	15/2	-/-	15/2	-/-	15/2	15/2	14/2	9/2	-/-	-/-	-/-	-/-
CZ	146/8	-/-	145/8	-/-	146/8	146/8	146/8	145/8	-/-	-/-	-/-	-/-
DE	422/8	117/7	391/7	-/-	415/8	414/8	415/8	402/8	7/-	7/-	5/-	5/-
DK	25/3	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
EE	96/-	2/-	62/-	14/-	83/-	83/-	82/-	79/-	13/-	13/-	13/-	13/-
ES	598/2	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
FI	630/32	-/-	493/32	61/-	567/28	554/28	531/28	504/-	63/4	63/4	62/4	-/-
FR	545/10	-/-	133/8	-/-	543/10	530/10	496/10	393/-	-/-	-/-	-/-	-/-
GB	166/4	1/-	115/4	-/-	129/4	138/4	144/4	143/4	43/-	28/-	21/-	12/-
GR	-/4	-/-	-/4	-/-	-/4	-/4	-/4	-/4	-/-	-/-	-/-	-/-
HU	78/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
IC	13/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
IE	35/3	-/-	2/-	-/-	1/-	2/-	2/-	4/-	1/-	2/-	1/-	-/-
IT	239/8	1/-	165/8	-/-	238/8	237/8	226/8	160/8	1/-	1/-	1/-	-/-
LT	62/2	62/2	48/2	-/-	57/2	57/2	57/2	58/2	5/-	5/-	5/-	4/-
LV	95/-	-/-	70/-	-/-	77/-	82/-	85/-	85/-	18/-	13/-	10/-	10/-
PL	524/6	1/-	383/6	7/-	501/6	504/6	509/6	511/6	25/-	20/-	14/-	12/-
PT	103/-	13/-	89/-	-/-	103/-	103/-	101/-	86/-	-/-	-/-	-/-	-/-
RS	27/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
SE	793/-	-/-	463/-	27/-	368/-	377/-	75/-	69/-	73/-	66/-	32/-	30/-
SI	45/1	1/-	44/-	-/-	43/-	41/-	40/-	36/-	2/-	1/-	1/-	1/-
SK	112/8	104/8	94/8	-/-	112/8	111/8	109/8	98/8	-/-	-/-	-/-	-/-
Total	**4914/ 114**	**305/ 19**	**2849/ 102**	**109/ 0**	**3542/ 101**	**3538/ 101**	**3175/ 101**	**2918/ 63**	**252/ 4**	**220/ 4**	**165/ 4**	**87/ 0**

Although pH-H_2O was a requested value on all layers except the OL layer, the data availability is lower compared to the pH-$CaCl_2$ (Table 2.6.13). Denmark, Spain, Hungary, Ireland and Serbia reported no or nearly none pH-H_2O measurements. As for pH-$CaCl_2$, the pH-H_2O data availability decreases gradually with depth in the mineral soil and peat layers. On Level I this is 77 % in the 0 – 10 and 10 - 20 cm layer, over 68 % in the 20 -40 cm layer to 61 % in the 40-80 cm layer. On Level II, this is 93 % in the layer 0 – 10, 10 – 20 and 20 – 40 cm and 55 % in the 40 – 80 cm layer.

2.6.4.7 Carbonates

The carbonate content was requested when the pH-$CaCl_2$ in the organic layers was above 5.5 or when above 6.0 in the mineral soil layers. There were 1172 Level I and 16 Level II plots where this condition was fulfilled. Only these plots are included in Table 2.6.14. The data on the $CaCO_3$ content is not complete. On 45 of the 1188 plots $CaCO_3$ data is missing (4 %). On the other hand, $CaCO_3$ was found in some samples with low pH-$CaCl_2$ values.

Table 2.6.14. Data availability of $CaCO_3$ by country and by layer. The number before the slash refers to the number of Level I plots. The number behind to Level II.

Country	N° plots pH > 5.5 or 6	N° plots with $CaCO_3$ data	OL	OFH	H	M01	M12	M24	M48	H01	H12	H24	H48
AT	42/1	42/-	1/-	18/-	-/-	31/-	34/-	35/-	32/-	-/-	-/-	-/-	-/-
BE	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
CY	15/2	15/2	-/-	13/2	-/-	14/2	14/2	13/2	8/2	-/-	-/-	-/-	-/-
CZ	10/-	0/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
DE	91/2	89/1	7/-	26/-	-/-	27/-	37/-	50/-	69/1	1/-	1/-	1/-	1/-
DK	1/-	1/-	-/-	-/-	-/-	-/-	-/-	-/-	1/-	-/-	-/-	-/-	-/-
EE	41/-	35/-	-/-	-/-	1/-	16/-	20/-	20/-	32/-	-/-	-/-	-/-	-/-
ES	326/1	324/1	-/-	202/1	-/-	278/1	264/1	-/1	-/1	-/-	-/-	-/-	-/-
FI	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
FR	199/2	197/2	-/-	31/-	-/-	135/-	135/-	134/2	89/-	-/-	-/-	-/-	-/-
GB	19/-	18/-	-/-	3/-	-/-	10/-	12/-	11/-	15/-	-/-	-/-	-/-	-/-
GR	-/3	-/3	-/-	-/3	-/-	-/-	-/-	-/-	-/1	-/-	-/-	-/-	-/-
HU	54/-	43/-	2/-	2/-	-/-	24/-	25/-	29/-	38/-	-/-	-/-	-/-	-/-
IC	5/-	5/-	-/-	2/-	-/-	3/-	3/-	-/-	-/-	-/-	-/-	-/-	-/-
IE	2/-	2/-	-/-	-/-	-/-	-/-	2/-	2/-	2/-	-/-	-/-	-/-	-/-
IT	153/3	153/2	-/-	91/1	-/-	106/-	107/1	107/2	71/1	-/-	-/-	-/-	-/-
LT	30/-	30/-	1/-	4/-	-/-	6/-	8/-	13/-	28/-	2/-	2/-	2/-	2/-
LV	38/-	34/-	-/-	-/-	-/-	8/-	11/-	19/-	33/-	-/-	1/-	-/-	-/-
PL	52/-	52/-	-/-	-/-	-/-	14/-	16/-	26/-	42/-	8/-	9/-	7/-	6/-
PT	17/-	17/-	-/-	15/-	-/-	5/-	3/-	4/-	3/-	-/-	-/-	-/-	-/-
RS	7/-	4/-	-/-	-/-	-/-	3/-	4/-	-/-	-/-	-/-	-/-	-/-	-/-
SE	16/-	15/-	-/-	7/-	1/-	3/-	7/-	2/-	4/-	1/-	2/-	1/-	1/-
SI	19/1	19/1	1/-	5/-	-/-	10/-	8/-	9/-	11/1	1/-	-/-	-/-	1/-
SK	35/1	35/1	13/-	16/1	-/-	18/-	19/-	21/-	22/-	-/-	-/-	-/-	-/-
Total	**1172/16**	**1130/13**	**25/0**	**435/8**	**2/-**	**711/3**	**729/4**	**495/7**	**500/7**	**13/-**	**15/-**	**11/-**	**11/-**

The majority of calcareous forest soils are located in southern Europe: 60 % is located in Cyprus, France, Greece, Italy and Spain. In Belgium and Finland no forest soils with pH-$CaCl_2$ above 5.5 (organic layer) or above 6.0 (mineral soil) were met. Overall, the data availability decreases with depth but clearly less dramatically compared to the other soil variables. This is to be expected as many calcareous soils have leached surface layers on top of carbonate rich subsoils.

2.6.4.8 Organic Carbon

Together with total nitrogen, the organic carbon (OC) content are the best covered chemical parameters of the BioSoil^{+} database. It has been analysed by all countries on most of their plots and layers (Table 2.6.15). Spain (including the Canary Islands) and Serbia measured the OC to the depth of 20 cm only. Sweden reported the analyses on a subset of their plots.

Table 2.6.15. Data availability of Organic Carbon by country and by layer. The number before the slash refers to the number of Level I plots. The number behind to Level II.

Country	N° PLOTS	OL	OFH	H	M01	M12	M24	M48	H01	H12	H24	H48
AT	135/2	126/2	128/2	-/	134/2	134/2	133/2	126/2	1/-	1/-	-/-	-/-
BE	10/11	1/1	9/11	-/	10/11	10/11	10/11	10/11	-/-	-/-	-/-	-/-
CY	15/2	-/-	15/2	-/	15/2	15/2	14/2	9/2	-/-	-/-	-/-	-/-
CZ	146/8	-/-	145/8	-/	146/8	146/8	146/8	145/8	-/-	-/-	-/-	-/-
DE	422/8	123/7	391/7	-/	414/8	414/8	415/7	402/7	7/-	6/-	5/-	5/-
DK	25/3	25/3	25/3	-/	25/3	25/3	25/3	25/3	-/-	-/-	-/-	-/-
EE	96/-	69/-	62/-	14/-	83/-	83/-	82/-	79/-	13/-	13/-	13/-	13/-
ES	598/2	-/-	538/2	-/	598/2	585/2	-/1	-/1	-/-	-/-	-/-	-/-
FI	630/32	-/32	493/32	61/	567/28	554/28	531/28	504/-	63/4	63/4	62/4	-/-
FR	545/10	-/10	133/8	-/	542/10	530/10	496/10	392/-	-/-	-/-	-/-	-/-
GB	166/4	1/-	115/4	-/	129/4	138/4	144/4	143/4	43/-	28/-	21/-	12/-
GR	-/4	-/4	-/4	-/	-/4	-/4	-/4	-/4	-/-	-/-	-/-	-/-
HU	78/-	68/-	34/-	-/-	76/-	76/-	77/-	76/-	-/-	-/-	-/-	-/-
IC	13/-	-/-	9/-	-/-	10/-	10/-	-/-	-/-	-/-	-/-	-/-	-/-
IE	35/3	-/3	29/3	-/	11/2	15/2	22/2	29/2	24/1	20/1	13/1	6/1
IT	239/8	1/-	165/8	-/	238/8	237/8	226/8	160/8	1/-	1/-	1/-	-/-
LT	62/2	62/2	48/2	-/	57/2	57/2	57/2	58/2	5/-	5/-	5/-	4/-
LV	95/-	-/-	70/-	-/-	77/-	82/-	85/-	85/-	18/-	13/-	10/-	10/-
PL	524/6	470/6	383/6	7/	501/6	504/6	509/6	511/6	25/-	20/-	14/-	12/-
PT	103/-	14/-	89/-	-/-	103/-	103/-	101/-	86/-	-/-	-/-	-/-	-/-
RS	27/-	-/-	27/-	-/-	27/-	27/-	-/-	-/-	-/-	-/-	-/-	-/-
SE	793/-	-/-	464/-	27/-	370/-	378/-	75/-	69/-	73/-	66/-	32/-	30/-
SI	45/1	45/1	44/1	-/	43/1	41/1	40/1	36/1	2/-	1/-	1/-	1/-
SK	112/8	104/8	94/8	-/	112/8	111/8	109/8	98/8	-/-	-/-	-/-	-/-
Total	**4914/114**	**1109/79**	**3510/111**	**109/0**	**4288/109**	**4275/109**	**3297/107**	**3043/69**	**275/5**	**237/5**	**177/5**	**93/1**

Although not requested for the OL layer, organic carbon data are available on 23 % of the Level I plots and 69 % of the Level II plots. Concerning the OFH layer, 71 % of the Level I and 97 % of the Level II plots are covered. For the upper 10 cm of mineral soils and peat soils, carbon concentration data are available on 93 % of the Level I. From Table 2.6.15, we see that the missing carbon data mainly concern Swedish plots. For the M12 layer the data availability is lower than for the M01 layer though in a number of northern countries it is higher. This can be explained by the fact that some M12 layers underly H01 layers. The data availability in the M24 layers decreases mainly because of this missing data for Spain and Serbia.

2.6.4.9 Total Nitrogen

The data availability of total nitrogen is very similar to organic carbon with the exception that on Level I Finland did nearly not report any total nitrogen concentrations in mineral soil layers below 20 cm (Table 2.6.16).

Table 2.6.16. Data availability of Total Nitrogen by country and by layer. The number before the slash refers to the number of Level I plots. The number behind to Level II.

Country	N° plots	OL	OFH	H	M01	M12	M24	M48	H01	H12	H24	H48
AT	135/2	126/2	128/2	-/-	134/2	134/2	133/2	126/2	1/-	1/-	-/-	-/-
BE	10/11	-/1	9/11	-/-	10/11	10/11	10/11	10/11	-/-	-/-	-/-	-/-
CY	15/2	-/-	15/2	-/-	15/2	15/2	14/2	9/2	-/-	-/-	-/-	-/-
CZ	146/8	-/-	145/8	-/-	146/8	146/8	146/8	145/8	-/-	-/-	-/-	-/-
DE	422/8	123/7	391/7	-/-	415/8	414/8	415/7	402/7	7/-	6/-	5/-	5/-
DK	25/3	25/3	25/3	-/-	25/3	25/3	25/3	25/3	-/-	-/-	-/-	-/-
EE	96/-	69/-	62/-	14/-	83/-	83/-	82/-	79/-	13/-	13/-	13/-	13/-
ES	598/2	-/-	538/2	-/-	598/2	585/2	-/1	-/1	-/-	-/-	-/-	-/-
FI	630/32	-/32	493/32	60/-	566/28	552/28	2/28	4/-	63/4	63/4	62/4	-/-
FR	545/10	-/10	133/8	-/-	542/10	530/10	495/10	391/-	-/-	-/-	-/-	-/-
GB	166/4	1/-	115/4	-/-	129/4	138/4	144/4	143/4	43/-	28/-	21/-	12/-
GR	-/4	-/4	-/4	-/-	-/4	-/4	-/4	-/4	-/-	-/-	-/-	-/-
HU	78/-	68/-	34/-	-/-	76/-	76/-	77/-	76/-	-/-	-/-	-/-	-/-
IC	13/-	-/-	9/-	-/-	10/-	10/-	-/-	-/-	-/-	-/-	-/-	-/-
IE	35/3	-/3	29/3	-/-	11/2	15/2	22/2	29/2	24/1	20/1	13/1	6/1
IT	239/8	1/-	165/8	-/-	238/8	237/8	226/8	160/8	1/-	1/-	1/-	-/-
LT	62/2	62/2	48/2	-/-	57/2	57/2	57/2	58/2	5/-	5/-	5/-	4/-
LV	95/-	-/-	70/-	-/-	77/-	82/-	85/-	85/-	18/-	13/-	10/-	10/-
PL	524/6	470/6	383/6	7/-	501/6	504/6	509/6	511/6	25/-	20/-	14/-	12/-
PT	103/-	14/-	89/-	-/-	103/-	103/-	101/-	86/-	-/-	-/-	-/-	-/-
RS	27/-	-/-	27/-	-/-	27/-	27/-	-/-	-/-	-/-	-/-	-/-	-/-
SE	793/-	-/-	464/-	27/-	370/-	378/-	75/-	69/-	73/-	66/-	32/-	30/-
SI	45/1	45/1	44/1	-/-	43/1	41/1	40/1	36/1	2/-	1/-	1/-	1/-
SK	112/8	104/8	94/8	-/-	112/8	111/8	109/8	98/8	-/-	-/-	-/-	-/-
Total	**4914/ 114**	**1108/ 79**	**3510/ 111**	**108/ -**	**4288/ 109**	**4273/ 109**	**2767/ 107**	**2542/ 69**	**275/ 5**	**237/ 5**	**177/ 5**	**93/ 1**

The data availability decreases gradually with depth in the mineral soil and peat layers. On Level I this is 93 % in the 0 – 10 cm, 92 % in the 10 - 20 cm layer, over 60 % in the 20 -40 cm layer to 54 % in the 40-80 cm layer. On Level II, this is 100 % in the layers 0 – 10, 10 – 20 cm, 98 % in the 20 – 40 cm and 61 % in the 40 – 80 cm layer.

2.6.4.10 Exchangeable elements

The group of the exchangeable elements comprises the basic cations (Ca, K, Mg and Na), the acid cations (Al, Fe and Mn), exchangeable acidity and free H^+. As the data availability of all these elements is very comparable (maximum 1 % variation amongst the elements), only the information available for Ca is shown in Table 2.6.17.

Table 2.6.17. Data availability of exchangeable Ca by country and by layer. The number before the slash refers to the number of Level I plots. The number behind to Level II.

Country	N° plots	OL	OFH	H	M01	M12	M24	M48	H01	H12	H24	H48
AT	135/2	-/-	125/2	-/-	134/2	133/2	128/2	120/2	1/-	-/-	-/-	-/-
BE	10/11	-/-	9/10	-/-	10/11	10/11	10/11	10/11	-/-	-/-	-/-	-/-
CY	15/2	-/-	15/2	-/-	15/2	15/2	14/2	9/2	-/-	-/-	-/-	-/-
CZ	146/8	-/-	145/8	-/-	146/8	146/8	146/8	145/8	-/-	-/-	-/-	-/-
DE	422/8	45/7	389/7	-/-	415/8	414/8	415/8	402/8	7/-	7/-	5/-	5/-
DK	25/3	-/-	25/3	-/-	25/3	25/3	25/3	25/3	-/-	-/-	-/-	-/-
EE	96/-	2/-	62/-	14/-	83/-	83/-	82/-	79/-	13/-	13/-	13/-	13/-
ES	598/2	-/-	-/-	-/-	418/2	411/2	-/1	-/1	-/-	-/-	-/-	-/-
FI	630/32	-/-	493/32	61/-	567/28	554/28	531/28	504/-	63/4	63/4	62/4	-/-
FR	545/10	-/-	133/8	-/-	543/10	530/10	496/10	393/-	-/-	-/-	-/-	-/-
GB	166/4	-/-	115/4	-/-	129/4	138/4	144/4	144/4	43/-	28/-	21/-	12/-
GR	-/4	-/-	-/4	-/-	-/4	-/4	-/4	-/4	-/-	-/-	-/-	-/-
HU	78/-	61/-	32/-	-/-	56/-	55/-	53/-	48/-	-/-	-/-	-/-	-/-
IC	13/-	-/-	-/-	-/-	3/-	3/-	-/-	-/-	-/-	-/-	-/-	-/-
IE	35/3	29/3	29/3	-/-	11/2	15/2	22/2	29/2	24/1	20/1	13/1	6/1
IT	239/8	1/-	165/8	-/-	238/8	237/8	226/8	160/8	1/-	1/-	1/-	-/-
LT	62/2	9/-	48/2	-/-	57/2	57/2	57/2	58/2	5/-	5/-	5/-	4/-
LV	95/-	-/-	69/-	-/-	77/-	82/-	85/-	84/-	18/-	13/-	10/-	10/-
PO	524/6	1/-	381/6	1/-	501/6	504/6	509/6	511/6	25/-	20/-	14/-	12/-
PT	103/-	13/-	89/-	-/-	103/-	103/-	101/-	86/-	-/-	-/-	-/-	-/-
RS	27/-	-/-	-/-	-/-	27/-	27/-	-/-	-/-	-/-	-/-	-/-	-/-
SE	793/-	-/-	270/-	11/-	225/-	151/-	30/-	31/-	37/-	36/-	20/-	20/-
SI	45/1	-/-	44/1	-/-	43/1	41/1	40/1	36/1	2/-	1/-	1/-	1/-
SK	112/8	1/-	93/8	-/-	112/8	111/8	109/8	98/8	-/-	-/-	-/-	-/-
Total	**4914/ 114**	**162/ 10**	**2731/ 108**	**87/ -**	**3938/ 109**	**3845/ 109**	**3223/ 108**	**2972/ 70**	**239/ 5**	**207/ 5**	**165/ 5**	**83/ 1**

The exchangeable elements were requested to be reported on the OFH layer. It was not a requested parameter on the OL layer. On 74 % of the OFH layers present in the database this data is available. In the mineral soil layer, the data availability clearly decreases with depth. Note that if the deeper layers were sampled, the exchangeable cations were usually measured, as 96 % of the plots sampled at 20 – 40 cm and 40 – 80 cm have data on the exchangeable cations. About 80 % of the peat samples were analysed for exchangeable cations.

2.6.4.11 Aqua regia extractable elements

In the soil manual (FSCC 2006) the aqua regia extractable elements were listed according to the reporting requirements. In BioSoil the elements P, Ca, K, Mg and Mn had to be measured on all layers on the Level I plots (Table 2.4.4). On Level II, they were mandatory in the OFH layer but optional on the other layers. The trace metals Cu, Pb, Cd and Zn had to be reported on the organic layers and the mineral topsoil layer (0 - 10 cm). On Level II, these elements were mandatory to report on the OFH and 0 -10 cm layer but optional on all other layers. The elements Al, Fe, Cr, Ni, S and Na were on Level I mandatory on the organic layers and the mineral topsoil layer (0 – 10 cm) but on Level II optional for all layers. Hg was optional on all layers on both Levels. The final data availability however, depended largely on the equipment of the laboratories. In the following tables the data availability of each individual element is shown.

Phosphorus (P)

As the reporting requirements were very similar, the data availability of P, K, Ca, Mg and Mn in the BioSoil^{+} database is also very similar (Table 2.6.18). These were the only aqua regia extractable elements which had to be reported till the depth of 80 cm. The reasoning behind this is that P, K, Ca, K and Mg are important macronutrients for forest trees and tree roots explore the soil easily to the depth of 80 cm.

Table 2.6.18. Data availability of aqua regia extractable P by country and by layer. The number before the slash refers to the number of Level I plots. The number behind to Level II.

Country	N° plots	OL	OFH	H	M01	M12	M24	M48	H01	H12	H24	H48
AT	135/2	107/2	125/2	-/-	134/2	133/2	129/2	120/2	1/-	-/-	-/-	-/-
BE	10/11	10/10	9/11	-/-	10/11	10/11	10/11	10/11	-/-	-/-	-/-	-/-
CY	15/2	14/2	15/2	-/-	15/2	15/2	14/2	9/2	-/-	-/-	-/-	-/-
CZ	146/8	146/-	145/8	-/-	146/8	146/8	146/8	145/8	-/-	-/-	-/-	-/-
DE	422/8	188/7	391/7	-/-	410/8	321/6	322/6	312/6	7/-	6/-	4/-	4/-
DK	25/3	25/-	25/3	-/-	25/3	25/-	25/-	25/-	-/1	-/1	-/1	-/1
EE	96/-	88/-	62/-	14/-	83/-	83/-	82/-	79/-	13/-	13/-	13/-	13/-
ES	598/2	-/-	245/2	-/-	267/2	264/2	-/1	-/1	-/-	-/-	-/-	-/-
FI	630/32	-/32	493/32	61/-	567/28	7/28	1/28	5/-	63/-	63/-	62/-	-/-
FR	545/10	-/-	133/8	-/-	543/10	530/10	496/10	393/-	-/-	-/-	-/-	-/-
GB	166/4	138/4	115/4	-/-	129/4	138/4	144/4	143/4	43/-	28/-	21/-	12/-
GR	-/4	-/3	-/3	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
HU	78/-	70/-	34/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
IC	13/-	-/-	2/-	-/-	3/-	3/-	-/-	-/-	-/-	-/-	-/-	-/-
IE	35/3	29/3	29/3	-/-	11/2	15/2	22/2	29/2	24/-	20/-	13/-	6/-
IT	239/8	235/7	165/8	-/-	238/8	237/8	226/8	160/8	1/-	1/-	1/-	-/-
LT	62/2	62/2	48/2	-/-	56/-	57/-	57/-	58/-	5/-	5/-	5/-	4/-
LV	95/-	-/-	70/-	-/-	77/-	82/-	85/-	85/-	18/-	13/-	10/-	10/-
PL	524/6	470/6	383/6	7/-	501/6	504/6	509/6	511/6	25/4	20/4	14/4	12/-
PT	103/-	103/-	89/-	-/-	103/-	103/-	101/-	86/-	-/-	-/-	-/-	-/-
RS	27/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
SE	793/-	-/-	585/-	29/-	444/-	76/-	70/-	79/-	76/-	46/-	35/-	34/-
SI	45/1	45/1	44/1	-/-	43/1	41/1	40/-	36/-	2/-	1/-	1/-	1/-
SK	112/8	104/8	94/8	-/-	112/8	111/8	109/8	98/8	-/-	-/-	-/-	-/-
Total	**4914/ 114**	**1834/ 87**	**3301/ 110**	**111/ -**	**3917/ 103**	**2901/ 98**	**2588/ 96**	**2383/ 58**	**278/ 5**	**216/ 5**	**179/ 5**	**96/ 1**

Keeping this reporting requirement in mind, the data availability on the depths below 10 cm is still rather low. The availability of P, Ca, K, Mg and Mn decreases from ~ 86 % of all plots in the upper 10 cm, to 64 % in the 10 – 20 cm layer, over 57 % in the 20 – 40 cm layer to 50 % in the 40 – 80 cm layer. Although a decrease of chemical analysis with soil depth is rather logical (as not all soils reach a rootable depth till 80 cm), Table 2.6.18 shows that for example Spain did not analyse the layers below 20 cm on any of their Level I plots. Also Sweden conducted analyses on the layers below 10 cm only a small subset of their plots. Serbia only analysed these elements on the OL layers and also Hungary did not analyse these macronutrients on any of the mineral soil samples. A possible reason for this is that the ICP Forests soil manual (Expert Panel on Soil and FSCC 2003, FSCC 2006) did not define these macronutrients as mandatory parameters in the mineral soil layers.

Potassium (K)

On Level I, K analyses are available in the 0 – 10 cm mineral soil layer for 85 % of the plots and in the OFH and for 67 % of the plots. The availability of data decreases with depth but not that drastically as some of the other aqua regia extractable elements as K was a requested parameter within the BioSoil survey to the depth of 80 cm. Table 2.6.19.

Table 2.6.19. Data availability of aqua regia extractable K by country and by layer. The number before the slash refers to the number of Level I plots. The number behind to Level II.

Country	N° plots	OL	OFH	H	M01	M12	M24	M48	H01	H12	H24	H48
AT	135/2	107/2	125/2	-/-	134/2	133/2	129/2	120/2	1/-	-/-	-/-	-/-
BE	10/11	10/10	9/11	-/-	10/11	10/11	10/11	10/11	-/-	-/-	-/-	-/-
CY	15/2	14/2	15/2	-/-	15/2	15/2	14/2	9/2	-/-	-/-	-/-	-/-
CZ	146/8	143/-	145/8	-/-	146/8	144/8	144/8	143/8	-/-	-/-	-/-	-/-
DE	422/8	188/7	391/7	-/-	410/8	321/6	322/6	312/6	7/-	6/-	4/-	4/-
DK	25/3	25/-	25/3	-/-	25/3	25/-	25/-	25/-	-/-	-/-	-/-	-/-
EE	96/-	88/-	62/-	14/-	83/-	83/-	82/-	79/-	13/-	13/-	13/-	13/-
ES	598/2	-/-	245/2	-/-	267/2	264/2	-/1	-/1	-/-	-/-	-/-	-/-
FI	630/32	-/32	493/32	61/-	567/28	7/28	1/28	5/-	63/4	63/4	62/4	-/-
FR	545/10	-/-	133/8	-/-	543/10	530/10	495/10	393/-	-/-	-/-	-/-	-/-
GB	166/4	138/4	115/4	-/-	129/4	138/4	144/4	143/4	43/-	28/-	21/-	12/-
GR	-/4	-/4	-/4	-/-	-/4	-/-	-/-	-/-	-/-	-/-	-/-	-/-
HU	78/-	70/-	34/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
IC	13/-	-/-	2/-	-/-	3/-	3/-	-/-	-/-	-/-	-/-	-/-	-/-
IE	35/3	29/3	29/3	-/-	11/1	15/1	22/-	29/-	24/1	20/1	13/1	6/1
IT	239/8	235/7	165/8	-/-	238/8	237/8	226/8	160/8	1/-	1/-	1/-	-/-
LT	62/2	62/2	48/2	-/-	56/-	57/-	57/-	58/-	5/-	5/-	5/-	4/-
LV	95/-	-/-	70/-	-/-	77/-	82/-	85/-	85/-	18/-	13/-	10/-	10/-
PL	524/6	470/6	383/6	7/-	501/6	504/6	509/6	511/6	25/-	20/-	14/-	12/-
PT	103/-	103/-	89/-	-/-	103/-	103/-	101/-	86/-	-/-	-/-	-/-	-/-
RS	27/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
SE	793/-	-/-	585/-	29/-	444/-	76/-	70/-	79/-	76/-	46/-	35/-	34/-
SI	45/1	45/1	44/1	-/-	43/1	41/1	40/-	36/-	2/-	1/-	1/-	1/-
SK	112/8	104/8	94/8	-/-	112/8	111/8	109/8	98/8	-/-	-/-	-/-	-/-
Total	**4914/ 114**	**1831/ 88**	**3301/ 111**	**111/ -**	**3917/ 106**	**2899/ 97**	**2585/ 94**	**2381/ 56**	**278/ 5**	**216/ 5**	**179/ 5**	**96/ 1**

Calcium (Ca)

The data availability of Ca is very comparable to that of P and K as shown in Table 2.6.20.

Table 2.6.20. Data availability of aqua regia extractable Ca by country and by layer. The number before the slash refers to the number of Level I plots. The number behind to Level II.

Country	N° plots	OL	OFH	H	M01	M12	M24	M48	H01	H12	H24	H48
AT	135/2	107/2	125/2	-/-	134/2	133/2	129/2	120/2	1/-	-/-	-/-	-/-
BE	10/11	10/10	9/11	-/-	10/11	10/11	10/11	10/11	-/-	-/-	-/-	-/-
CY	15/2	14/2	15/2	-/-	15/2	15/2	14/2	9/2	-/-	-/-	-/-	-/-
CZ	146/8	143/-	145/8	-/-	146/8	146/8	146/8	145/8	-/-	-/-	-/-	-/-
DE	422/8	188/7	391/7	-/-	410/8	321/6	322/6	312/6	7/-	6/-	4/-	4/-
DK	25/3	25/-	25/3	-/-	25/3	25/-	25/-	25/-	-/-	-/-	-/-	-/-
EE	96/-	88/-	62/-	14/-	83/-	83/-	82/-	79/-	13/-	13/-	13/-	13/-
ES	598/2	-/-	245/1	-/-	267/2	264/2	-/1	-/1	-/-	-/-	-/-	-/-
FI	630/32	-/32	493/32	61/-	567/28	7/28	1/28	5/-	63/4	63/4	62/4	-/-
FR	545/10	-/-	133/8	-/-	543/10	530/10	496/10	393/-	-/-	-/-	-/-	-/-
GB	166/4	138/4	115/4	-/-	129/4	138/4	144/4	143/4	43/-	28/-	21/-	12/-
GR	-/4	-/4	-/4	-/-	-/4	-/-	-/-	-/-	-/-	-/-	-/-	-/-
HU	78/-	70/-	34/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
IC	13/-	-/-	2/-	-/-	3/-	3/-	-/-	-/-	-/-	-/-	-/-	-/-
IE	35/3	29/3	29/3	-/-	11/1	15/1	21/-	28/-	24/1	20/1	13/1	6/1
IT	239/8	235/7	165/8	-/-	238/8	237/8	226/8	160/8	1/-	1/-	1/-	-/-
LT	62/2	62/2	48/2	-/-	56/-	57/-	57/-	58/-	5/-	5/-	5/-	4/-
LV	95/-	-/-	70/-	-/-	77/-	82/-	85/-	85/-	18/-	13/-	10/-	10/-
PL	524/6	470/6	383/6	7/-	501/6	504/6	509/6	511/6	25/-	20/-	14/-	12/-
PT	103/-	103/-	89/-	-/-	103/-	103/-	101/-	86/-	-/-	-/-	-/-	-/-
RS	27/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
SE	793/-	-/-	585/-	29/-	444/-	76/-	70/-	79/-	76/-	46/-	35/-	34/-
SI	45/1	45/1	44/1	-/-	43/1	41/1	40/-	36/-	2/-	1/-	1/-	1/-
SK	112/8	104/8	94/8	-/-	112/8	111/8	109/8	98/8	-/-	-/-	-/-	-/-
Total	**4914/ 114**	**1831/ 88**	**3301/ 110**	**111/ -**	**3917/ 106**	**2901/ 97**	**2587/ 94**	**2382/ 56**	**278/ 5**	**216/ 5**	**179/ 5**	**96/ 1**

Magnesium (Mg)

The data availability of Mg is very similar to the data availability of P, K and Ca as shown in Table 2.6.21.

Table 2.6.21. Data availability of aqua regia extractable Mg by country and by layer. The number before the slash refers to the number of Level I plots. The number behind to Level II.

Country	N° plots	OL	OFH	H	M01	M12	M24	M48	H01	H12	H24	H48
AT	135/2	107/2	125/2	-/-	134/2	133/2	129/2	120/2	1/-	-/-	-/-	-/-
BE	10/11	10/10	9/11	-/-	10/11	10/11	10/11	10/11	-/-	-/-	-/-	-/-
CY	15/2	14/2	15/2	-/-	15/2	15/2	14/2	9/2	-/-	-/-	-/-	-/-
CZ	146/8	143/-	145/8	-/-	146/8	146/8	146/8	145/8	-/-	-/-	-/-	-/-
DE	422/8	188/7	391/7	-/-	410/8	321/6	322/6	312/6	7/-	6/-	4/-	4/-
DK	25/3	25/-	25/3	-/-	25/3	25/-	25/-	25/-	-/-	-/-	-/-	-/-
EE	96/-	88/-	62/-	14/-	83/-	83/-	82/-	79/-	13/-	13/-	13/-	13/-
ES	598/2	-/-	245/2	-/-	267/2	264/2	-/1	-/1	-/-	-/-	-/-	-/-
FI	630/32	-/32	493/32	61/-	567/28	7/28	1/28	5/-	63/4	63/4	62/4	-/-
FR	545/10	-/-	133/8	-/-	543/10	530/10	495/10	393/-	-/-	-/-	-/-	-/-
GB	166/4	138/4	115/4	-/-	129/4	138/4	144/4	143/4	43/-	28/-	21/-	12/-
GR	-/4	-/4	-/4	-/-	-/4	-/-	-/-	-/-	-/-	-/-	-/-	-/-
HU	78/-	70/-	34/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
IC	13/-	-/-	2/-	-/-	3/-	3/-	-/-	-/-	-/-	-/-	-/-	-/-
IE	35/3	29/3	29/3	-/-	11/1	15/1	22/-	29/-	24/1	20/1	13/1	6/1
IT	239/8	235/7	165/8	-/-	238/8	237/8	226/8	160/8	1/-	1/-	1/-	-/-
LT	62/2	62/2	48/2	-/-	56/-	57/-	57/-	58/-	5/-	5/-	5/-	4/-
LV	95/-	-/-	70/-	-/-	77/-	82/-	85/-	85/-	18/-	13/-	10/-	10/-
PL	524/6	470/6	383/6	7/-	501/6	504/6	509/6	511/6	25/-	20/-	14/-	12/-
PT	103/-	103/-	89/-	-/-	103/-	103/-	101/-	86/-	-/-	-/-	-/-	-/-
RS	27/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
SE	793/-	-/-	582/-	29/-	444/-	76/-	70/-	79/-	76/-	46/-	35/-	34/-
SI	45/1	45/1	44/1	-/-	43/1	41/1	40/-	36/-	2/-	1/-	1/-	1/-
SK	112/8	104/8	94/8	-/-	112/8	111/8	109/8	98/8	-/-	-/-	-/-	-/-
Total	**4914/ 114**	**1831/ 88**	**3298/ 111**	**111/ -**	**3917/ 106**	**2901/ 97**	**2587/ 94**	**2383/ 56**	**278/ 5**	**216/ 5**	**179/ 5**	**96/ 1**

The number of reported analyses can also be evaluated with respect to the number of sampled (but not necessarily analysed for all parameters) layers (Table 2.6.7). Doing so, for the aqua regia extractable macronutrients P, K, Ca, Mg - and for Mn – we see that these elements were reported for 87 % of the sampled OFH layers, for 88 % of the 0 – 10 cm layers, for 69 % of the 10 – 20 cm layer, for 78 % of the 20 – 40 cm layers and for 77 % of the 40 – 80 cm layers. So most of the OFH layers and the upper 10 cm were analysed for macro nutrients when sampled. Also when the layers below 20 cm were sampled, they were usually analysed. Though it also shows that more than 30 % of the sampled layers at 10 – 20 cm depth were not analysed for the macro nutrients.

Sulphur (S)

While sulphur is an optional parameter in the ICP Forests manual, it was mandatory on the BioSoil Level I plots till 10 cm depth and remained optional on Level II. So the data availability of sulphur is rather low compared to the other macronutrients. It was not reported by Spain (including Canary Islands), Greece, Hungary, Ireland and Serbia (Table 2.6.22). In the 0 – 10 cm layer it is available for 71 % of the Level I plots and 80 % of the Level II plots but in the 10 – 20 cm layer S is only available for 29 % of the Level I and 58 % of the Level II plots.

Table 2.6.22. Data availability of sulphur by country and by layer. The number before the slash refers to the number of Level I plots. The number behind to Level II.

Country	N° plots	OL	OFH	H	M01	M12	M24	M48	H01	H12	H24	H48
AT	135/2	107/2	125/2	-/-	134/2	133/2	129/2	120/2	1/-	-/-	-/-	-/-
BE	10/11	10/10	9/11	-/-	10/11	10/11	10/11	10/11	-/-	-/-	-/-	-/-
CY	15/2	14/2	15/2	-/-	15/2	1/-	-/-	-/-	-/-	-/-	-/-	-/-
CZ	146/8	146/-	145/-	-/-	146/-	3/-	3/-	3/-	-/-	-/-	-/-	-/-
DE	422/8	154/7	360/7	-/-	400/8	267/6	268/6	261/6	7/-	6/-	4/-	4/-
DK	25/3	25/-	25/3	-/-	25/3	25/-	25/-	25/-	-/-	-/-	-/-	-/-
EE	96/-	88/-	62/-	14/-	83/-	24/-	24/-	23/-	13/-	13/-	13/-	13/-
ES	598/2	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
FI	630/32	-/32	493/32	61/-	567/28	7/28	1/28	5/-	63/4	63/4	62/4	-/-
FR	545/10	-/-	133/-	-/-	543/10	-/-	-/-	-/-	-/-	-/-	-/-	-/-
GB	166/4	138/-	115/-	-/-	129/-	138/-	144/-	143/-	43/-	28/-	21/-	12/-
GR	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
HU	78/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
IC	13/3	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
IE	35/8	-/7	-/8	-/-	-/8	-/-	-/-	-/-	-/-	-/-	-/-	-/-
IT	239/2	235/-	165/-	-/-	238/-	70/-	67/-	48/-	1/-	-/-	-/-	-/-
LT	62/-	62/-	48/-	-/-	56/-	-/-	-/-	-/-	5/-	-/-	-/-	-/-
LV	95/6	-/6	70/6	-/-	76/6	1/6	-/6	-/6	18/-	-/-	-/-	-/-
PL	524/-	470/-	383/-	7/-	501/-	504/-	509/-	511/-	25/-	20/-	14/-	12/-
PT	103/-	102/-	89/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
RS	27/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
SE	793/1	-/1	492/1	28/-	412/1	68/1	65/1	59/1	73/-	43/-	33/-	32/-
SI	45/8	45/8	44/8	-/-	43/8	41/8	40/8	36/8	2/-	1/-	1/-	1/-
SK	112/4	104/4	94/4	-/-	112/4	111/4	109/4	98/4	-/-	-/-	-/-	-/-
Total	**4914/ 114**	**1700/ 79**	**2867/ 84**	**110/ -**	**3490/ 91**	**1403/ 66**	**1394/ 66**	**1342/ 38**	**251/ 4**	**174/ 4**	**148/ 4**	**74/ -**

Sodium (Na)

Table 2.6.23 shows that the data availability on Na is quite poor seen its reporting requirements. Although it was mandatory on Level I, Na analyses are available in the 0 – 10 cm mineral soil layer for 76 % of the plots and in the OFH and for 58 % of the plots. Countries like Austria, Sweden (including Canary Islands), Greece, Hungary, Ireland, Serbia did not report any aqua regia extractable sodium analysis. This can partly be due because of analytical problems in the laboratories identified for this particular analysis which was discussed at the meeting of the heads of the labs, 9 - 10 June 2008 (Cools and Mencke 2008). Though it can also be due to the fact that Na was in the ICP Forests manual an optional parameter which was made mandatory in the BioSoil inventory. The availability of data drastically decreases with depth (31 % in the 10 -20 and 20 – 40 cm layers and 28 % in the 40 – 80 cm layer) which is to be expected as this information was not asked for the deeper layers.

Table 2.6.23. Data availability of aqua regia extractable Na by country and by layer. The number before the slash refers to the number of Level I plots. The number behind to Level II.

Country	N° plots	OL	OFH	H	M01	M12	M24	M48	H01	H12	H24	H48
AT	135/2	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
BE	10/11	10/10	9/11	-/-	10/11	10/11	10/11	10/11	-/-	-/-	-/-	-/-
CY	15/2	14/2	15/2	-/-	15/2	-/-	-/-	-/-	-/-	-/-	-/-	-/-
CZ	146/8	146/-	145/8	-/-	146/8	11/8	11/8	11/8	-/-	-/-	-/-	-/-
DE	422/8	188/7	391/7	-/-	410/8	276/6	277/6	270/6	7/-	6/-	4/-	4/-
DK	25/3	25/-	25/3	-/-	25/3	25/-	25/-	25/-	-/-	-/-	-/-	-/-
EE	96/-	88/-	62/-	14/-	83/-	1/-	1/-	-/-	13/-	13/-	13/-	13/-
ES	598/2	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
FI	630/32	-/32	493/32	61/-	567/28	7/28	1/28	5/-	63/4	63/4	62/4	-/-
FR	545/10	-/-	133/-	-/-	543/10	-/-	-/-	-/-	-/-	-/-	-/-	-/-
GB	166/4	138/4	115/4	-/-	129/4	138/4	144/4	143/4	43/-	28/-	21/-	12/-
GR	-/4	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
HU	78/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
IC	13/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
IE	35/3	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
IT	239/8	235/7	165/8	-/-	238/8	74/-	70/-	50/-	1/-	1/-	1/-	-/-
LT	62/2	62/-	48/-	-/-	56/-	-/-	-/-	-/-	5/-	-/-	-/-	-/-
LV	95/-	-/-	70/-	-/-	77/-	82/-	85/-	85/-	18/-	13/-	10/-	10/-
PL	524/6	470/6	383/6	7/-	501/6	504/6	509/6	511/6	25/-	20/-	14/-	12/-
PT	103/-	103/-	89/-	-/-	103/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
RS	27/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
SE	793/-	-/-	585/-	29/-	444/-	76/-	70/-	79/-	76/-	46/-	35/-	34/-
SI	45/1	45/1	44/1	-/-	43/1	-/-	-/-	-/-	2/-	-/-	-/-	-/-
SK	112/8	104/8	94/8	-/-	112/8	111/8	109/8	98/8	-/-	-/-	-/-	-/-
Total	**4914/ 114**	**1628/ 77**	**2866/ 90**	**111/-**	**3502/ 97**	**1315/ 71**	**1312/ 71**	**1287/ 43**	**253/ 4**	**190/ 4**	**160/ 4**	**85/ -**

Aluminium (Al)

On Level I, Al analyses are available in the 0 – 10 cm mineral soil layer for 85 % of the plots and in the OFH for 66 % of the plots. Table 2.6.24 shows that the availability of data drastically decreases with depth (37 % for the 10 – 20 cm layer, 30 % for the 20 – 40 cm layer and 28 % for the 40 - 80 cm layer) , as this information was not asked for the deeper layers.

Table 2.6.24. Data availability of aqua regia extractable Al by country and by layer. The number before the slash refers to the number of Level I plots. The number behind to Level II.

Country	N° plots	OL	OFH	H	M01	M12	M24	M48	H01	H12	H24	H48
AT	135/2	107/2	125/2	-/-	134/2	133/2	129/2	120/2	1/-	-/-	-/-	-/-
BE	10/11	10/10	9/11	-/-	10/11	10/11	10/11	10/11	-/-	-/-	-/-	-/-
CY	15/2	14/2	15/2	-/-	15/2	1/1	-/-	-/-	-/-	-/-	-/-	-/-
CZ	146/8	146/-	145/8	-/-	146/8	-/8	-/8	-/8	-/-	-/-	-/-	-/-
DE	422/8	188/7	391/7	-/-	409/8	276/6	277/6	270/6	7/-	6/-	4/-	4/-
DK	25/3	25/-	25/3	-/-	25/3	25/-	25/-	25/-	-/-	-/-	-/-	-/-
EE	96/-	88/-	62/-	14/-	83/-	1/-	1/-	-/-	13/-	13/-	13/-	13/-
ES	598/2	-/-	245/1	-/-	267/2	264/2	-/1	-/1	-/-	-/-	-/-	-/-
FI	630/32	-/32	493/32	61/-	567/28	7/28	1/28	5/-	63/4	63/4	62/4	-/-
FR	545/10	-/-	133/-	-/-	543/10	-/-	-/-	-/-	-/-	-/-	-/-	-/-
GB	166/4	137/4	115/4	-/-	129/4	138/4	144/4	143/4	43/-	28/-	21/-	12/-
GR	-/4	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
HU	78/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
IC	13/-	-/-	2/-	-/-	3/-	3/-	-/-	-/-	-/-	-/-	-/-	-/-
IE	35/3	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
IT	239/8	235/7	165/8	-/-	238/8	76/-	72/-	51/-	1/-	1/-	1/-	-/-
LT	62/2	62/-	48/-	-/-	56/-	-/-	-/-	-/-	5/-	-/-	-/-	-/-
LV	95/-	-/-	70/-	-/-	77/-	-/-	-/-	-/-	18/-	-/-	-/-	-/-
PL	524/6	470/6	383/6	7/-	501/6	504/6	509/6	511/6	25/-	20/-	14/-	12/-
PT	103/-	103/-	89/-	-/-	103/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
RS	27/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
SE	793/-	-/-	585/-	29/-	444/-	76/-	70/-	79/-	77/-	47/-	36/-	35/-
SI	45/1	45/1	44/1	-/-	43/1	-/-	-/-	-/-	2/-	-/-	-/-	-/-
SK	112/8	104/8	94/8	-/-	112/8	111/8	109/8	98/8	-/-	-/-	-/-	-/-
Total	**4914/ 114**	**1734/ 79**	**3238/ 93**	**111/ -**	**3905/ 101**	**1625/ 76**	**1347/ 74**	**1312/ 46**	**255/ 4**	**178/ 4**	**151/ 4**	**76/ -**

On Level II the availability of Al data decreases from 92 % of the plots in the 0 – 10 cm layer, over 70 % in the 10 – 20 cm and 68 % in the 20 – 40 cm layer to 40 % in the 40 – 80 cm layer.

Iron (Fe)

On Level I, Fe analyses are available in the 0 – 10 cm mineral soil layer for 85 % of the plots and in the OFH and for 66 % of the plots (Table 2.6.25). The availability of data drastically decreases with depth, as this information was not asked for the deeper layers. It is available for 40 % of the Level I plots in the 10 – 20 cm layer, for 33 % of the plots in the 20 -40 cm layer and for 31 % of the plots in the 40 – 80 cm layer. So the data availability for iron is a bit better than that of aluminium.

Table 2.6.25. Data availability of aqua regia extractable Fe by country and by layer. The number before the slash refers to the number of Level I plots. The number behind to Level II.

Country	N° plots	OL	OFH	H	M01	M12	M24	M48	H01	H12	H24	H48
AT	135/2	107/2	125/2	-/-	134/2	133/2	129/2	120/2	1/-	-/-	-/-	-/-
BE	10/11	10/10	9/11	-/-	10/11	10/11	10/11	10/11	-/-	-/-	-/-	-/-
CY	15/2	14/2	15/2	-/-	15/2	-/-	-/-	-/-	-/-	-/-	-/-	-/-
CZ	146/8	146/-	145/8	-/-	146/8	11/8	11/8	11/8	-/-	-/-	-/-	-/-
DE	422/8	188/7	391/7	-/-	410/8	276/6	277/6	270/6	7/-	6/-	4/-	4/-
DK	25/3	25/-	25/3	-/-	25/3	25/-	25/-	25/-	-/-	-/-	-/-	-/-
EE	96/-	88/-	62/-	14/-	83/-	1/-	1/-	-/-	13/-	13/-	13/-	13/-
ES	598/2	-/-	245/2	-/-	267/2	264/2	-/1	-/1	-/-	-/-	-/-	-/-
FI	630/32	-/32	493/32	61/-	567/28	7/28	1/28	5/-	63/4	63/4	62/4	-/-
FR	545/10	-/-	133/-	-/-	543/10	-/-	-/-	-/-	-/-	-/-	-/-	-/-
GB	-/4	-/4	-/4	-/-	-/4	-/4	-/4	-/4	-/-	-/-	-/-	-/-
GR	166/4	138/4	115/4	-/-	129/4	138/-	144/-	143/-	43/-	28/-	21/-	12/-
HU	78/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
IC	13/-	-/-	2/-	-/-	3/-	3/-	-/-	-/-	-/-	-/-	-/-	-/-
IE	35/3	28/3	28/3	-/-	10/2	14/2	20/2	28/2	24/1	20/1	13/1	6/1
IT	239/8	235/7	165/8	-/-	238/8	76/-	72/-	51/-	1/-	1/-	1/-	-/-
LT	62/2	62/-	48/-	-/-	56/-	-/-	-/-	-/-	5/-	-/-	-/-	-/-
LV	95/-	-/-	70/-	-/-	77/-	82/-	85/-	85/-	18/-	13/-	10/-	10/-
PL	524/-	470/-	383/-	7/-	501/-	504/-	509/-	511/-	25/-	20/-	14/-	12/-
PT	103/6	103/6	89/6	-/-	103/6	-/6	-/6	-/6	-/-	-/-	-/-	-/-
RS	27/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
SE	793/-	-/-	585/-	29/-	444/-	76/-	70/-	79/-	77/-	47/-	36/-	35/-
SI	45/1	45/1	44/1	-/-	43/1	-/-	-/-	-/-	2/-	-/-	-/-	-/-
SK	112/8	104/8	94/8	-/-	112/8	111/8	109/8	98/8	-/-	-/-	-/-	-/-
Total	**4914/ 114**	**1763/ 86**	**3266/ 101**	**111/ -**	**3916/ 107**	**1731/ 77**	**1463/ 76**	**1436/ 48**	**279/ 5**	**211/ 5**	**174/ 5**	**92/ 1**

On Level II, Fe data are available in the OL layer on 75 % of the plots and in the OFH layer on 89 % of the plots. In the mineral soil and peat soils, the data availability decreases with depth. In the 0 – 10 cm layer it is available for 98 % of the plots, in the 10 – 20 cm layer for 72 %, in the 20 – 40 cm layer for 71 % and in the 40 – 80 cm layer for 43 % of the plots.

Manganese (Mn)

Table 2.6.26 shows the data availability of Mn which is very similar to the data availability of the macronutrients P, K, Ca and Mg. On Level I, Mn analyses are available in the 0 – 10 cm mineral soil layer for 85 % of the plots and in the OFH for 68 % of the plots. Data availability decreases with depth: 63 % in the 10 – 20 cm, 56 % in the 20 – 40 cm and 50 % in the 40 – 80 cm layer.

Table 2.6.26. Data availability of aqua regia extractable Mn by country and by layer. The number before the slash refers to the number of Level I plots. The number behind to Level II.

Country	N° plots	OL	OFH	H	M01	M12	M24	M48	H01	H12	H24	H48
AT	135/2	107/2	125/2	-/-	134/2	133/2	129/2	120/2	1/-	-/-	-/-	-/-
BE	10/11	10/10	9/11	-/-	10/11	10/11	10/11	10/11	-/-	-/-	-/-	-/-
CY	15/2	14/2	15/2	-/-	15/2	15/2	14/2	9/2	-/-	-/-	-/-	-/-
CZ	146/8	143/-	145/8	-/-	146/8	146/8	146/8	145/8	-/-	-/-	-/-	-/-
DE	422/8	188/7	391/7	-/-	410/8	321/6	322/6	312/6	7/-	6/-	4/-	4/-
DK	25/3	25/-	25/3	-/-	25/3	25/-	25/-	25/-	-/-	-/-	-/-	-/-
EE	96/-	88/-	62/-	14/-	83/-	83/-	82/-	79/-	13/-	13/-	13/-	13/-
ES	598/2	-/-	245/2	-/-	267/2	264/2	-/1	-/1	-/-	-/-	-/-	-/-
FI	630/32	-/32	493/32	61/-	567/28	7/28	1/28	5/-	63/4	63/4	62/4	-/-
FR	545/10	-/-	133/8	-/-	543/10	530/10	496/10	393/-	-/-	-/-	-/-	-/-
GB	166/4	138/4	115/4	-/-	129/4	138/4	144/4	143/4	43/-	28/-	21/-	12/-
GR	-/4	-/4	-/4	-/-	-/4	-/-	-/-	-/-	-/-	-/-	-/-	-/-
HU	78/-	70/-	34/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
IC	13/-	-/-	2/-	-/-	3/-	3/-	-/-	-/-	-/-	-/-	-/-	-/-
IE	35/3	29/3	29/3	-/-	11/2	15/2	22/2	29/2	24/1	20/1	13/1	6/1
IT	239/8	235/7	165/8	-/-	238/8	237/8	226/8	160/8	1/-	1/-	1/-	-/-
LT	62/2	62/2	48/2	-/-	56/-	57/-	57/-	58/-	5/-	5/-	5/-	4/-
LV	95/-	-/-	70/-	-/-	77/-	82/-	85/-	85/-	18/-	13/-	10/-	10/-
PL	524/6	470/6	383/6	7/-	501/6	504/6	509/6	511/6	25/-	20/-	14/-	12/-
PT	103/-	103/-	89/-	-/-	103/-	103/-	101/-	86/-	-/-	-/-	-/-	-/-
RS	27/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
SE	793/-	-/-	585/-	29/-	444/-	76/-	70/-	79/-	76/-	46/-	35/-	34/-
SI	45/1	45/1	44/1	-/-	43/1	41/1	40/-	36/-	2/-	1/-	1/-	1/-
SK	112/8	104/8	94/8	-/-	112/8	111/8	109/8	98/8	-/-	-/-	-/-	-/-
Total	**4914/ 114**	**1831/ 88**	**3301/ 111**	**111/ -**	**3917/ 107**	**2901/ 98**	**2588/ 96**	**2383/ 58**	**278/ 5**	**216/ 5**	**179/ 5**	**96/ 1**

On Level II, Mn data are available in the OL layer on 77 % of the plots and in the OFH layer on 97 % of the plots. In the mineral soil and peat soils, the data availability decreases with depth. In the 0 – 10 cm layer it is available for 98 % of the plots, in the 10 – 20 cm layer for 90 %, in the 20 – 40 cm layer for 87 % and in the 40 – 80 cm layer for 52 % of the plots.

Copper (Cu)

On Level I, Cu analyses are available in the 0 – 10 cm mineral soil layer for 87 % of the plots and in the OFH and for 67 % of the plots. The availability of data again drastically decreases with depth, as this information was not asked for the deeper layers (Table 2.6.27). It is available for the 10 – 20 cm layer on 38 % of the plots, for the 20 – 40 cm layer on 32 % and for the 40 – 80 cm layer for 30 % of the Level I plots.

On Level II, Cu data are available in the OL layer on 77 % of the plots and in the OFH layer on 97 % of the plots. In the mineral soil and peat soils, the data availability decreases with depth. In the 0 – 10 cm layer it is available for 100 % of the plots, in the 10 – 20 cm layer for 72 %, in the 20 – 40 cm layer for 71 % and in the 40 – 80 cm layer for 43 % of the plots.

Table 2.6.27. Data availability of aqua regia extractable Cu by country and by layer. The number before the slash refers to the number of Level I plots. The number behind to Level II.

Country	N° plots	OL	OFH	H	M01	M12	M24	M48	H01	H12	H24	H48
AT	135/2	107/2	125/2	-/-	134/2	133/2	129/2	120/2	1/-	-/-	-/-	-/-
BE	10/11	10/10	9/11	-/-	10/11	10/11	10/11	10/11	-/-	-/-	-/-	-/-
CY	15/2	14/2	15/2	-/-	15/2	-/-	-/-	-/-	-/-	-/-	-/-	-/-
CZ	146/8	146/-	145/8	-/-	146/8	-/8	-/8	-/8	-/-	-/-	-/-	-/-
DE	422/8	188/7	391/7	-/-	410/8	229/6	230/6	225/6	7/-	6/-	4/-	4/-
DK	25/3	25/-	25/3	-/-	25/3	25/-	25/-	25/-	-/-	-/-	-/-	-/-
EE	96/-	88/-	62/-	14/-	83/-	1/-	1/-	-/-	13/-	13/-	13/-	13/-
ES	598/2	-/-	245/2	-/-	267/2	264/2	-/1	-/1	-/-	-/-	-/-	-/-
FI	630/32	-/32	493/32	61/-	567/28	7/28	1/28	5/-	63/4	63/4	62/4	-/-
FR	545/10	-/-	133/8	-/-	543/10	-/-	-/-	-/-	-/-	-/-	-/-	-/-
GB	166/4	138/4	115/4	-/-	129/4	138/4	144/4	143/4	43/-	28/-	21/-	12/-
GR	-/4	-/4	-/4	-/-	-/4	-/-	-/-	-/-	-/-	-/-	-/-	-/-
HU	78/-	71/-	34/-	-/-	75/-	74/-	76/-	76/-	-/-	-/-	-/-	-/-
IC	13/-	-/-	2/-	-/-	3/-	3/-	-/-	-/-	-/-	-/-	-/-	-/-
IE	35/3	29/3	29/3	-/-	11/2	15/2	22/2	28/2	24/1	20/1	12/1	6/1
IT	239/8	235/7	165/8	-/-	238/8	76/-	72/-	51/-	1/-	1/-	1/-	-/-
LT	62/2	62/2	48/2	-/-	56/2	-/-	-/-	-/-	5/-	-/-	-/-	-/-
LV	95/-	-/-	70/-	-/-	77/-	-/-	-/-	-/-	18/-	-/-	-/-	-/-
PL	524/6	470/6	383/6	7/-	501/6	504/6	509/6	511/6	25/-	20/-	14/-	12/-
PT	103/-	103/-	89/-	-/-	103/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
RS	27/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
SE	793/-	-/-	585/-	29/-	444/-	76/-	70/-	79/-	76/-	46/-	35/-	34/-
SI	45/1	45/1	44/1	-/-	43/1	-/-	-/-	-/-	2/-	-/-	-/-	-/-
SK	112/8	104/8	94/8	-/-	112/8	111/8	109/8	98/8	-/-	-/-	-/-	-/-
Total	**4914/ 114**	**1835/ 88**	**3301/ 111**	**111/ -**	**3992/ 109**	**1666/ 77**	**1398/ 76**	**1371/ 48**	**278/ 5**	**197/ 5**	**162/ 5**	**81/ 1**

Based on Table 2.4.4 showing the reporting requirements, one would expect similar data availability of the elements Cu, Pb, Cd and Zn as for Al, Cr, Fe, Na, Ni and S. The slightly better coverage of Cu, Pb, Cd and Zn is because a few countries rather followed the specifications of the ICP Forests manual where aqua regia extractable Cu, Pb, Cd and Zn have always been mandatory in contrast to Al, Cr, Fe, Na, Ni and S which were optional.

Lead (Pb)

On Level I, Pb analyses are available in the 0 – 10 cm mineral soil layer for 87 % of the plots and in the OFH for 67 % of the plots. The availability of data again drastically decreases with depth (from 38 % in the 10 – 20 cm layer over 32 % in the 20 – 40 cm to 30 % in the 40 – 80 cm layer), as this information was not asked for the deeper layers (Table 2.6.28).

Table 2.6.28. Data availability of aqua regia extractable Pb by country and by layer. The number before the slash refers to the number of Level I plots. The number behind to Level II.

Country	N° plots	OL	OFH	H	M01	M12	M24	M48	H01	H12	H24	H48
AT	135/2	107/2	125/2	-/-	134/2	133/2	129/2	120/2	1/-	-/-	-/-	-/-
BE	10/11	10/10	9/11	-/-	10/11	10/11	10/11	10/11	-/-	-/-	-/-	-/-
CY	15/2	10/2	15/2	-/-	11/2	-/-	-/-	-/-	-/-	-/-	-/-	-/-
CZ	146/8	146/-	145/8	-/-	146/8	-/8	-/8	-/8	-/-	-/-	-/-	-/-
DE	422/8	188/7	391/7	-/-	410/8	229/6	230/6	225/6	7/-	6/-	4/-	4/-
DK	25/3	25/-	25/3	-/-	25/3	25/-	25/-	25/-	-/-	-/-	-/-	-/-
EE	96/-	88/-	62/-	14/-	83/-	1/-	1/-	-/-	13/-	13/-	13/-	13/-
ES	598/2	-/-	245/2	-/-	267/2	264/2	-/1	-/1	-/-	-/-	-/-	-/-
FI	630/32	-/32	493/32	61/-	567/28	7/28	1/28	5/-	63/4	63/4	62/4	-/-
FR	545/10	-/-	133/8	-/-	543/10	-/-	-/-	-/-	-/-	-/-	-/-	-/-
GB	166/4	138/4	115/4	-/-	129/4	138/4	144/4	143/4	43/-	28/-	21/-	12/-
GR	-/4	-/4	-/4	-/-	-/4	-/-	-/-	-/-	-/-	-/-	-/-	-/-
HU	78/-	71/-	34/-	-/-	75/-	74/-	76/-	76/-	-/-	-/-	-/-	-/-
IC	13/-	-/-	2/-	-/-	3/-	3/-	-/-	-/-	-/-	-/-	-/-	-/-
IE	35/3	27/3	26/3	-/-	11/2	14/2	21/2	27/2	22/1	19/1	12/1	6/1
IT	239/8	235/7	165/8	-/-	238/8	74/-	70/-	50/-	1/-	1/-	1/-	-/-
LT	62/2	62/2	48/2	-/-	56/2	1/-	1/-	1/-	5/-	-/-	-/-	-/-
LV	95/-	-/-	70/-	-/-	77/-	-/-	-/-	-/-	18/-	-/-	-/-	-/-
PL	524/6	470/6	383/6	7/-	501/6	504/6	509/6	511/6	25/-	20/-	14/-	12/-
PT	103/-	103/-	89/-	-/-	103/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
RS	27/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
SE	793/-	-/-	585/-	29/-	444/-	76/-	70/-	79/-	76/-	46/-	35/-	34/-
SI	45/1	45/1	44/1	-/-	43/1	-/-	-/-	-/-	2/-	-/-	-/-	-/-
SK	112/8	104/8	94/8	-/-	112/8	111/8	109/8	98/8	-/-	-/-	-/-	-/-
Total	**4914/ 114**	**1829/ 88**	**3298/ 111**	**111/ -**	**3988/ 109**	**1664/ 77**	**1396/ 76**	**1370/ 48**	**276/ 5**	**196/ 5**	**162/ 5**	**81/ 1**

On Level II, Pb data are available in the OL layer on 77 % of the plots and in the OFH layer on 97 % of the plots. In the mineral soil and peat soils, the data availability decreases with depth. In the 0 – 10 cm layer it is available for 100 % of the plots, in the 10 – 20 cm layer for 72 %, in the 20 – 40 cm layer for 71 % and in the 40 – 80 cm layer for 43 % of the plots.

Nickel (Ni)

Notwithstanding similar reporting requirements as for Al, Fe and S, the data availability for nickel is obviously lower (Table 2.6.29). On Level I, Ni analyses are available in the 0 – 10 cm mineral soil layer for only 43 % of the plots and in the OFH layer for 66 % of the plots. The availability of data further decreases with depth (36 % in the 10 – 20 cm, 30 % in the 20 – 40 cm and 28 % in the 40 – 80 cm layer), as this information was not asked for the deeper layers.

Table 2.6.29. Data availability of aqua regia extractable Ni by country and by layer. The number before the slash refers to the number of Level I plots. The number behind to Level II.

Country	N° plots	OL	OFH	H	M01	M12	M24	M48	H01	H12	H24	H48
AT	135/2	107/2	125/2	-/-	134/2	133/2	129/2	120/2	1/-	-/-	-/-	-/-
BE	10/11	10/10	9/11	-/-	10/11	10/11	10/11	10/11	-/-	-/-	-/-	-/-
CY	15/2	10/2	15/2	-/-	-/2	-/-	-/-	-/-	-/-	-/-	-/-	-/-
CZ	146/8	146/-	145/8	-/-	-/8	-/8	-/8	-/8	-/-	-/-	-/-	-/-
DE	422/8	178/5	352/5	-/-	363/8	229/6	230/6	225/6	7/-	6/-	4/-	4/-
DK	25/3	25/-	25/3	-/-	25/3	25/-	25/-	25/-	-/-	-/-	-/-	-/-
EE	96/-	88/-	62/-	14/-	82/-	1/-	1/-	-/-	13/-	13/-	13/-	13/-
ES	598/2	-/-	245/2	-/-	268/2	264/2	-/1	-/1	-/-	-/-	-/-	-/-
FI	630/32	-/32	493/32	61/-	7/28	7/28	1/28	5/-	63/4	63/4	62/4	-/-
FR	545/10	-/-	133/8	-/-	-/10	-/-	-/-	-/-	-/-	-/-	-/-	-/-
GB	166/4	138/4	115/4	-/-	138/4	138/4	144/4	143/4	43/-	28/-	21/-	12/-
GR	-/4	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
HU	78/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
IC	13/-	-/-	2/-	-/-	3/-	3/-	-/-	-/-	-/-	-/-	-/-	-/-
IE	35/3	27/2	26/2	-/-	15/2	15/2	22/2	29/2	23/1	19/1	12/1	6/1
IT	239/8	235/7	165/8	-/-	74/8	74/-	70/-	50/-	1/-	1/-	1/-	-/-
LT	62/2	62/-	48/-	-/-	-/-	-/-	-/-	-/-	5/-	-/-	-/-	-/-
LV	95/-	-/-	70/-	-/-	-/-	-/-	-/-	-/-	18/-	-/-	-/-	-/-
PL	524/6	470/6	383/6	7/-	504/6	504/6	509/6	511/6	25/-	20/-	14/-	12/-
PT	103/-	103/-	89/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
RS	27/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
SE	793/-	-/-	585/-	29/-	80/-	76/-	70/-	79/-	76/-	46/-	35/-	34/-
SI	45/1	45/1	44/1	-/-	43/1	-/-	-/-	-/-	2/-	-/-	-/-	-/-
SK	112/8	104/8	94/8	-/-	111/8	111/8	109/8	98/8	-/-	-/-	-/-	-/-
Total	**4914/ 114**	**1748/ 79**	**3225/ 102**	**111/ -**	**1857/ 103**	**1590/ 77**	**1320/ 76**	**1295/ 48**	**277/ 5**	**196/ 5**	**162/ 5**	**81/ 1**

On Level II, Ni data are available in the OL layer on 69 % of the plots and in the OFH layer on 89 % of the plots. In the mineral soil and peat soils, the data availability decreases with depth. In the 0 – 10 cm layer it is available for 95 % of the plots, in the 10 – 20 cm layer for 72 %, in the 20 – 40 cm layer for 71 % and in the 40 – 80 cm layer for 43 % of the plots.

Chromium (Cr)

Although chromium had the same reporting requirements as nickel and only occurs in small amounts in forest soils, Cr analyses are on Level I available in the 0 – 10 cm mineral soil layer for 85 % of the plots and in the OFH and for 65 % of the plots (Table 2.6.30). The availability of data again drastically decreases with depth (35 % in the 10 – 20 cm, 29 % in the 20 – 40 cm and 27 % in the 40 – 80 cm layer), as this information was not asked for the deeper layers.

Table 2.6.30. Data availability of aqua regia extractable Cr by country and by layer. The number before the slash refers to the number of Level I plots. The number behind to Level II.

Country	N° plots	OL	OFH	H	M01	M12	M24	M48	H01	H12	H24	H48
AT	135/2	107/2	125/2	-/-	134/2	133/2	129/2	120/2	1/-	-/-	-/-	-/-
BE	10/11	10/10	9/11	-/-	10/11	10/11	10/11	10/11	-/-	-/-	-/-	-/-
CY	15/2	13/2	15/2	-/-	15/2	-/-	-/-	-/-	-/-	-/-	-/-	-/-
CZ	146/8	146/-	145/8	-/-	145/8	-/8	-/8	-/8	-/-	-/-	-/-	-/-
DE	422/8	178/5	352/5	-/-	410/8	229/6	230/6	225/6	7/-	6/-	4/-	4/-
DK	25/3	25/-	25/3	-/-	25/3	25/-	25/-	25/-	-/-	-/-	-/-	-/-
EE	96/-	88/-	62/-	14/-	83/-	1/-	1/-	-/-	13/-	13/-	13/-	13/-
ES	598/2	-/-	245/2	-/-	267/2	264/2	-/1	-/1	-/-	-/-	-/-	-/-
FI	630/32	-/32	493/32	61/-	567/28	7/28	1/28	5/-	63/4	63/4	62/4	-/-
FR	545/10	-/-	133/8	-/-	543/10	-/-	-/-	-/-	-/-	-/-	-/-	-/-
GB	166/4	138/4	115/4	-/-	129/4	138/4	144/4	143/4	43/-	28/-	21/-	12/-
GR	-/4	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
HU	78/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
IC	13/-	-/-	2/-	-/-	3/-	3/-	-/-	-/-	-/-	-/-	-/-	-/-
IE	35/3	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
IT	239/8	235/7	165/8	-/-	238/8	74/-	70/-	50/-	1/-	1/-	1/-	-/-
LT	62/2	62/-	48/-	-/-	56/-	1/-	1/-	1/-	5/-	-/-	-/-	-/-
LV	95/-	-/-	70/-	-/-	77/-	-/-	-/-	-/-	18/-	-/-	-/-	-/-
PL	524/6	470/6	383/6	7/-	501/6	504/6	509/6	511/6	25/-	20/-	14/-	12/-
PT	103/-	103/-	89/-	-/-	103/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
RS	27/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
SE	793/-	-/-	585/-	29/-	444/-	76/-	70/-	79/-	76/-	46/-	35/-	34/-
SI	45/1	45/1	44/1	-/-	43/1	-/-	-/-	-/-	2/-	-/-	-/-	-/-
SK	112/8	104/8	94/8	-/-	112/8	111/8	109/8	98/8	-/-	-/-	-/-	-/-
Total	**4914/ 114**	**1724/ 77**	**3199/ 100**	**111/ -**	**3905/ 101**	**1576/ 75**	**1299/ 74**	**1267/ 46**	**254/ 4**	**177/ 4**	**150/ 4**	**75/ -**

On Level II, Cr data are available in the OL layer on 68 % of the plots and in the OFH layer on 88 % of the plots. In the mineral soil and peat soils, the data availability decreases with depth. In the 0 – 10 cm layer it is available for 92 % of the plots, in the 10 – 20 cm layer for 69 %, in the 20 – 40 cm layer for 68 % and in the 40 – 80 cm layer for 40 % of the plots.

Zinc (Zn)

Reporting requirements of Zn were very comparable to those of the other heavy metals Cd, Cu and Pb and so is its data availability. On Level I, Zn analyses are available in the 0 – 10 cm mineral soil layer for 87 % of the plots and in the OFH and for 67 % of the plots (Table 2.6.31). Data availability decrease with depth: so from 87 % in the 0 -10 cm, over 38 % in the 10 – 20 cm and 32 % in the 20 – 40 cm layer to 30 % in the 40 – 80 cm layer.

Table 2.6.31. Data availability of aqua regia extractable Zn by country and by layer. The number before the slash refers to the number of Level I plots. The number behind to Level II.

Country	N° plots	OL	OFH	H	M01	M12	M24	M48	H01	H12	H24	H48
AT	135/2	107/2	125/2	-/-	134/2	133/2	129/2	120/2	1/-	-/-	-/-	-/-
BE	10/11	10/10	9/11	-/-	10/11	10/11	10/11	10/11	-/-	-/-	-/-	-/-
CY	15/2	14/2	15/2	-/-	15/2	-/-	-/-	-/-	-/-	-/-	-/-	-/-
CZ	146/8	146/-	145/8	-/-	146/8	-/8	-/8	-/8	-/-	-/-	-/-	-/-
DE	422/8	188/7	391/7	-/-	410/8	276/6	277/6	269/6	7/-	6/-	4/-	4/-
DK	25/3	25/-	25/3	-/-	25/3	25/-	25/-	25/-	-/-	-/-	-/-	-/-
EE	96/-	88/-	62/-	14/-	83/-	2/-	1/-	-/-	13/-	13/-	13/-	13/-
ES	598/2	-/-	245/2	-/-	267/2	264/2	-/1	-/1	-/-	-/-	-/-	-/-
FI	630/32	-/32	493/32	61/-	567/28	7/28	1/28	5/-	63/4	63/4	62/4	-/-
FR	545/10	-/-	133/8	-/-	543/10	-/-	-/-	-/-	-/-	-/-	-/-	-/-
GB	166/4	138/4	115/4	-/-	129/4	138/4	144/4	143/4	43/-	28/-	21/-	12/-
GR	-/4	-/4	-/4	-/-	-/4	-/-	-/-	-/-	-/-	-/-	-/-	-/-
HU	78/-	71/-	34/-	-/-	75/-	74/-	76/-	76/-	-/-	-/-	-/-	-/-
IC	13/-	-/-	2/-	-/-	3/-	3/-	-/-	-/-	-/-	-/-	-/-	-/-
IE	35/3	29/3	29/3	-/-	11/2	2/1	3/-	2/-	24/1	6/1	3/1	2/1
IT	239/8	235/7	165/8	-/-	238/8	74/-	70/-	50/-	1/-	1/-	1/-	-/-
LT	62/2	62/2	48/2	-/-	56/2	2/-	2/-	2/-	5/-	-/-	-/-	-/-
LV	95/-	-/-	70/-	-/-	77/-	-/-	-/-	-/-	18/-	-/-	-/-	-/-
PL	524/6	470/6	383/6	7/-	501/6	504/6	509/6	511/6	25/-	20/-	14/-	12/-
PT	103/-	103/-	89/-	-/-	103/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
RS	27/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
SE	793/-	-/-	584/-	29/-	444/-	75/-	70/-	79/-	76/-	46/-	35/-	34/-
SI	45/1	45/1	44/1	-/-	43/1	-/-	-/-	-/-	2/-	-/-	-/-	-/-
SK	112/8	104/8	94/8	-/-	112/8	111/8	109/8	98/8	-/-	-/-	-/-	-/-
Total	**4914/ 114**	**1835/ 88**	**3300/ 111**	**111/ -**	**3992/ 109**	**1700/ 76**	**1426/ 74**	**1390/ 46**	**278/ 5**	**183/ 5**	**153/ 5**	**77/ 1**

On Level II, Zn data are available in the OL layer on 77 % of the plots and in the OFH layer on 97 % of the plots. In the mineral soil and peat soils, the data availability decreases with depth. In the 0 – 10 cm layer it is available for all plots, in the 10 – 20 cm layer for 71 %, in the 20 – 40 cm layer for 69 % and in the 40 – 80 cm layer for 41 % of the plots.

Cadmium (Cd)

On Level I, Cd analyses are available in the 0 – 10 cm mineral soil layer for 86 % of the plots and in the OFH and for 67 % of the plots. This is very comparable to the data availability of the other heavy metals Cu, Pb and Zn. Table 2.6.32. shows that the data availability drastically decreases with depth (38 % in the 10 – 20 cm, 32 % in the 20 – 40 cm and 30 % in the 40 – 80 cm layer), as this information was not asked for the deeper layers.

Table 2.6.32. Data availability of aqua regia extractable Cd by country and by layer. The number before the slash refers to the number of Level I plots. The number behind to Level II.

Country	N° plots	OL	OFH	H	M01	M12	M24	M48	H01	H12	H24	H48
AT	135/2	107/2	125/2	-/-	134/2	133/2	129/2	120/2	1/-	-/-	-/-	-/-
BE	10/11	10/10	9/11	-/-	10/11	10/11	10/11	10/11	-/-	-/-	-/-	-/-
CY	15/2	7/2	15/2	-/-	15/2	-/-	-/-	-/-	-/-	-/-	-/-	-/-
CZ	146/8	146/-	145/8	-/-	146/8	-/8	-/8	-/8	-/-	-/-	-/-	-/-
DE	422/8	188/7	391/7	-/-	410/8	228/6	229/6	224/6	7/-	6/-	4/-	4/-
DK	25/3	25/-	25/3	-/-	25/3	25/-	25/-	25/-	-/-	-/-	-/-	-/-
EE	96/-	88/-	62/-	14/-	62/-	1/-	1/-	-/-	13/-	13/-	13/-	13/-
ES	598/2	-/-	245/2	-/-	267/2	264/2	-/1	-/1	-/-	-/-	-/-	-/-
FI	630/32	-/32	493/32	61/-	567/28	7/28	1/28	5/-	63/4	63/4	62/4	-/-
FR	545/10	-/-	133/8	-/-	543/10	-/-	-/-	-/-	-/-	-/-	-/-	-/-
GB	166/4	138/4	115/4	-/-	129/4	138/4	144/4	143/4	43/-	28/-	21/-	12/-
GR	-/4	-/4	-/4	-/-	-/4	-/-	-/-	-/-	-/-	-/-	-/-	-/-
HU	78/-	71/-	34/-	-/-	75/-	74/-	76/-	76/-	-/-	-/-	-/-	-/-
IC	13/-	-/-	2/-	-/-	3/-	3/-	-/-	-/-	-/-	-/-	-/-	-/-
IE	35/3	29/3	29/3	-/-	11/2	15/2	22/2	28/2	24/1	20/1	13/1	6/1
IT	239/8	235/7	165/8	-/-	238/8	76/-	72/-	51/-	1/-	1/-	1/-	-/-
LT	62/2	62/2	48/2	-/-	56/2	-/-	-/-	-/-	5/-	-/-	-/-	-/-
LV	95/-	-/-	70/-	-/-	77/-	-/-	-/-	-/-	18/-	-/-	-/-	-/-
PL	524/6	470/6	383/6	7/-	501/6	504/5	509/6	511/6	25/-	20/-	14/-	12/-
PT	103/-	103/-	89/-	-/-	103/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
RS	27/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
SE	793/-	-/-	585/-	29/-	444/-	76/-	70/-	79/-	76/-	46/-	35/-	34/-
SI	45/1	45/1	44/1	-/-	43/1	-/-	-/-	-/-	2/-	-/-	-/-	-/-
SK	112/8	104/8	94/8	-/-	112/8	111/8	109/8	98/8	-/-	-/-	-/-	-/-
Total	**4914/ 114**	**1828/ 88**	**3301/ 111**	**111/ -**	**3971/ 109**	**1665/ 76**	**1397/ 76**	**1370/ 48**	**278/ 5**	**197/ 5**	**163/ 5**	**81/ 1**

On Level II, Cd data are available in the OL layer on 77 % of the plots and in the OFH layer on 97 % of the plots. In the mineral soil and peat soils, the data availability decreases with depth. In the 0 – 10 cm layer it is available for all plots, in the 10 – 20 cm layer for 71 %, in the 20 – 40 cm layer for 71 % and in the 40 – 80 cm layer for 43 % of the plots.

Mercury (Hg)

As the analysis of mercury asks for specialised equipment, the determination of mercury was optional. Hg was reported by some German federal states, Estonia, France, Italy, Lithuania, Latvia, Slovak Republic and Great Britain. The Hg in peat soils was analysed by Estonia and Great Britain. One third of the German, a fifth of the Italian, most of the Slovakian and British plots were analysed till 80 cm. In the other countries the Hg analyses mainly concerned the forest floor and the upper 10 cm of the mineral soil (Table 2.6.33).

On Level I, mercury data are available in the OL layer on 14 % of the plots and in the OFH layer on 19 % of the plots. In the mineral soil layers and peat layers the data availability decreases with depth: from 30 % in the 0 – 10 cm layer, over 10 % in the 10 – 20 and 20 – 40 cm layer to 9 % in the 40 – 80 cm layer.

Table 2.6.33. Data availability of aqua regia extractable Hg by country and by layer. The number before the slash refers to the number of Level I plots. The number behind to Level II.

Country	N° plots	OL	OFH	H	M01	M12	M24	M48	H01	H12	H24	H48
DE	422/8	90/1	168/2	-/-	171/2	142/-	143/-	139/-	1/-	1/-	-/-	-/-
EE	96/-	88/-	62/-	14/-	84/-	1/-	1/-	-/-	13/-	13/-	13/-	13/-
FR	545/10	-/-	133/-	-/-	543/10	-/-	-/-	-/-	-/-	-/-	-/-	-/-
GB	166/4	138/4	115/4	-/-	145/4	145/4	144/4	143/4	22/-	21/-	21/-	13/-
IT	239/8	216/-	147/-	-/-	213/-	73/-	69/-	48/-	1/-	-/-	-/-	-/-
LT	62/2	62/-	48/-	-/-	57/-	-/-	-/-	-/-	5/-	-/-	-/-	-/-
LV	95/-	-/-	70/-	-/-	77/-	-/-	-/-	-/-	18/-	-/-	-/-	-/-
SK	112/8	104/8	94/8	-/-	112/8	111/8	109/8	98/8	-/-	-/-	-/-	-/-
Total		**698/ 13**	**837/ 14**	**14/ -**	**1402/ 24**	**472/ 12**	**466/ 12**	**428/ 12**	**60/ -**	**35/ -**	**34/ -**	**26/ -**

On Level II, mercury data are available in the OL layer on 11 % of the plots and in the OFH layer on 12 % of the plots. In the mineral soil and peat soils, the data availability decreases with depth. In the 0 – 10 cm layer it is available for 21 % of the plots and in the 10 – 20 cm, 20 – 40 cm and 40 – 80 cm layer for 11 % of the plots.

2.6.4.12 Total Elements

There is extremely limited data available on the total elements. Table 2.6.34 has been split for two groups of elements. Three countries reported total elements for a number of their plots and layers. France measured all total elements on most of the mineral soil samples.

Table 2.6.34. Data availability of the total elements by country and by layer. The number before the slash refers to the number of Level I plots. The number behind to Level II.

Ca, K and Mg

Country	N° plots	OL	OFH	OH	M01	M12	M24	M48
FR	545/10	-/10	133/-	-/4	543/-	530/-	496/-	393/-
DE	422/8	-/-	-/-	-/-	-/5	-/5	-/5	-/5
RS	27/-	27/-	-/-	-/-	-/-	-/-	-/-	-/-

Al, Fe, Mn, Na

Country	N° plots	OL	OFH	OH	M01	M12	M24	M48
FR	545/10	-/-	133/-	-/-	543/-	530/-	496/-	393/-
DE	422/8	-/-	-/-	-/-	-/5	-/5	-/5	-/5
RS	27/-	27/-	-/-	-/-	-/-	-/-	-/-	-/-

2.6.4.13 Acid oxalate extractable elements

The acid ammonium oxalate extractable Al and Fe content was mandatory on Level I in the organic layer (except the OL layer) and in all fixed depth layers till a depth of 80 cm. On Level II it was mandatory for the mineral soil layers and optional in the OFH and H layers. Keeping this in mind, the data availability on Level I is rather poor. Table 2.6.35 shows that in the upper 10 cm the acid

oxalate extractable Fe and Al is only available on 53 % of the plots and in the OFH layer on 27 % of the plots. It gradually decreases with depth. In Sweden the reactive Al and Fe was only reported on a small number of plots. The analyses were not done by Spain (including the Canary Islands), Austria, Hungary and Serbia. Finland only analysed the reactive Al and Fe on the Level II plots. On Level II, the reactive Al and Fe is available on 93 % of the sampled plots in the BioSoil survey in the 0 – 10, 10 – 20 and 20 – 40 cm layer.

Table 2.6.35. Data availability of acid oxalate extractable Al and Fe by country and by layer. The number before the slash refers to the number of Level I plots. The number behind to Level II.

Country	N° plots	OL	OFH	H	M01	M12	M24	M48	H01	H12	H24	H48
AT	135/2	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
BE	10/11	-/-	9/10	-/-	10/11	10/11	10/11	10/11	-/-	-/-	-/-	-/-
CY	15/2	-/-	15/2	-/-	15/2	15/2	14/2	9/2	-/-	-/-	-/-	-/-
CZ	146/8	-/-	-/-	-/-	144/8	146/8	146/8	145/8	-/-	-/-	-/-	-/-
DE	422/8	18/-	42/-	-/-	309/8	310/8	312/8	302/8	6/-	6/-	4/-	4/-
DK	25/3	-/-	25/-	-/-	25/3	25/3	25/3	25/3	-/-	-/-	-/-	-/-
EE	96/-	2/-	62/-	14/-	83/-	83/-	82/-	79/-	13/-	13/-	13/-	13/-
ES	598/2	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
FI	630/32	-/-	-/-	-/-	-/28	-/28	-/28	-/-	-/-	-/-	-/-	-/-
FR	545/10	-/-	133/8	-/-	543/10	530/10	496/10	393/-	-/-	-/-	-/-	-/-
GB	166/4	-/-	115/4	-/-	129/4	138/4	144/4	143/4	43/-	28/-	21/-	12/-
GR	-/4	-/-	-/-	-/-	-/4	-/4	-/4	-/4	-/-	-/-	-/-	-/-
HU	78/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
IC	13/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
IE	35/3	1/-	29/-	-/-	11/2	15/2	22/2	29/2	23/1	20/1	12/1	5/1
IT	239/8	1/-	165/8	-/-	238/8	237/8	226/8	160/8	1/-	1/-	1/-	-/-
LT	62/2	10/-	48/-	-/-	57/2	57/2	57/2	58/2	5/-	5/-	5/-	4/-
LV	95/-	-/-	70/-	-/-	77/-	82/-	85/-	85/-	18/-	13/-	10/-	10/-
PO	524/6	3/-	383/6	7/-	501/6	504/6	509/6	511/6	25/-	20/-	14/-	12/-
PT	103/-	13/-	89/-	-/-	103/-	103/-	101/-	86/-	-/-	-/-	-/-	-/-
RS	27/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-	-/-
SE	793/-	-/-	66/-	4/-	46/-	49/-	11/-	11/-	8/-	9/-	1/-	2/-
SI	45/1	-/-	-/-	-/-	43/1	41/1	40/1	36/1	2/-	1/-	1/-	1/-
SK	112/8	2/8	93/8	-/-	112/8	111/8	109/8	98/8	-/-	-/-	-/-	-/-
Total	**4914/ 114**	**50/ 8**	**1344/ 46**	**25/ -**	**2446/ 105**	**2456/ 105**	**2389/ 105**	**2180/ 67**	**144/ 1**	**116/ 1**	**82/ 1**	**63/ 1**

An important reason for the low data availability of reactive Fe and Al in the OFH layers, is that many soil scientists were non convinced of the scientific adequacy of the acid ammonium oxalate extractable Fe and Al determination in an organic matrix. This has been a subject of discussion at the meetings of the FSEP and was the reason of making this analysis optional for the organic layer in the ICP Forest soil manual. But as all optional parameters became mandatory in the BioSoil survey, reactive Fe and Al became mandatory to report, also for forest floor layers.

2.7 Use of additional data, geodata and derived data

2.7.1 Introduction

Various data sources were employed to get explanatory information of EU forest ecosystems and their environment. This additional information was mainly used to stratify specific forest soil characteristics and to investigate their correlation with ecological and anthropogenic factors.

Table 2.7.1 lists the additional data that were collected and their source, indicating whether the data were drawn from literature, a database or from a geodata (GIS) coverage. Each data type is briefly described in the consecutive chapters.

Table 2.7.1. Additional data sources consulted for evaluation of the BioSoil$^+$ data

Type of data	Variables	Geodata	Reference
Forest Soil databases	PlotID, coordinates, altitude Level I Soil data 1st Survey Level II Historical soil data	Yes	Level I: FSCDB 2003 (FSCC, ICP Forests) Level II: ICP Forests
EU Soil map 1:1000000	Dominant Soil Typological unit (STU), Soil mapping unit (SMU), soil types (WRBFU, FAO90FU, FAO85FU)	Yes	SGDBE v4.0 (JRC)
Plot & Stand characteristics	PlotID, coordinates, altitude Tree species, forest type	Yes	ICP Forests GIS data (PCCDB) NFCs and biodiversity component of the BioSoil survey
Forest Cover Map 2006	Forest, Non forest according to 25 m pixels	Yes	JRC Pan-European Forest/Non-Forest Map 2006; Beta version 1.0. Kempeneers et al. 2010
Forest cover	Forest cover per country	Yes	European Forest Institute, Schuck et al. 2002
Forest cover	Forest cover per country	No	SOEF 2011, FOREST EUROPE, UNECE and FAO. 2011.
Corine land cover code	Corine code, 3-level cover code (complex, unit, detailed)	Yes	CLC (2006, 100 m resolution)
Altudinal & Climatological data (current climate 1950-2000)	Altitude, Mean annual temperature, Mean annual precipitation, Maximum temp of warmest month, Coldest temp of coldest month	Yes	WORLDCLIM geodatabase version 1.3 (2009) SamSamWater climate tool (de Haas 2010)
Biogeographical region	Region name	Yes	Biogeographical region (2005)
Ecoregion	Ecoregion ID and name	Yes	Ecoregion name
Natura 2000	Site code, Site name, Site type	Yes	

2.7.2 Forest Soil databases

The existing ICP Forests soil databases holding data of previous soil surveys are the Forest Soil Condition Database (FSCDB) for Level I plots and the overall ICP-Forests database for Level II. The FSCDB was initially created by the FSCC mainly for the elaboration of the first Forest Soil Condition Report (Vanmechelen et al. 1997). A final version of this Level I database was transferred both to the EC/JRC and ICP-Forests in 2003.

Solid soil information for Level II plots is stored in the ICP-Forests database in Hamburg. It consists mainly of soil data provided by the countries when they installed their Level II plots. This solid soil

data complements the soil solution database of Level II. In this study however, we refer to all 'historical' soil data as belonging to the FSCDB, whereas data related to Level I crown assessment plots or Level II intensive monitoring plots are referred to as part of the PCCDB (database hosted by the Programme Coordinating Centre of ICP Forests, see 2.7.4).

In Volume I of this report, only PlotIDs, coordinates and elevation are used for comparison with BioSoil$^+$. In Volume II, the BioSoil$^+$ data is compared with the historical soil data to investigate temporal changes on the revisited plots.

2.7.3 Soil map at EU level

The Soil Geographical Database of Eurasia (SGDBE, version 4) at scale 1:1 000 000 is part of the European Soil Information System (EUSIS). It is a digitised European soil map with related attributes and it provides a generalised representation of the diversity and spatial variability of the soil coverage in Europe. The aim of the SGDBE is to provide a harmonised set of soil parameters covering Europe to be used in agro-meteorological and environmental modelling at regional, state, or continental levels.

The database contains a spatial domain of vector data consisting of Soil Mapping Units (SMUs). Soil characteristics are stored in two tables with various attributes. The attributes are combined to typical characteristics in form of Soil Typological Units (STUs). SMUs and STUs are explained in detail in JRC (2001) and Lambert et al. (2003).

A point in polygon overlay was made for each BioSoil$^+$ plot and the SGDBE coverage, both projected within ETRS89 LAEA. Five variables were selected from the resulting attribute table for use as stratifiers (Table 2.7.2). The soil mapping unit (SMU), identified by a unique integer-number, represents a kind of 'soil association'. Since each SMU is composed of at least one Soil Typological Unit (STU), we selected the dominant STU (STU.DOM) which is the STU with greatest estimated percentage of area within a given SMU. Since the STU defines a soil type with a unique set of homogeneous properties and characteristics over a certain area, it is considered the most likely (generalised) soil type for the selected BioSoil$^+$ plot. This STU has also a numeric STU-identifier linking with the STU table from which we selected three soil classification names: (1) WRBFU; the full soil reference group and one qualifier according to WRB 1998 (FAO, ISRIC and ISSS 1998), (2) FAO90FU, FAO-UNESCO Soil Revised Legend (FAO-UNESCO-ISRIC 1990) and (3) FAO85FU; the modified CEC (1985) FAO legend (FAO-UNESCO 1974). Table 2.7.2. provides an example of the coding.

Table 2.7.2. Soil type stratifiers selected from SGDBE v.4.0

Stratifier	Description	Example
SMU	Soil mapping unit	*340229*
STU.DOM	Dominant Soil Typological unit	*340753*
WRBFU	WRB (1998) Reference Soil Group code with one soil unit adjective code	*CMeu*
FAO90FU	FAO90 Major Soil Grouping code with one soil unit code	*CMe*
FAO85FU	Full soil code of the STU from the 1974 (modified CEC 1985) FAO-UNESCO Soil Legend	*Be*

Since the WRB 1998 system has been revised substantially and we are using WRB 2006 (update 2007) in this report, we decided to avoid confusion and to use only the original FAO85FU attribute for stratification and upscaling applications. The main scientific reason is that both FAO90FU and WRBFU in the SGDBE are a translation from the original FAO legend but not a reclassification and it is unknown how and to which extent the extra soil information required for proper WRB

classification was available and effectively used in this conversion process. Recently defined Reference Soil Groups such as Stagnosols and Umbrisols in WRB 2006 (update 2007), which play an important role in the European forests, are for example not present in the SGDBE. Since apart from a soil name, no soil properties or characteristics are derived from the SGDBE, the original soil legend is most probably the least erroneous and most appropriate, even if outdated.

The description of the codes applied in FAO85FU have been obtained from the European Soil Portal: http://eusoils.jrc.ec.europa.eu/ESDB_Archive/ESDBv3/legend/LegendData.cfm. In addition, six special numerical codes are used for areas on the soil map were no soil name could be attributed: (code 1) Town (i.e. sealed soil), (2) Disturbed soil, (3) Water body, (4) Marsh, (5) Glacier and (6) Rock. Volume II of this report will elaborate on the relation between the SGDBE and the classification according to WRB 2006 carried out during the BioSoil survey.

2.7.4 Characteristics of Level I and II plots

Basic information of the ICP-Forests Level I and II plots such as PlotID and coordinates were derived from the ICP-Forests databases, further referred to as PCCDB. The reference plot locations were needed to check the overlap of BioSoil plots with the crown assessment plots on Level I and with the intensive monitoring plots on Level II. PlotIDs were recoded from the ICP-Forests notation (plotN° *100 + countrycode) to BioSoil^{+} compatible PlotIDs (e.g. 2901 to 1_29). Plot coordinates, originally in decimal degrees WGS84, were projected in ETRS89 LAEA for compatibility with the GIS coverages.

Information on the forest stand and dominant tree species is of interest to find relationships with forest floor and soil type and their inherent physico-chemical properties. The crown condition database of ICP-Forests was the main provider of these data. Both for Level I and II plots GIS coverages were used to relate forest type and tree species to the plot, mainly based on PLOTID. However, since ~80 % of the BioSoil^{+} plots are also present in the ICP-Forests Level I crown condition database additional information on the main tree species on the missing BioSoil plots was gathered from the NFCs (Poland, Great Britain, Finland) or from BioSoil-biodiversity files, when available (Hessen, Niedersachsen, Saarland). Essentially nine variables were selected (Table 2.7.3).

Table 2.7.3. Forest related stratifiers selected from ICP Forests databases and other sources

Variable	Description	Example
plotid	PlotID	*2901*
Xgeo	X coordinate (WGS84)	*48.990*
Ygeo	Y coordinate (WGS84)	*7.72944*
CODE.TREE	Code of tree species	*129*
LIB.TREE.S	Name of tree species	*Pinus nigra*
GRP.TREE.S	Broadleaves/conifers	*conifers*
SPCODE	Acronym tree species	*Pinnig*
CAT.N	Forest Type N°	*10*
CAT	Forest type	*CONIFEROUS_FOREST_OF_THE_MEDITERRANEAN, _ANATOLIAN_AND_MACARONESIAN_REGIONS*

The code of the tree species conforms to the ICP-Forests tree species list (data submission forms of ICP Forest manual) holding about 146 species. For linking with other databases and proper display we added an acronym, consisting of the first three characters of genus and species name (Table 2.7.3). Whether the main tree species is broadleaved or coniferous is given by the stratifier

GRP.TREE.S. Mixed stands of coniferous and broadleaved species are not mentioned here. Finally, a European forest classification type is attributed to most plots using the first tier of the European forest types nomenclature (EEA 2006) containing 14 categories.

2.7.5 Forest (soil) cover

2.7.5.1 Area estimates

A reliable estimate of the total forest cover in our study area is essential for upscaling stocks from plot to the European level. This is important since forest cover determines also directly forest soil area, when corrected for building areas, roads, water bodies and glaciers. A specific forest area at EU or even country level, useful as an international reference is hard to find, mainly due to great differences in national forest definitions. More on these definitions can be found in Schuck et al. (2002).

Table 2.7.4. summarizes forest areas for European countries (without the Russian Federation) according to three data sources: (i) EFI2002; European Forest Institute (Schuck et al. 2002), (ii) FMAP2006; Joint Research Centre (Kempeneers et al. 2010) and (iii) SOEF2011; State of European Forest's (FOREST EUROPE, UNECE and FAO 2011).

So, depending on the forest definition or the way forest information is gathered (e.g. by remote sensing, national forest inventories, …) forest area for all listed EU countries varies from 131 to 202 Mha. For the BioSoil countries this forest (soil) area ranges from 107 to 169 Mha. Hence, BioSoil surveyed about 82 % of the total European Forest, when excluding the forest area of the Russian Federation.

For some countries a large disparity in forest area between the JRC's Forest cover map (remote sensing based) and the SOEF2011 (NFI based) may be observed. Large differences are found both for Southern countries (Portugal, Spain, Greece) as for Northern countries (Sweden, Finland, Norway). The national estimates by EFI are often in between. Analysis of the reasons for this disparity is outside the scope of this report, but we recommend further investigation on this matter.

For this report, we inferred the reference forest area (**RFA**) as the average of the three sources, being **163 Mha** for all EU countries and **135 Mha** for the area covered by the BioSoil countries.

Assuming the BioSoil sample as representative for the European forest (i.e. a similar proportional distribution of forest and soil types), a factor 1.2 is used to upscale the findings for BioSoil countries to all countries mentioned in Table 2.7.4.

Table 2.7.4. Forest Area (kha) and Forest Index (percent forest of total land area) by country according to three data sources. BioSoil countries are in bold.

ISO code	COUNTRY	EFI2002		FMAP2006		SOEF2011	
		kha	%	kha	%	kha	%
AL	Albania	1031	35.9	539.0	18.9	1032.0	38.0
AD	Andorra	-	-	14.5	30.5	16.0	36.0
AT	**Austria**	**3819.0**	**45.5**	**3363.4**	**40.1**	**3991.0**	**48.0**
BE	**Belgium***	**689.1**	**22.6**	**770.4**	**25.3**	**706.0**	**23.0**
BA	Bosnia-Hercegovina	906.0	35.2	1997.8	38.8	3021.0	59.0
BG	Bulgaria	3295.1	30.3	3089.1	28.0	3927.0	36.0
HR	Croatia	1774.8	31.4	1457.0	26.1	2474.0	44.0
CY	**Cyprus**	**-**	**-**	**-**	**-**	**387.0**	**42.0**
CZ	**Czech Republic**	**2583.1**	**32.8**	**2611.9**	**33.1**	**2657.0**	**34.0**
DK	**Denmark**	**445.4**	**10.3**	**416.4**	**9.8**	**635.0**	**15.0**
EE	**Estonia**	**2015.9**	**44.6**	**1870.6**	**42.2**	**2337.0**	**55.0**
FI	**Finland**	**19862.3**	**58.7**	**14241.4**	**43.6**	**23116.0**	**76.0**
FR	**France**	**14825.1**	**27.0**	**13796.1**	**25.3**	**17572.0**	**32.0**
DE	**Germany**	**10741.0**	**30.1**	**11058.3**	**31.3**	**11076**	**32.0**
GR	**Greece**	**3359.0**	**25.5**	**2072.4**	**16.0**	**6539.0**	**51.0**
HU	**Hungary**	**1767.0**	**19.0**	**1412.9**	**15.2**	**2039.0**	**23.0**
IE	**Ireland**	**591.0**	**8.4**	**178.0**	**2.6**	**788.0**	**11.0**
IT	**Italy**	**6686.2**	**22.2**	**6456.0**	**21.5**	**10916.0**	**37.0**
LV	**Latvia**	**2883.9**	**44.6**	**2371.5**	**37.1**	**3467.0**	**56.0**
LI	Liechtenstein	7.0	43.8	4.6	30.2	7.0	46.0
LT	**Lithuania**	**1977.9**	**30.3**	**1831.3**	**28.3**	**2249.0**	**36.0**
LU	Luxemburg	88.8	24.7	97.3	37.3	88.0	34.0
MK	Macedonia	2275.9	44.5	638.1	25.2	1141.0	45.0
MC	Monaco	-	-	0.0	3.6	0.0	0.0
NL	Netherlands	334.0	8.1	385.1	11.1	365.0	11.0
NO	Norway	8709.0	26.9	8478.9	27.3	12384.0	41.0
PL	**Poland**	**8850.0**	**28.3**	**9344.8**	**30.2**	**9319.0**	**30.0**
PT	**Portugal**	**3382.0**	**38.1**	**1504.4**	**17.1**	**3611.0**	**40.0**
RO	Romania	6300.7	26.4	6075.8	25.6	6733.0	29.0
SM	San Marino	-	-	0.3	4.2	-	-
RS	**Serbia-Montenegro**	**2894.5**	**28.3**	**2771.8**	**27.1**	**3123.0**	**36.0**
SK	**Slovakia**	**2016.1**	**41.1**	**1809.2**	**37.0**	**1938.0**	**40.0**
SI	**Slovenia**	**1098.9**	**54.2**	**1036.0**	**51.2**	**1274.0**	**63.0**
ES	**Spain**	**13961.0**	**28.1**	**7603.4**	**15.3**	**27748.0**	**56.0**
SE	**Sweden**	**22745.8**	**55.4**	**18457.7**	**41.6**	**30625.0**	**75.0**
CH	Switzerland	1138.9	27.6	1206.1	30.6	1311.0	33.0
GB	**United Kingdom**	**2469.0**	**10.1**	**2004.7**	**8.4**	**2901.0**	**12.0**
	All countries (Mha)	*155.5*	*31.5*	*131.0*	*26.0*	*201.5*	*38.2*
	BioSoil countries (Mha)	*129.7*	*32.1*	*107.0*	*27.2*	*169.0*	*40.1*

* Only Flanders region participated in BioSoil with approximately 143 Mha of forest

2.7.5.2 Grid based estimates

BioSoil plots were located on the ICP Forests 16 x 16 km Level I grid. Theoretically each plot represents approximately 256 km² (25600 ha) of forest. Consequently the 4926 plots sampled by the BioSoil countries represent all together 126 Mha of forest which is close to the forest area estimated by EFI (Table 2.7.4).

When dividing the BioSoil RFA of 135 Mha by the number of BioSoil plots each plot would represent 27405 ha. This is perfectly possible taking into account the deviances from the nominal 16 km grid size as in the North of Finland (32 km grid size) or in the Czech Republic (8 km) (Hiederer et al. 2011). Hence, from the proportional occurrence of a forest soil characteristic (e.g. soil type) its areal extent may be estimated applying a factor of **27.4 kha** of forest area per plot.

2.7.6 Corine Land Cover

The EEA and the European Topic Centre on Land Use and Spatial Information release on a regular basis updates of the Corine Land Cover (CLC) vector and raster geodata. CLC2006 is the year 2006 update of the first CLC database which was finalised in the early 1990s as part of the European Commission programme to COoRdinate INformation on the Environment (Corine). The most recent inventory is still from 2006 and is available at 100 and 250m spatial resolution. For this study we applied CLC2006 version 13 (release May 2010). An overlay was produced from BioSoil^{+} plot locations and CLC2006, and four fields were retrieved as stratifying variable for the plots (Table 2.7.5).

Table 2.7.5. Stratifiers derived from Corine Land Cover ()

Stratifier	Description	Example
CLC.CODE	Corine code	*312*
CLC.LABEL1	Complex	*Forest and semi natural areas*
CLC.LABEL2	Unit	*Forests*
CLC.LABEL3	Detailed	*Coniferous forest*

The numerical CLC code consists of three digits, linked with a hierarchical level of detail describing the land cover type. The codes and classes applicable for the afforested BioSoil plots are given in the results and discussion Chapter. The most detailed (tier 3 level) describes if the plot belongs for instance to a coniferous forest, an agro-forestry area or a transitional woodland-shrub ecosystem. More information and downloads can be found at http://www.eea.europa.eu/data-and-maps/.

2.7.7 Altitude and climate

Alitudinal and Bioclimatological data are derived from the WorldClim geodatabase version 1.3 (update 2009). Prior to the overlay with the BioSoil^{+} Level I and II plots, the WorldClim coverage was projected in ETRS89 LAEA. We selected and renamed some WorldClim variables to common abbreviations: the annual mean temperature (BIO1) is further referred to as MAT, annual mean precipitation (BIO12) as MAP, maximum temperature of the warmest month (BIO5) as TMAX and minimum temperature of the coldest month as TMIN. In the WorldClim model the temperature variables were reported in °C·10, but for uniformity we transformed the data in °C. Units are provided in Table 2.7.6. For 35 Level I and 4 Level II plots no data could be derived from the WorldClim model. These data were retrieved from Google Earth elevation and climatological data provided by national weather institutes.

WorldClim is based on a continuous climate surface model developed by Hijmans et al. (2005). It was assembled from existing climate databases (e.g. FAOCLIM 2.0 global climate database, WMO climatological normals (CLINO), among other) and has a high spatial resolution of 30 arc s (~1 km²). Basically, the model interpolates monthly input data from 47554 locations for precipitation and 24542 meteo stations for temperature, holding records of at least 10 years within the 1950-2000 period. Cross validation revealed average errors of <10 mm/month for precipitation and <0.3

°C for temperature. WorldClim is particularly developed for use in environmental, agricultural and biological sciences. The geodata is freely available for download from http://www.worldclim.org.

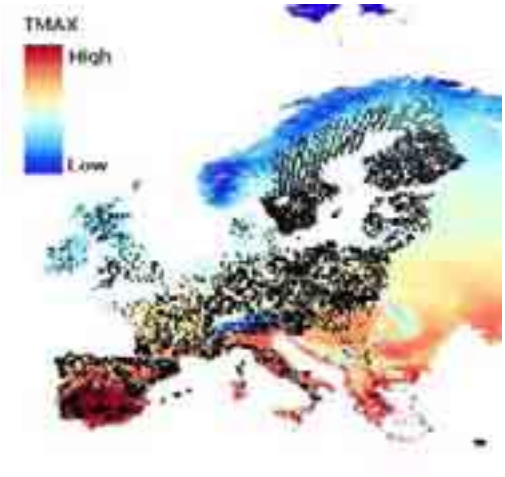


Figure 2.7.1. Temperature gradient across European forest plots

Table 2.7.6. Variables selected from WorldClim model: current climate dataset

Stratifier	Unit	Description
Altitude	m	Altitude from DTM
MAT	°C	Mean annual temperature
MAP	mm	Mean annual precipitation
TMAX	°C	Maximum temp of warmest month
TMIN	°C	Coldest temp of coldest month

WorldClim did not provide any estimates for Cyprus or the Canary Islands. The precipitation at these locations was estimated using the SamSamWater Climate Tool (de Haas, 2010). This tool uses data from 28800 stations of FAOCLIM 2.0 to estimate precipitation and evaporation anywhere on Earth. The tool is available at http://www.samsamwater.com/climate/.

2.7.8 Biogeographical regions and Ecoregions

Ecodistrict information for each BioSoil plot was derived from two coverages: (1) the biogeographical regions (EEA 2005) and (2) the ecoregions (EEA 2004). An overview of the development of the Biogeographical regions map of Europe can be found in EEA (2006). Figure 2.7.2 shows the pan-European coverage of these regions with national borders.



Figure 2.7.2. Biogeographical regions (EEA 2005)

Using a point in polygon overlay we linked each BioSoil^{+} plot with its biogeographical region (Table 2.7.7).

Ecoregions were originally developed by EEA as a tool for the zonation of fauna living in European inland waters, but can be used for forest ecosystems as well. It covers Pan-Europe excluding Turkey and Cyprus (Figure 2.7.3). Since there are Level plots in Cyprus and this Mediterranean island is home to a great variety of flora and fauna hosting over hundred endemic plants (WWF 2001), we added a specific region "Cyprus" to this list. Figure 2.7.3 shows the geographical borders of each ecoregion and their names.

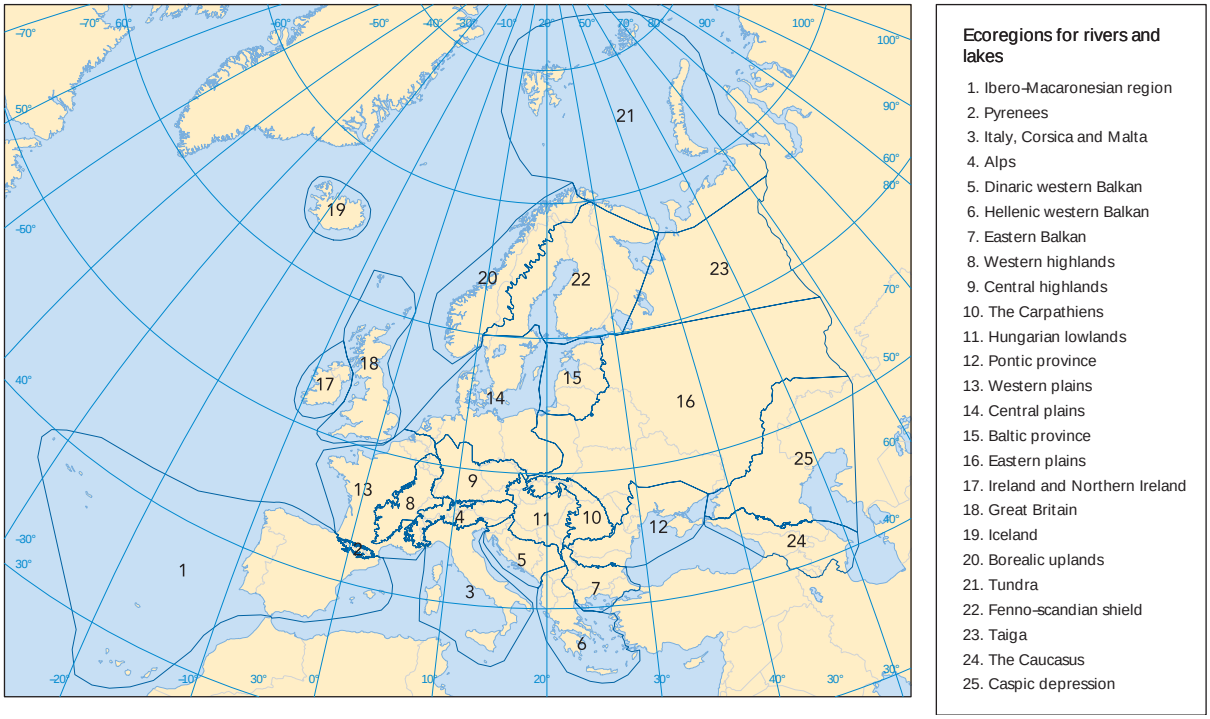


Figure 2.7.3. Delineation of Ecoregions (EEA 2004) across Europe

From the ecoregions coverage, we extracted the Ecoregion ID and Ecoregion name (Table 2.7.7) for each BioSoil plot. Cyprus was added as ECOREGID=0 and ECOREG="Cyprus".

Table 2.7.7. Stratifiers selected from Biogeographical and Ecoregion maps produced by the European Environmental Agency.

Stratifier	Description	Example
BIOGEO	Biogeographical region (2005)	*Mediterranean*
ECOREGID	Ecoregion ID	*1*
ECOREG	Ecoregion name	*Ibero-Macaronesian region*

2.7.9 Natura 2000 areas

The Nature 2000 network is formed by the sites classified under the "Birds" and the "Habitats" directives. It includes the Special Protection Areas (SPAs) under the Birds Directive and the Sites of Community Importance (SCIs) or Special Areas of Conservation (SACs) of the Habitats Directive. Site selection was solely based on the needs of endangered species and the quality of existing endangered habitat types. Since forests are an important habitat for both directives we analysed which BioSoil plots were situated in a Nature 2000 area, using the 2010 version of the Natura 2000 coverage. More information can be found at: http://ec.europa.eu/environment/nature/natura2000 and http://www.eea.europa.eu/data-and-maps/data/natura-1.

Basically three fields were retrieved when a BioSoil plot was located within a Natura2000 area: the unique site code, its area name (toponym) and a letter indicating the Natura 2000 type (Table 2.7.8).

Table 2.7.8. Variables selected from WorldClim model: current climate dataset

Field	Description	Example
SITECODE	Natura 2000 code	ES0000303
SITENAME	Name area	DESFILADEROS DEL RÍO MARTÍN
SITETYPE	Natura 2000 type	J

For further stratification we grouped the site types codes into three categories: i) A, D: site belonging to the Birds Directive; ii) B, E: site belonging to the Habitats Directive and iii) C, F, G, H, I, J, K: site belonging to the Birds and Habitat Directives

2.7.10 Solum depth for calculation of stocks

Based on the information contained in the three fields 'ROOT', 'ROCK' and 'OBSTACLE' in combination with the soil classification name, a new variable was derived 'DEPTHSTOCK'. This new variable is a best estimate of the effective soil depth. As stocks in this report are calculated for the maximally 100 cm of the soil profile, this field only provides information on the upper 100 m. In case the profile was described below 1 metre, the effected soil depth was considered to be at least 1 metre and the default value of 100 cm was given to the field 'DEPTHSTOCK'.

In case the rock depth of the profile was defined in the field 'ROCK', this depth was considered as the depth of the bedrock layer or continuous rock layer. In case the values were higher than 100 cm, the solum depth is deeper than 1 metre and the depth for stock calculation was set at 1 metre. In case the default values '99' (Sweden) or '101' (Finland) cm were given, it was replaced by 100 cm.

When following the FAO horizon designations, the master horizon symbol 'R' designates the depth of the continuous rock. In that case, the depth for stock calculations is equal to the upper boundary of the R horizon. Though, care should be taken as there are often indications that the 'R' symbol has been used for very stony horizons too. In that case, the lower boundary of the R horizons has been considered as the depth till continuous rock.

The soil classification following WRB (2006 or 2007) provided additional information:

– In case the profiles were classified as Leptosols or received the qualifier *leptic* (*endoleptic* and *epileptic*), the lower boundary of the deepest horizon has been used as the maximum depth for the stock calculations and cannot be more than 1 metre.

– In case the Leptosols received the qualifier *lithic*, the maximum profile depth is 10 cm.

– A solum depth of 0 cm is only possible when an organic layer is overlying continuous rock.

In case the soil has been described till the fixed sampling depths: 80 cm (France) or 90 cm (France, Germany, Poland) and no information is available on the layer below till 1 metre, it was assumed that the solum depth continued at least till 1 meter.

In case the soil has been described till another depth shallower than 1 metre and the stone content till this depth was below 40 % (CFCODE = 3) and no other information was available below this depth, it was assumed that the solum depth continued at least till 1 meter.

For a number of plots, the observation field contained additional information related to the solum depth. This information was taken into account at each moment e.g. 'rock not reached'.

One has to be very careful using the root limiting layer (field = 'ROOT') as the depth of the solum:

- In waterlogged soils, the water table will put restriction to the depth of the root growth.
- In case of 'ROOTABLE ROCK'.
- In case this field indicates a thin layer (continuous or discontinuous) in the soil profile putting restrictions to root growth.
- In many cases this field was equal to the lower boundary of the deepest described horizon. So it was equal to the max. OBSERVED depth of the roots meaning that at this depth roots were still observed without giving information whether roots occur at deeper layers.

On a number of profiles in Spain and in the Canaries no profile description neither a soil classification name was available. For these plots it was impossible to derive the depth for stock calculations. In that case, The field 'DEPTH_STOCK_CALC has been left blank or was coded 'NA'.

2.8 Data exploration and statistical evaluation

2.8.1 General statistics

2.8.1.1 Statistical software

The analysis, synthesis and interpretation of BioSoil$^+$ data is performed using advanced statistical techniques. Generally we employed the S-Plus software, both version 6.2 (Insightful Corp.) and version 8.1 (TIBCO Spotfire S$^+$) in combination with the R statistical language (Windows versions 2.7.1 and 2.13.1). In fact R is an implementation of the S programming language and hence both software are quite similar in their command structure. The capabilities of R, which is now the world-wide standard for statistical software development and data analysis, are extended through specialised packages. The latter allow the use of specific statistical techniques, graphical tools and devices, import/export capabilities, reporting tools, etc. More information on R may be found in the reference index (R Development Core Team 2008) and on the developers website: http://www.R-project.org. The packages used in this study are listed in Table 2.8.1 and are all freely available from the CRAN repository. The R programming was greatly facilitated using the GUI/editor Tinn-R ver. 1.19.4.7 also freely available under GNU General Public License (GPL).

Table 2.8.1. R statistical packages used for BioSoil$^+$ analysis and reporting

Package	Version (date)	Role	Author/reference
RODBC	1.2.4 (19/11/2008)	ODBC database connectivity	Lapsley, M. & Ripley, B.
plotrix	3.0 (9/9/2010)	Plotting functions and graphical tools	Lemon, J.
pcaMethods	1.12.0 (19/04/2009)	Extended Principal Component Analysis	Stacklies & Redestig 2010
fts	0.7.6 (15/10/2009)	Operations for time series objects (functions for handling missing values)	Armstrong, W.
NADA	1.5.3 (22/12/2010)	Analysis of left censored data with nondetects	Helsel 2005 Helsel & Lee 2006.
soiltexture	1.0.2 (5/10/2010)	Graphical tools for soil texture analysis	Moeys, J.

The BioSoil$^+$ masterfiles reside as Excel and Access data files. For statistical evaluation they were imported in S-PLUS (sdd format) or in R using the RODBC interface to become working datasets. Analysis was basically performed on these working datasets extended with temporary and derived variables, always unaffecting the original masterfiles. All S-PLUS and R scripts including new functions that were programmed were stored, enabling efficient recalculation when needed and documenting the working datasets and variables that were applied in each analysis. For all graphs produced with R, the scripts were also stored separately so that modification and reproduction of graphs was easy. Export of graphs was mainly as enhanced metafiles (EMF format).

2.8.1.2 Handling missing and left censored data

Classical statistical analysis of the soil data is complicated by missing values ('NA') and by data below the limit of quantification ('-1' LOQ values) as is described in Section 2.3.4. Zero values were always treated as real observations of 'nothing'.

Both S-PLUS and R can handle NA-values by specific actions. In this study, missing values were generally excluded (actions: na.exclude or na.rm=T) and the statistical procedures applied on the

remaining dataset. Rows of missing values in matrices were omitted using the functions na.omit() or remove.all.na.rows(). In case of multivariate principal component analysis, 'NA' values were imputed by probabilistic routines (Section 2.8.2.1).

Observations below LOQ were reported as '-1'. For classification and ranking of the variables '-1' was replaced by half of the respective LOQ value (Table 2.3.4). In contrast, for computing general statistics as mean and percentiles, methods for censored data (in our case left-censored) were applied using the NADA package in R (Helsel 2005). Essentially, each numeric vector of all observations (both censored and uncensored) is complemented with a logical vector (TRUE/FALSE) indicating if an element is censored (a less-than value) or not. If TRUE, the observation is considered censored and is treated as such by the statistical techniques, which can handle multiple censored observations (i.e. multiple LOQs). However, since we do not have a complete set of LOQ values for each laboratory and parameter, we applied the median value of all labs listed in Table 2.3.4 as single LOQ per parameter. Furthermore, the online submission module of BioSoil data asked for the detection limit (different from LOQ) and not for all samples. If the LOQ would have been unambiguously known for each analysis result, the statistical procedures for left-censored data could perfectly handle the dataset with more precision. However, the applied approach is already a great step in advance, taking into account the valuable left-censored observations for statistical inference.

In the general statistics tables in Annex II, the total number of non-missing observations (indicated as *n*) refer to the dataset for which the statistics are effectively computed. The number and percentage of *n* which are left-censored are indicated by *Cen-n* and *Cen-%*. The minimum (Min) and maximum (Max) values refer to both ends of the complete data range. The percentiles ($P_{2.5}$, P_{25}, P_{50} *(Median)*, P_{75}, $P_{97.5}$) are estimated using Regression on Order Statistics (ROS) from NADA. The *Mean* and its 95 % confidence interval (*LCL-UCL*) is estimated using the cenfit() NADA routine and are based on an estimate of the empirical cumulative distribution function (ECDF) for censored data using the Kaplan-Meier method. More details can be found in Helsel (2005).

Distribution characteristics of the variable are provided by skewness (*Skew*) and Kurtosis (*Kurt*). The first is a measure of the asymmetry of the probability distribution, with a negative skew indicating a longer left tail and a positive skew a longer right tail of the distribution. It shows where the mass of the distribution is located. Kurtosis is a measure of the "peakedness" of the distribution. When higher, it means that more of the variance is the result of infrequent extreme deviations as opposed to frequent modestly sized deviations. Most of the reported statistical values are rounded to three significant digits.

2.8.1.3 Univariate statistics

In Section 3.4 the statistics are merely presented by graphs, displaying the distribution characteristics for each variable according to 11 distinct layers.

Initially a censored boxplot is given with the highest censoring threshold shown as a horizontal line. Data are grouped by layer (OL, H, M01, H24, etc) and drawn on a logarithmical scale because concentration levels amongst layers may differ several orders of magnitude. The whiskers extend to the min and max data values of each layer. So, if the whiskers are below the horizontal line, left-censored statistics are required for proper statistical estimation. The boxplot allows to immediately evaluate the range, distribution and relative proportion of left-censored observations for all layers together.

For each soil compartment (forest floor, mineral soil and peat layers) a histogram of the constituting layers is drawn like in Figure 2.8.1, providing multiple information regarding the variable (extractable sulphur in the example). The variable and its unit is in X-axis, the number of observations in the left Y-axis (both in black colour). The title indicates the layer (here: mineral soil 20 to 40 cm of depth) and the total number *n* of observations (without missing values). A histogram of 10 to 15 bins characterises the distribution. If values below LOQ were reported, their number is indicated in the first bar and coloured in red. The value of the LOQ and the number of left-censored observations is then indicated in the legend. So, 86 observations were found below the LOQ of 20 mg sulphur kg^{-1}. At the high end, all observations exceeding the 97.5 percentile (thus 2.5 % of them) are displayed in a grey bar and also indicated in the legend. This way, outliers do not parse the distribution too much. Superimposed on the histogram, a blue graph of the cumulative distribution with percentiles in the right axis is presented. For each percentile (e.g. the median at 50%) its corresponding value can be inferred as indicated by the green arrow. The shape of the cumulative distribution immediately tells if the distribution is right skewed (convex), left skewed (concave) or approaching normality (S-shaped). Note that the cumulative curve starts at the percentile indicating the proportion of left censored values.

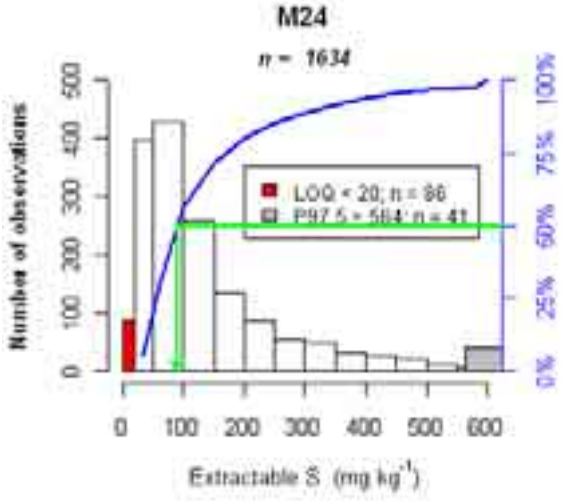


Figure 2.8.1. Example of histogram with cumulative distribution

Throughout our text, the 95 % range of a variable is generally considered as 'the plausible range', abandoning 2.5 % of the observations at both ends of its total range, but including the left-censored data.

Confidence intervals of the mean are generally determined at the 95 % level ($CI_{95\%}$) and estimated by bootstrapping the observations with 5000 resamples. The $CI_{95\%}$ is derived from bias corrected and accelerated (BCa) percentiles at 2.5 and 97.5 %. BCa intervals are a substantial improvement over empirical percentiles in both theory and practice (Efron and Tibshirani 1993). Uncertainty of the mean (precision) is based on the margin of error (ME) derived from half the $CI_{95\%}$.

When comparing two empirical distribution functions (e.g. histograms), a two sample Kolmogorov-Smirnov (KS) goodness-of-fit test is applied. The KS test is based on the maximum vertical distance between the two distributions. If the test statistic is greater than some critical value, the null hypothesis is rejected. For the two sample test, the alternative hypothesis is that the true distribution functions of both variables are not equal.

2.8.2 Multivariate analysis

2.8.2.1 Principal Components

Principal component analysis (PCA) is a well established technique to investigate patterns of covariance. It has been successfully applied in forest soil research (Clarke et al. 1996, Vervaet et

al. 2002). The analysis was performed using the statistical language R, using the **prcomp** function (stats package). Prior to the analysis, the data matrix (samples as rows, soil variables as columns) was first mean centred and scaled to have unit variance. Appropriate scaling is needed in order that the different concentration scales of the soil variables might not influence the results. Hence, each variable is considered equally important to the results. According to Clarke et al. (1996) this is crucial, because variables that are most important in soil processes may not necessarily be those that are present in the highest concentrations.
We mainly analysed the first three principal components (PCs) and reported the percentage of explained variance for each PC. Data were plotted using the **biplot** function, consisting of a scatterplot of the samples in two-dimensional spaces formed by PC 1-2, 2-3 and/or 1-3. The variables are represented by red arrows in each biplot. The length of each arrow is proportional to its contribution to the axes (PCs), the angle in between two arrows is a measure for the covariance between the variables. The smaller the angle, the better they are correlated.

We faced three problems to perform proper PCA data analysis: (i) a great proportion of left censored values (< LOQ) for specific variables, (ii) outliers strongly influencing the components, (iii) incompleteness of the data matrix due to missing values.

The first problem was solved by replacing all values smaller than LOQ by the LOQ value, which became the minimum value. Exception was made for carbonates, where 0 g kg^{-1} was allowed instead of the LOQ of 3 g kg^{-1}. Outlying samples after standardisation and initial PCA ordination, were discarded from the dataset and reported.

The problem of NA values is the most difficult one, since the standard PCA approach is not tolerant to missing data. Omitting samples with at least one NA value for a variable dramatically decreased the number of samples. That way, much information was lost and the remaining subsets were restricted to some countries with complete datasets only and therefore geographically biased. Replacing NA values by column wise means is a possible solution but statistically tentative. It is much better to impute NA values using prediction algorithms adapted to PCA analysis. We applied Probabilistic PCA (PPCA) which combines an expectation maximization approach with a probabilistic model. This is one function of the pcaMethods R package (Stacklies and Redestig 2010) providing different PCA methods that are robust against missing data and allow for NA estimation. For an overview see Stacklies et al. (2007). PPCA was selected based on its computational efficiency for large datasets, its tolerance to a relative high amount of missing data and similar scaling of scores, loadings and eigenvalues as standard PCA, respecting orthogonality among components.

PPCA was employed on the total level I SOM file to find the most explaining physico-chemical variables within forest floor, mineral and peat samples separately. Secondly, datasubsets were analysed consisting of logically grouped variables (e.g. exchangeable cations, total elements, trace metals) and PPCA was run again to explore the interrelationships within each group. In addition, correlation matrices of each group were developed and discussed.

2.8.2.2 Correlation matrix

A correlation matrix as shown in Figure 2.8.2 was programmed in R to provide information on bivariate relationships in a condensed way. The variables are ordered on the diagonal of the matrix

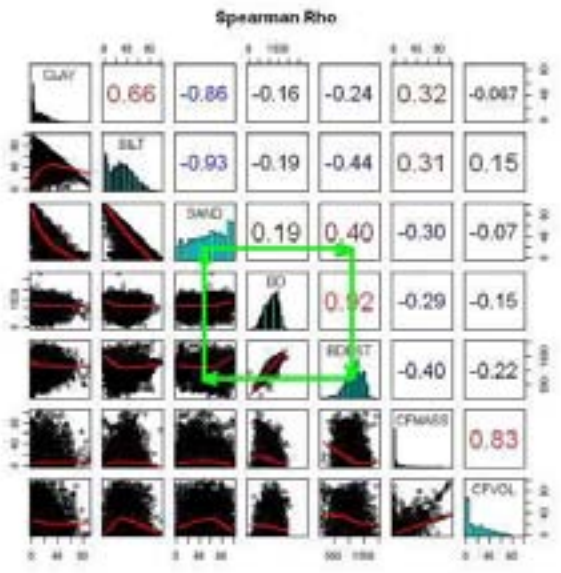


Figure 2.8.2. Example of correlation matrix

along with their distribution histogram. Note their respective X axis above or below the matrix. In the upper panel (above the diagonal) Spearman correlation 'Rho' values are given for each pairwise combination of variables. As in the example indicated by the green line: the correlation between sand (SAND) and estimated bulk density (BDEST) is 0.40. Increasing positive correlation values become larger and more reddish coloured, negative correlations become more blue coloured. Opposite to the correlation value and thus situated in the lower panel is a scatterplot of both variables against each other (black circles). A locally weighted regression (LOWESS) line in red colour depicts the shape of the relationship, indicating if it is linear or non-linear. For instance, the nice linear relationship between measured (BD) and estimated bulk density (BDEST) is immediately clear, but also a non-linear one between BDEST and SAND. For the computation of the correlation matrix all paired (non-missing) values were applied, including the outliers of both variables. Since Spearman rank correlation is robust to outliers, this coefficient is quite useful. Moreover, it is also less sensitive to non-normality compared to the standard Pearson correlation coefficient.

2.8.3 Geographical mapping

In order to highlight the geographical distribution patterns of the BioSoil^{+} data, EU wide maps are produced using ArcGis 9.3 (ESRI, Redlands, USA) for dot maps and Surfer 8.0 (Golden Software Inc., Colorado, US) for contour maps of continuous variables. In case of class variables, a bar chart is shown with the number of observations in each class. Annex III contains the collected maps.

In ArcGis, metric coordinates (ETRS89 LAEA) of all BioSoil^{+} Level I and II plots are plotted as coloured dots within the EU countries boundaries. For each variable, a specific colour scale was applied usually in 6 to 9 classes depending on the range. The plot observations in Cyprus and Canary Islands are depicted as framed insets below the continent.

A contour map was applied as an inset in the upper-left corner of the map page. This contour map is based on a 4 x 4 km grid across Europe (grid size 1026 rows x 876 columns; 898776 nodes) using standard point Kriging as gridding method. Kriging attempts to express trends suggested in the data and was applied to create a generalised map. The method incorporates anisotropy and underlying trends in an efficient and natural manner. To avoid misinterpretation countries or regions with no or too few data for proper Kriging are blanked. Countries of which we do not have data in the BioSoil^{+} survey are in grey. Other country borders were omitted. The colour scale for the contours is identical as for the dot maps enabling intuitive and related interpretation of both maps. The gridding is performed using metric ETRS89 coordinates with X ranging from 2500000 to 6000000 and Y from 1400000 to 550000 m. Values below quantification limit (-1) were replaced by half of their LOQ value, only when they were classified.

3 Results and discussion

3.1 General plot information

3.1.1 Survey period

The period of surveying in the field and the subsequent laboratory analyses is different among the countries, both for the profile (Table 3.1.1) and fixed depth (Table 3.1.2) assessments.
On Level I, with the exception of France, Denmark, the majority of the plots in North Rhine-Westphalia (Germany) and a high number of plots in Sweden, all countries participating in the BioSoil survey made a (new) profile description and sampled the genetic horizons for further analysis in the laboratory. On Level II, Denmark, France, Italy and UK made profile descriptions during the Forest Soil Condition survey in the 1990s though these data were not yet reported to the central ICP Forests soil condition database. All other countries made a (new) profile description and analysed the samples taken from the genetic horizons.

Table 3.1.1. Time span of the description and sampling of the soil profiles in the field and the laboratory analysis for each of the participating countries in the BioSoil project both on Level I and Level II

		Level I		Level II	
Country code	**Country**	**Profile description/ sampling**	**Laboratory analysis**	**Profile description/ sampling**	**Laboratory analysis**
AT	Austria	2006-08	2006-08	2006-08	2006-08
BE	Belgium	2006	2006	2005-07	2007-08
CY	Cyprus	2005	2006	2005	2007
CZ	Czech Republic	2006-07	2006-08	2006-07	2006-07
DE	Germany	1989-2008	2005 - 08	2006-08	2004-08
DK	Denmark	1987-94	1988	1996	1996
EE	Estonia	2006-07	2008	-	-
ES	Spain	2006-08	2008	2008	-
FI	Finland	2006	2007	2006-08	2006
FR	France	1993-99	1993-99	1994-95	1994-95
GB	Great Britain	2005-06	2008	1995	1995-96
GR	Greece	-	-	2007	2008
HU	Hungary	2006	2006	-	-
IE	Ireland	2006-07	2007-08	2006-07	2007
IT	Italy	2006-07	2006-08	1995-2008	1995-2008
LT	Lithuania	2006	2007	2006	2007
LV	Latvia	2005-08	2005-08	-	-
PL	Poland	2008	2007-08	2008	2007-08
RS	Serbia	2004	NA	-	-
SE	Sweden	1993-06	1993-2006	-	-
SI	Slovenia	2005-06	2006	2006	2008
SK	Slovakia	2006	2007-08	2006-08	2007-08
	All countries	**1987-2008**	**1988-2008**	**1994-2008**	**1994-2008**

NA = not available

Table 3.1.2. Time span of the sampling of the soil samples taken at fixed depth and the laboratory analysis for each of the participating countries in the BioSoil project both on Level I and Level II

		Level I		Level II	
Country code	**Country**	**Field sampling**	**Laboratory analysis**	**Field sampling**	**Laboratory analysis**
AT	**Austria**	2005-07	2006-08	2006-08	2006-07
CY	**Cyprus**	2005	2007	2007	NA
CZ	**Czech Republic**	2007	2006-08	2006-07	2006-07
DE	**Germany**	2005-2008	2006-09	2007-08	2006-08
DK	**Denmark**	1989-2007	2008	2008	2007
EE	**Estonia**	2007	2007-08	-	-
ES	**Spain**	2006-08	2008-09	2008	2008
FE	**Belgium**	2004	2007	2007	2005-07
FI	**Finland**	2006	2007	2008-09	2006
FR	**France**	2006-07	2006-07	2009	2007-08
GB	**Great Britain**	2005-07	2006-08	2008	2008
GR	**Greece**	-	-	2008	2008
HU	**Hungary**	2006	2007	-	-
IE	**Ireland**	2006-07	2008	2008	2006-07
IT	**Italy**	2006-07	2006-08	2008	2007-08
LT	**Lithuania**	2006	2007	2007	2006
LV	**Latvia**	2008	2008	-	-
PL	**Poland**	2006-07	2006-08	2007-08	2007
RS	**Serbia**	2004	NA	-	-
SE	**Sweden**	1992-2005	2008	-	-
SI	**Slovenia**	2006	2008	2008	2006
SK	**Slovakia**	2006-09	2008	2008	2007-08
	All countries	**2004-08**	**2006-09**	**2006-09**	**2005-08**

NA = not available

For the samples taken at fixed depths, the sampling period corresponds better with the BioSoil survey period. In Denmark the sampling date of 1989 (on one plot only) is not correct. This plot was not resampled during BioSoil due to a large disturbance of the soil profile. The plot was replaced to a new location where new samples were taken. In Sweden the situation is less clear. There we would have expected sampling dates between 2003 and 2006. Sweden applies a rotation system on their national survey plots. It is documented that samples taken from 2003 onwards could be used in BioSoil.

3.1.2 Plot location

3.1.2.1 The BioSoil^{+} Level I and II plots

BioSoil^{+} Level I plots range from -18°03' in the west (plot 95_2113 on the Canary islands, Spain) to 33°22' in the east (plot 66_15 in Cyprus) and from +28°01' in the south (plot 95_2111 on Gran Canaria) to 69°38' in the very north (plot 15_3955 in Finland). The total longitudinal range is about 14 % longer than the latitudinal range, and both are more than 4000 km long (Table 3.1.3). When focusing on the continent, the most westwards BioSoil^{+} Level I plot is situated near Lisboa, Portugal (plot 10_200 at -08°59' longitude) whereas the plot most to the east is situated in Finland (plot 15_1988 at 31°24' longitude). The longitudinal distance on the continent is therefore 2706 km. The latitudinal range is 3629 km, from plot 11_1959 (+36°21' latitude) near Gibraltar, Spain to plot 15_3955 (+69°38' latitude) in the north of Finnish Lapland. Hence on the European continent, the longitudinal range is about 75 % of the latitudinal range.

Since no Level II BioSoil$^+$ plots are situated on the Canary Islands or the Azores, the plot most to the west is located in West-Galicia (Spain, plot 11_102) whereas Level II plot 66_101 on Cyprus is its eastern counterpart. Cyprus also hosts the most southern Level II plot (plot 66_102) and the most northern Level II plot is the Finnish plot 15_1. The latter is the same plot for the BioSoil$^+$, FSCDB and PCCDB Level II databases (Table 3.1.3).

Table 3.1.3. Summary statistics of metric ETRS89 LAEA and WGS84 LAT/LONG* coordinates of BioSoil$^+$, FSCDB and PCCDB

	BioSoil$^+$		**FSCDB**		**PCCDB**	
	Level I	**Level II**	**Level I**	**Level II**	**Level I**	**Level II**
N° of unique coordinates	4926	127	5269	587	11705	801
Min X (m)	1557672	2802201	2661313	1641572	1557542	1118596
Min longitude	-18°03′	-8°42′	-9°18′	-17°18′	-18°04′	-28°14′
Max X (m)	6444433	6412282	5827476	5758386	7289420	6412282
Max longitude	+33°22′	+33°03′	+29°19′	+27°47′	+44°31′	+33°03′
Min Y (m)	981881	1632279	1576430	1031891	981882	1031892
Min Latitude	+28°01′	+34°57′	+37°08′	+28°11′	+28°02′	+28°11′
Max Y (m)	5250568	5262949	5355102	5262949	5355102	5262950
Max Latitude	+69°38′	+69°35′	+70°28′	+69°35′	+70°28′	+69°35′
X range (m)	4886760	3610081	3166163	4116814	5731877	5293687
Y range (m)	4268687	3630670	3778672	4231058	4373221	4231057

** Coordinates are rounded to the minute level as requested by some countries and EU directives*

Compared to the plots surveyed during the 1st soil condition survey (FSCDB), the Level I plot coverage has been extended to the east, west and south, but not to the north (Table 3.1.3). The subset of 127 Level II plots reassessed in BioSoil$^+$ cover only partially the Level II plots stored in the FSCDB or the PCCDB. Their extent is much less to the south and to the west.

Both for Level I and Level II the PCCDB (crown assessment) has clearly the largest European coverage, from 18°04′W on Canary islands to 44°31′E in western-Turkey, and from plot 95_2111 at 28°02′N again on the Canary islands to the Norwegian plot 55_26 at 70°28′N. The PCCDB shows that Level I has been substantially extended to the east (Russian Federation, Belarus and Turkey) hereby increasing the longitudinal range to 5732 km. With plots on the Azores, Level II ranges from 28°14′W (plot 10_5) to 33°03′E (66_101) on Cyprus, and from 28°11′N (plot 11_53 on Tenerife) to 69°35′N in Finland.

Figure 3.1.1 shows the longitudinal distribution pattern of the Level I plots that were assessed in the first (FSCDB) and the second soil survey (BioSoil$^+$). Most plots occur clearly at a longitude of 14° and 15° E. During BioSoil, more plots were assessed between 6° W and 2° E, whereas fewer plots between 3° - 17° E and 23° – 27° E. This is leading to a more even longitudinal plot distribution in BioSoil$^+$ than during the previous survey. Roughly, at least 50 Level I plots are present at each longitudinal degree between 8° W and 29° E.

Level II plots assessed during the previous soil survey (FSCDB) show some similarities with the longitudinal distribution pattern of Level I (Figure 3.1.2). Plot occurrences show maxima at 15° E , and plots are well represented between 5° – 23° E. However, Level II plots with soil data are greatly missing between 24° - 28° E. At least 8 Level II plots with FSCDB data are present at each longitudal degree between 8° W and 23° E, whereas at least 1 plot with BioSoil$^+$ data, excluding the 7° W. It is clear that the 127 Level II BioSoil plots do not follow the representative distribution found for Level I and although they cover almost the complete continental range from west to east, the number of plots at each longitudinal degree is quite small (less than 5 plots).

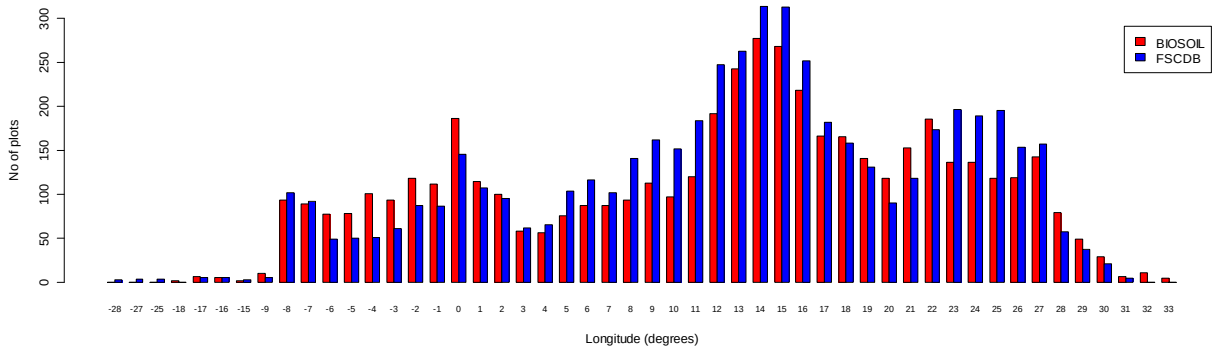


Figure 3.1.1. Longitudinal distribution of number of Level I plots of BioSoil$^+$ and FSCDB

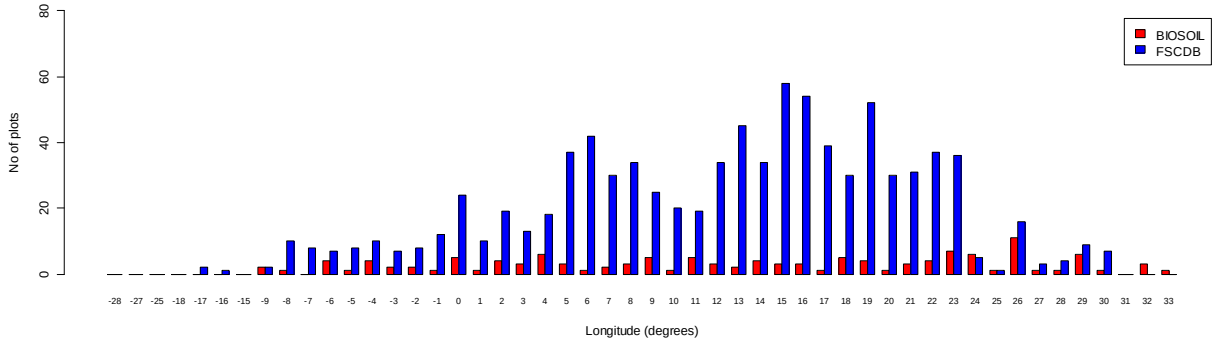


Figure 3.1.2. Longitudinal distribution of number of Level II plots of BioSoil$^+$ and FSCDB

The latitudinal distribution is given in Figures 3.1.3 and 3.1.4 for Level I and Level II plots respectively. For Level I, at least 50 plots occur between 37° and 67° N with a maximum number of plots at 49° N for BioSoil$^+$ and at 47° N for FSCDB. The bar graph clearly shows more northern plots being assessed in the previous survey than during BioSoil$^+$, which is mainly explained by the fact that in BioSoil$^+$ no Norwegian plots were reassessed. Conversely, more Level I plots were surveyed between 48° and 55° N, mainly due to a greater plot density in Poland. Less plots in BioSoil$^+$ between 45° – 47° N are explained by the absence of observations in Switzerland and Romania. The number of plots in the south remained quite constant.

The Level II latitudinal distribution pattern is different from Level I and should not be considered 'representative' for European forest soils. Plots are predominantly situated between 49° and 53° N and northern and southern European plots are underrepresented compared to the Level I pattern. BioSoil$^+$ Level II plots between 57° and 59° N are completely missing (south-Sweden, south-Norway, Estonia, Latvia) and the total number of plots per latitudinal degree is low (3 on average).

It is obvious that Level II BioSoil$^+$ plots alone are unsuitable for spatial analysis at the EU scale, like for the investigation of longitudinal or latitudinal patterns of soil types or specific variables. They should be considered together for proper geographical analysis.

Since Level I is a systematic network and Level II plots are chosen specifically based on national criteria, it seems interesting to determine their separation distance characteristics of neighbouring plots at the EU Level (Table 3.1.4). For BioSoil$^+$ the distance between neighbouring Level I plots ranges from ~200 m to ~100 km, whereas between ~100 m and ~340 km for Level II plots. The median distance for Level I is 15.9 km which is obviously close to the 16 km grid distance, and 55 km for Level II plots. In the FSCDB the median distance of Level II plots was ~33 km, due to the

higher number of plots (587 instead of 127) but the median distance for Level I remained nearly the same. Based on PCCDB plot coordinates, plot distance between neighbouring Level I plots range from 23 m to 114 km and from 93 m to 271 km, with median distances of 13 km and 30 km respectively. The short distances may be explained by plots that were slightly moved over time or that they have been measured more precisely during the BioSoil survey.

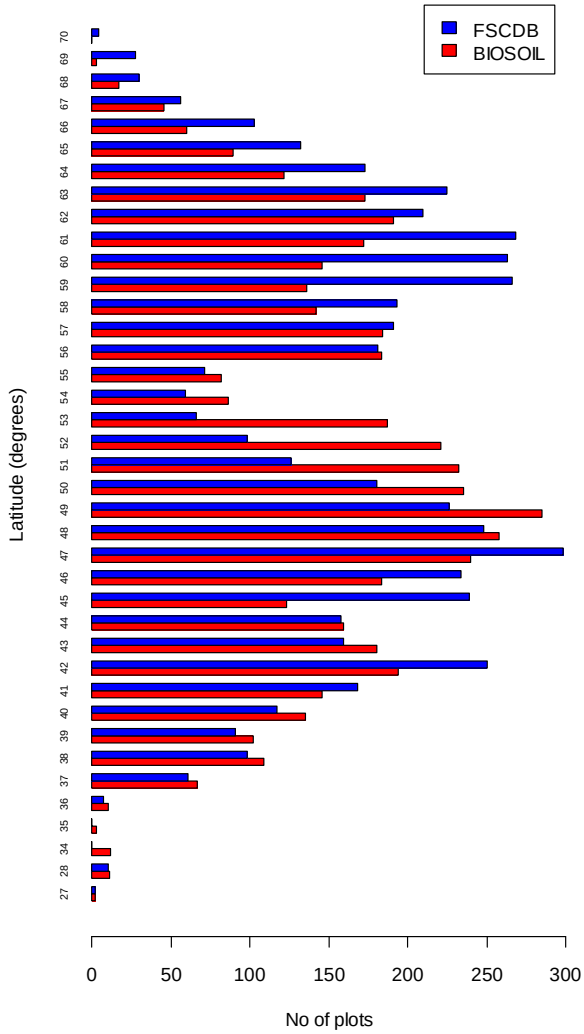


Figure 3.1.3. Latitudinal distribution of number of Level I plots of BioSoil+ and FSCDB

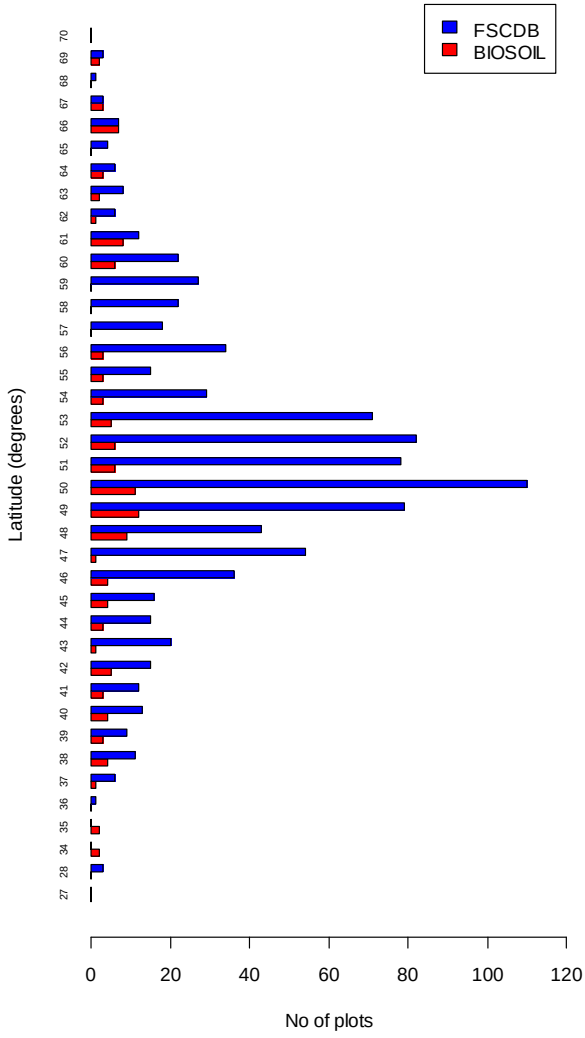


Figure 3.1.4. Latitudinal distribution of number of Level II plots of BioSoil+ and FSCDB

Table 3.1.4. Nearest Neighbour Statistics of separation distance (m)

	BioSoil+		FSCDB		PCCDB	
	Level I	**Level II**	**Level I**	**Level II**	**Level I**	**Level II**
Minimum	195	92.8	774	92.8	22.7	92.6
P_{25}	15155	9479	12722	17591	4664	14730
Median	15894	55094	15846	32954	13372	30359
P_{75}	16349	112336	16522	52224	15966	46436
Maximum	101586	339419	177655	330198	114175	271024
Mean	17228	74490	16741	41785	11847	35013
SD	6882	71076	9378	38809	9035	31842
Skewness	3.50	1.07	3.97	2.57	1.80	2.57

3.1.2.2 Distance among ICP Forests plots

Based on PLOTID

Level I

Distance was calculated between the coordinates of each BioSoil$^+$ Level I plot and the soil plots of the previous forest soil survey (Vanmechelen et al. 1997) as stored in the FSCDB (Table 3.1.5). Based on PLOTID, more than half of the BioSoil$^+$ plots were not assessed during the previous soil survey.We consider a threshold of 2 km, approximately the distance where coordinates were rounded to minute level. For 2326 plots, distance between the plots with identical PLOTIDs is less than the threshold. Of these plots, 1186 (51 %) have exactly the same coordinates (distance = 0 m). Apparently these coordinates were copied from the FSCDB into the BioSoil reports. For 80 plots, distance was more than 2 km and therefore these plots are considered to have different locations. Hiederer and Durrant (2010) compared also these two soil surveys and found 903 plots with identical coordinates and linked 2216 plots based on a distance threshold of 2750 m. Despite a larger threshold, they found less common plots than we did. Hence, for temporal analysis of soil condition on Level I plots, the BioSoil$^+$ data suggest that 2326 plots may be used (Table 3.1.5: distance class = 1).

Table 3.1.5. Number and fraction of Level I plots sharing common PLOTIDs for databases BioSoil$^+$, FSCDB (previous soil survey) and PCCDB (crown assessment) grouped per distance class.

Class	Description	BioSoil$^+$ - FSCDB		BioSoil$^+$ - PCCDB		FSCDB - PCCDB	
		n	%	n	%	n	%
0	No common PLOTID	2522	51.2	902	18.3	1486	28.1
1	Distance ≤ 2000 m	2326	47.2	3965	80.5	3652	69.0
2	Distance > 2000 m	80	1.6	61	1.2	151	2.9
		4928	100	4928	100	5289	100

Overlap of the BioSoil$^+$ with the crown condition plots (PCCDB) is larger now than for the previous soil survey. Eighty percent of the BioSoil$^+$ plots could be linked based on PLOTID and an inter-plot distance less than 2 km, compared to ~70 % of the FSCDB plots. Over one-quart (28 %) of the FSCDB plots cannot be related to crown assessment data.
However, in the 1st Soil condition report (Vanmechelen et al. 1997) it was reported that crown and soil databases shared 2939 common plots out of 4532 plots (65 %). After the final submission date (1 November 1996) the total number of FSCDB plots increased with 757 and 95 % of these were also crown plots. This shows an increasing overlap between soil and crown assessment plots over time. Spatial discrepancy is considered too large for 61 BioSoil$^+$ and for 151 FSCDB plots to link with crown assessment data, although all these share common PLOTIDs.

In Figure 3.1.5 the cumulative number of plots having common PLOTIDs is graphed against the $\log_{10}$ of the distance (m) between the plots. Clearly two jumps in number of plots are observed between two distance intervals: (i) 0.1 - 1.3 m (i.e. $\log_{10}$ interval: -1 to 0.11) for the comparison BioSoil$^+$ - PCCDB and FSCDB – PCCDB and (ii) 100 - 500 m ($\log_{10}$ interval: 2 to 2.7) for the comparison BioSoil$^+$ - FSCDB and BioSoil$^+$ - PCCDB. Since the minimum non-zero distance for the BioSoil$^+$ - FSCDB is 31 m, the cumulative distribution starts at x = 1.5. The BioSoil$^+$ - PCCDB distribution shows a large number of plots with small deviances in distance, mostly due to errors in conversion between WGS84 and ETRS89 LAEA.

For the comparison between BioSoil$^+$ - FSCDB and FSCDB - PCCDB similar relationships were found and most distances are below 500 m. These distances can be attributed to various reasons. In the past (FSCDB and PCCDB), coordinates were mainly derived from topographic maps with national coordinate systems whereas for the recent surveys plot coordinates were mostly reassessed by the countries using GPS and the associated WGS84 reference coordinate system, which led to a much greater positional accuracy. In any case, the distance threshold of 2000 m (vertical dashed line) includes almost all plot pairs and this analysis suggests that this threshold could be further narrowed to 1 km (x = 3) without significant effects on the selected number of plots.

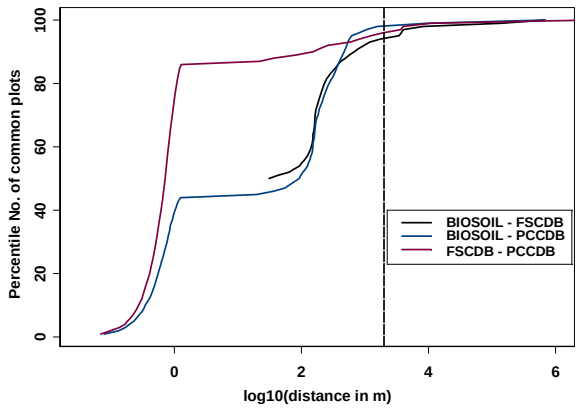


Figure 3.1.5. Cumulative distribution (percentiles) of common Level I plots of three datasets against log distance between plots. Vertical dashed line indicates the 2000 m threshold.

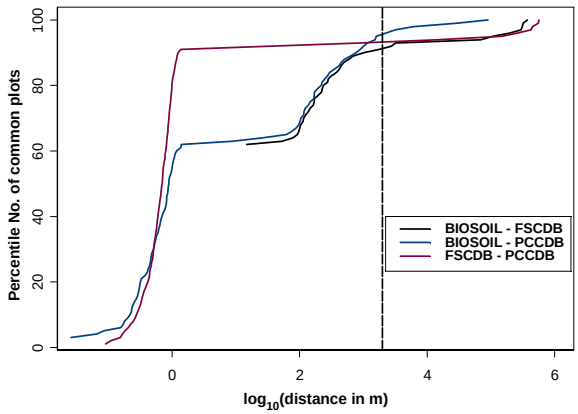


Figure 3.1.6. Cumulative distribution (percentiles) of common Level II plots of three datasets against log distance between plots. Vertical dashed line indicates the 2000 m threshold.

Level II

The cumulative distribution of Level II plots against plot distance (Figure 3.1.6) shows a similar pattern as for Level I. Over 60 % of the distances between plots of the BioSoil$^+$ - PCCDB and 90 % of the distances of FSCDB - PCCDB are lower than 1.3 m. A second distance interval is situated between 100 and 2000 m for ~30 % of the number of plots for the comparisons BioSoil$^+$ - FSCDB and BioSoil$^+$ - PCCDB. This distance interval is wider than observed for Level I. However, it should be stressed that only a small subset of the total number of Level II plots (n = 891 in FSCDB and n = 819 in PCCDB) were assessed in BioSoil$^+$ (n= 127).

Just as for Level I, the Level II plots can be classified in three distance classes. For those Level II plots that were assessed in BioSoil$^+$, only 17 % were not assessed in the past as soil plots (FSCDB) and less than 4.7 % were not registered in the PCCDB (Table 3.1.6).

Table 3.1.6. Number and fraction of Level II plots sharing common PLOTIDs for databases BioSoil$^+$, FSCDB (previous soil survey) and PCCDB (intensive monitoring plots) grouped per distance class.

Class	Description	BioSoil$^+$ - FSCDB		BioSoil$^+$ - PCCDB		FSCDB - PCCDB	
		n	%	n	%	n	%
0	No common PLOTID	22	17.3	6	4.7	241	27.1
1	Distance ≤ 2000 m	95	74.8	115	90.6	606	68.0
2	Distance > 2000 m	10	7.9	6	4.7	44	4.9
		127	100	127	100	891	100

So, the Level II BioSoil$^+$ plots highly coincide with intensive monitoring plots. The previous Level II soil dataset (FSCDB) covered 68 % of the PCCDB plots, which is very similar to the situation in Level I (69 %). When looking at the absolute number of plots, much more Level II plots (n = 491) were assessed for soil in the past than during the BioSoil survey.

The percentage of plots were the spatial discrepancy is considered too large (i.e. exceeding the threshold) is two to five times larger than for Level I. This is remarkable, since it could be expected that intensive monitoring plots on Level II are more accurately georeferenced than Level I plots, which is apparently not the case. Hence, comparison of BioSoil$^+$ Level II data with data of the Level II FSCDB is justified for 95 plots and and with PCCDB for 115 plots.

Based on spatial neighbourhood

Level I

A spatial neighbourhood analysis was performed employing GIS and the nearest neighbour distances (NNDs) were determined between plots of different geodatasets. This procedure was applied for geodataset BioSoil$^+$ compared to geodataset FSCDB, and the other way around, comparing geodataset FSCDB to geodataset BioSoil$^+$. We performed this procedure for the six combinations of the three geodatasets: BioSoil$^+$, FSCDB and PCCDB (Table 3.1.7).

Median distance between a BioSoil$^+$ Level I plot and its nearest neighbour in the Level I FSCDB is ~500 m, whatever its PLOTID, and 95 % of all computed distances are between 0 and 47.8 km. Considering identical PLOTIDs only, median NND is just 12 m and 95 % of all NNDs are situated between 0 and 3744 m. The latter limit is greater than the 2000 m threshold, but this is just a difference of a few percentiles (P_{95} is 1479 m). At the other hand, a substantial number of plots (~10 % of total, see Table 3.1.7) with completely different PLOTIDs show also between plot distances below the 2000 m threshold. It is possible that some of these concern basically the same plots of which PLOTIDs have changed over time, but these situations can only be retrieved confidently with the help of the local surveyors. For the BioSoil$^+$ - FSCDB comparison, the number of plots with identical PLOTIDs that are further away than 2 km is rather small (~2 %).

Table 3.1.7. Bootstrapped percentiles of nearest neighbour distance (m) between Level I plots of the databases BioSoil$^+$, FSCDB and PCCDB. Ninety five percent of the interplot distances are comprised within the $P_{2.5}$ and $P_{97.5}$ distance interval.

Description	BioSoil$^+$ - FSCDB				FSCDB - BioSoil$^+$			
	n	$P_{2.5}$	Median	$P_{97.5}$	n	$P_{2.5}$	Median	$P_{97.5}$
All plots	4928	0	516	47885	5289	0	990	318968
Different PLOTIDs	2562	143	15073	60793	2932	148	14308	369506
Identical PLOTIDs	2366	0	12	3744	2357	0	11	3736
	BioSoil$^+$ - PCCDB				**PCCDB - BioSoil$^+$**			
All plots	4928	0	94	14810	11737	0	6596	667700
Different PLOTIDs	1004	0	159	32246	7754	19	16269	731752
Identical PLOTIDs	3924	0	76	943	3983	0	86	957
	FSCDB - PCCDB				**PCCDB – FSCDB**			
All plots	5289	0	1	14738	11737	0	9068	789100
Different PLOTIDs	1544	0	7070	19663	7968	1	15940	905200
Identical PLOTIDs	3745	0	1	2173	3769	0	1	3227

When for the FSCDB neighbouring plots are selected from the BioSoil$^+$ database, the 95 % range is much wider than for the BioSoil$^+$-FSCDB comparison, up to 369 km for plots with different PLOTIDs. About half of all plots have a NND less than 2 km of which 81 % of them have identical PLOTIDs. Less than 1.9 % of the total plots with identical PLOTIDs are exceeding the 2 km threshold (Table 3.1.8).

Nearest neighbour distances between BioSoil$^+$ and PCCDB plots reveal mostly smaller values than for the BioSoil$^+$-FSCDB comparison. More than 95 % of all distances between plots with identical PLOTIDs are less than 1 km, both for the BioSoil$^+$-PCCDB and PCCDB-BioSoil$^+$ comparison. For BioSoil$^+$-PCCDB comparison, distances are mainly (~94 %) below 2 km for all plots and most of them have identical PLOTIDs (Table 3.1.8). Conversely for the inverse PCCDB-BioSoil$^+$ comparison, most plots have distances above 2 km though only very few have identical PLOTIDs.

Table 3.1.8. Number and proportion (%) of Level I plots with nearest neighbour distance less or more than the 2 km threshold for all dataset comparisons

Comparison	n	All plots		Different PLOTIDs		Identical PLOTIDs	
		≤ 2 km	> 2 km	≤ 2 km	> 2 km	≤ 2 km	> 2 km
BioSoil$^+$ - FSCDB	4928	2741	2187	477	2085	2264	102
	(100%)	*(55.6%)*	*(44.4%)*	*(9.7%)*	*(42.3%)*	*(45.9%)*	*(2.1%)*
FSCDB - BioSoil$^+$	5289	2770	2519	514	2418	2256	101
	(100%)	*(52.4%)*	*(47.6%)*	*(9.7%)*	*(45.7%)*	*(42.7%)*	*(1.9%)*
BioSoil$^+$ - FSCDB =	3357	2733	624	477	524	2256	100
FSCDB - BioSoil$^+$ *	*(100%)*	*(81.4%)*	*(18.6%)*	*(14.2%)*	*(15.6%)*	*(67.2%)*	*(3.0%)*
BioSoil$^+$ - PCCDB	4928	4620	308	717	287	3903	21
	(100%)	*(93.8%)*	*(6.2%)*	*(14.6%)*	*(5.8%)*	*(79.2%)*	*(0.4%)*
PCCDB - BioSoil$^+$	11737	5129	6608	1171	6583	3958	25
	(100%)	*(43.7%)*	*(56.3%)*	*(10.0%)*	*(56.1%)*	*(33.7%)*	*(0.2%)*
FSCDB - PCCDB	5289	4155	1134	505	1039	3650	95
	(100%)	(78.6%)	(21.4%)	(9.6%)	(19.6%)	(69.0%)	(1.8%)
PCCDB – FSCDB	11737	4396	7341	744	7224	3652	117
	(100%)	(37.5%)	(62.5%)	(6.3%)	(61.6%)	(31.1%)	(1.0%)

* *indicates equidistance between plot-pairs both in BioSoil$^+$ - FSCDB and FSCDB - BioSoil$^+$ comparison*

For the comparison between FSCDB and PCCDB, 95 % of the interplot distances are comprised within 0 to 14.7 km for FSCDB-PCCDB and within 0 to 789 km for PCCDB - FSCDB. Plots with identical IDs have median distances of ~1 m and 95 % of all distances range from zero to 2.2 km for FSCDB-PCCDB and 0 - 3.2 km for PCCDB - FSCDB (Table 3.1.5). Less than 10 % of the plots with NNDs less than 2 km have different PLOTIDs and less than 2 % of plots with identical PLOTIDs exceed the 2 km threshold.

For Level I it may be concluded that for roughly half of all plots, NNDs are below 2 km, except for the BioSoil$^+$-PCCDB comparison. Distances larger than 2 km can go up to several hundredths of kms, especially when datasets with many plots (e.g. PCCDB) are compared with datasets with less than half of these plots (e.g. BioSoil$^+$ or FSCDB). The inverse comparison leads to maximum distances up to 50 km. If only plots with identical PLOTIDs are considered, most (i.e. 95 %) of these plots have NNDs between 0 and 3.7 km and about 90 % of them have NNDs between 0 – 2 km. Without considering PLOTIDs and assuming that plots are identical when their distance is less than the 2 km threshold leads to about 20 % more selected plots than when taking also identical PLOTIDs into account.

When using an equidistance criterion for the plot-pairs (i.e. the NND of BioSoil$^+$-FSCDB comparison should be equal to the NND of FSCDB-BioSoil$^+$ comparison, see 'BioSoil$^+$ - FSCDB =FSCDB - BioSoil$^+$' in Table 3.1.8), the number of resulting plots is strongly reduced, mainly by eliminating plots exceeding the 2 km threshold. However, the number of plots with different PLOTIDs remains as high as in the BioSoil$^+$ - FSCDB or FSCDB - BioSoil$^+$ comparisons.

Again, there is a serious risk of making type I errors (assuming that plots are identical when in fact they are not). Therefore, it is reasonable to use the available PLOTID information to complement the 2 km threshold to avoid mistakes. Based on the NND computations, this threshold seems justified since less than 3 % of the NNDs between all plots with identical PLOTIDs exceed this 2 km, for all Level I comparisons.

Using the equidistance criterion for nearest neighbouring plots, reduces substantially the number of plots that are further away, but does not solve uncertainty for plot-pairs with different PLOTIDs and a NND less than 2 km.

Level II

For Level II, the same analysis was performed for the three datasets (Table 3.1.9). Since only a small subset (n = 127) of Level II plots were assessed in BioSoil$^+$, nearest neighbour distances (NNDs) with the other datasets may be very high (up to 683 km). When considering identical PLOTIDs half of the NNDs are between 0 and 6 m. When comparing BioSoil$^+$ with FSCDB and PCCDB, 95 % of all NNDs are between 0 and 2369 m. However, when computing the inverse relation, NNDs range from 0 to 47.6 km. It is also clear that when considering identical PLOTIDs, the FSCDB-PCCDB and PCCDB-FSCDB comparisons reveal very short distances (95 % of the NNDs less than 60 m), which was also derived from Figure 3.1.6.

From Table 3.1.10 it may concluded that about 7 to 27 % more common plots are selected based on the 2 km threshold solely than when using also the identical-PLOTID-criterium. Just as for Level I, the overall proportion of plots with identical PLOTIDs having NNDs greater than 2 km is negligible (0.6 to 3.2 %). However, the amount of plots with different PLOTIDs having NNDs within the 2 km threshold is substantial, even up to 18 % for the FSCDB-PCCDB comparison. Hence, it is recommended to consider PLOTID information also to evaluate if plots are overlapping or not.

Table 3.1.9. Bootstrapped percentiles of nearest neighbour distance (m) between Level II plots of the databases BioSoil$^+$, FSCDB and PCCDB. Ninety five percent of the interplot distances are comprised within the $P_{2.5}$ and $P_{97.5}$ distance interval.

Description	BioSoil$^+$ - FSCDB				FSCDB - BioSoil$^+$			
	n	$P_{2.5}$	Median	$P_{97.5}$	n	$P_{2.5}$	Median	$P_{97.5}$
All plots	127	0	26	560526	891	0	93878	438833
Different PLOTIDs	32	20	19037	931213	789	3589	103142	447514
Identical PLOTIDs	95	0	0	1743	102	0	1	47619
		BioSoil$^+$ - PCCDB				PCCDB - BioSoil$^+$		
All plots	127	0	5	12310	819	2	97610	584698
Different PLOTIDs	12	9	1533	56485	699	4882	112989	683579
Identical PLOTIDs	115	0	4	2369	120	0	6	36310
		FSCDB - PCCDB				PCCDB – FSCDB		
All plots	891	0	4	34660	819	0	4	295400
Different PLOTIDs	292	1	147	42451	249	1	13740	1051000
Identical PLOTIDs	599	0	3	44	570	0	3	60

Table 3.1.10. Number and proportion (%) of Level II plots with nearest neighbour distance less or more than the 2 km threshold for all dataset comparisons

Comparison	n	All plots		Different PLOTIDs		Identical PLOTIDs	
		≤ 2 km	> 2 km	≤ 2 km	> 2 km	≤ 2 km	> 2 km
BioSoil⁺ - FSCDB	127	104	23	12	20	92	3
	(100%)	*(81.9%)*	*(18.1%)*	*(9.5%)*	*(15.8%)*	*(72.4%)*	*(2.4%)*
FSCDB - BioSoil⁺	891	115	776	19	770	96	6
	(100%)	*(12.9%)*	*(87.1%)*	*(2.1%)*	*(86.4%)*	*(10.8%)*	*(0.7%)*
BioSoil⁺ - PCCDB	127	119	8	8	4	111	4
	(100%)	*(93.7%)*	*(6.3%)*	*(6.3%)*	*(3.15%)*	*(87.4%)*	*(3.2%)*
PCCDB - BioSoil⁺	819	130	689	16	683	114	6
	(100%)	*(15.9%)*	*(83.4%)*	*(2.0%)*	*(83.4%)*	*(13.9%)*	*(0.7%)*
FSCDB - PCCDB	891	756	135	162	130	594	5
	(100%)	*(84.9%)*	*(15.2%)*	*(18.2%)*	*(14.6%)*	*(66.7%)*	*(0.6%)*
PCCDB – FSCDB	819	675	144	110	139	565	5
	(100%)	*(82.4%)*	*(17.6%)*	*(13.4%)*	*(17.0%)*	*(69.0%)*	*(0.6%)*

3.1.3 Altitude

Information on plot elevation above mean sea Level (AMSL) is provided in different datasets in BioSoil⁺ and in one dataset in FSCDB (Table 3.1.5). In BioSoil⁺, elevation class in the PLS dataset refers to the elevation of the plot centre, whereas in the PRF dataset to the elevation of the soil profile. For most BioSoil⁺ plots (91 % for Level I and 99 % of Level II) elevation classes in PLS and PRF are identical. If not, respectively 6 and 0.5 % are situated in an adjacent elevation class.

Table 3.1.5. Elevation data in BioSoil⁺

Database	Dataset	Fieldname	Type	M/O	Description
BioSoil⁺	PLS	CODEELEV	Class	M	Elevation AMSL in 50 m classes from 1-51
BioSoil⁺	PRF	ELEV	Integer	O	Elevation in meters AMSL
BioSoil⁺	PRF	CODEELEV	Class	M	Elevation AMSL in 50 m classes from 1-51
FSCDB	PLOT	ALTID	Class	M	Elevation AMSL in 50 m classes from 1-51

Altitudinal information is quite complete, especially when provided according to elevation classes (Table 3.1.6). In BioSoil⁺, metric elevation levels are available for about 72 % of the plots.

Table 3.1.6. Number and completeness (% of total) of elevation data in BioSoil⁺ and FSCDB

		BioSoil⁺			FSCDB
		PLS class	PRF class	PRF integer	PLOT class
Level I	No of observations	4897	4819	3542	5289
	Completeness (%)	99.4	99.3	72.0	100
Level II	No of observations	127	137	100	891
	Completeness (%)	100	100	73.0	100

The distribution of all BioSoil⁺ and FSCDB plots according to elevation classes is shown in Figure 3.1.5. For BioSoil⁺ Level I, altitude levels range from elevation class 1 (≤ 50 m AMSL) to class 45 (2201 – 2250 m AMSL), while for Level I plots of the FSCDB the highest class is 44 (2151 – 2200 m AMSL). For Level II plots, highest class is 36 (1751 – 1800 m AMSL) for BioSoil⁺ and class 41 (2001 - 2050 m AMSL) for the FSCDB, but for both databases this represents only one Level II plot. Most forest plots are clearly situated in elevation class 3 (101 - 150 m AMSL) except for BioSoil⁺ Level II plots that are most abundant in class 2 (51 - 100 m AMSL).

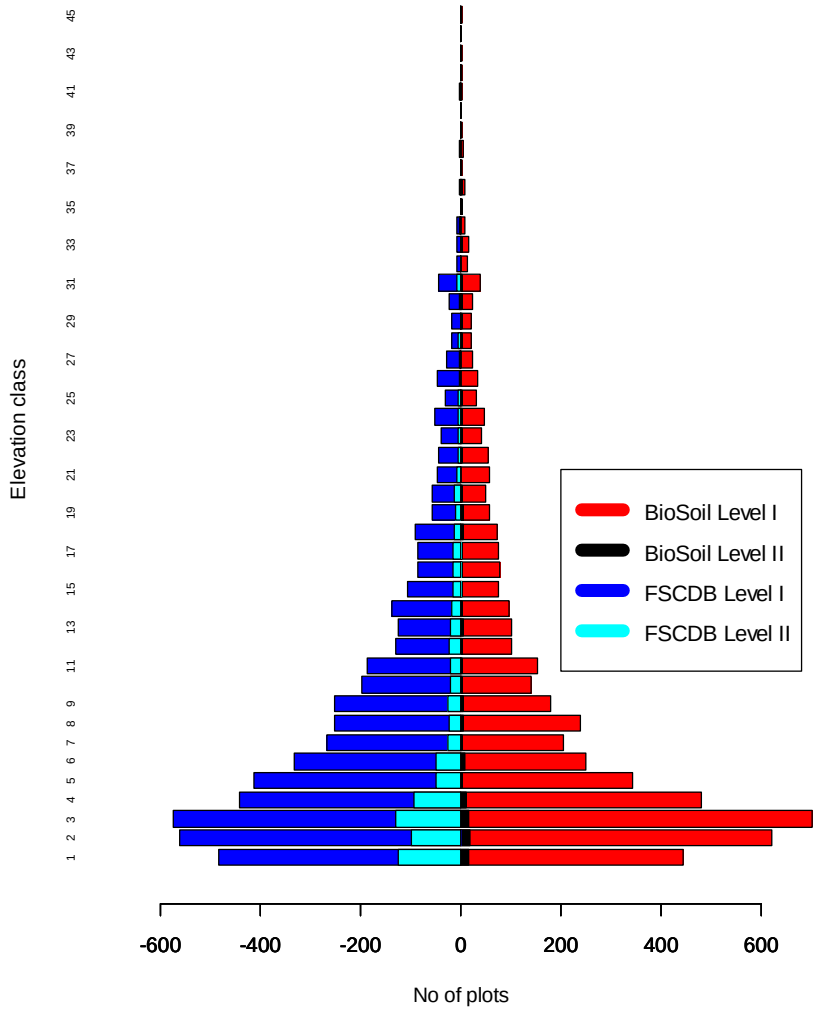


Figure 3.1.5. Altitudinal distribution of number of Level I and Level II plots from BioSoil$^+$ (right) and FSCDB (left) according to 50 m elevation classes

This shows that due to the limited number of Level II plots in BioSoil$^+$, some elevation classes are under- or over-represented. This is illustrated in the cumulative plot distribution of all datasets (Figure 3.1.6). The Level I altitudinal distribution of both BioSoil$^+$ and FSCDB is very similar. A two-sample Kolmogorov-Smirnov test reveals that these distributions are not significantly different from each other ($p = 0.65$). The distribution of the Level II plots of the FSCDB database resembles the Level I distribution, but the number of plots in elevation classes less than 10 (451 - 500 m AMSL) are slightly overrepresented. In contrast, Level II plots in BioSoil$^+$ are substantially underrepresented from elevation class 4 up to 30 (~150 to 1500 m AMSL). However, when performing KS goodness-of-fit tests, both Level II plot distributions are not significantly different (at $p = 0.05$) from their respective Level I distribution (p values are 0.08 for BioSoil$^+$ and 0.95 for FSCDB respectively).

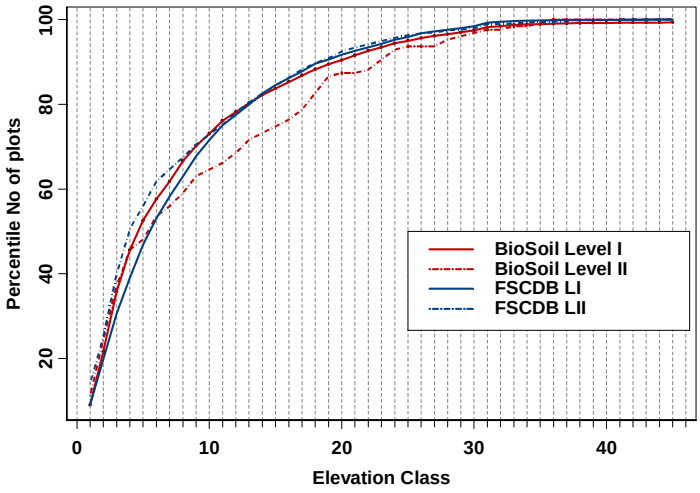


Figure 3.1.6: Cumulative distribution of elevation classes for level I and level II plots of BioSoil⁺ and FSCDB

Note however, that the distribution of the Level II BioSoil⁺ plots is close to the critical Level for deviant distributions and its altitudinal representativeness can be questioned. It is apparent from both Figures 3.1.5 and 3.1.6 that the number of plots is strongly reduced from class 10 (> 500 m AMSL) onwards. Less than 10 Level I plots are found in each elevation class higher than class 33 (>1650 m). The cumulative distribution shows that about 50 % of the plots is below elevation class 5 (201 - 250 m AMSL) and 80 % of all plots below class 13 (601-650 m AMSL).

3.1.4 Temperature

Table 3.1.7 shows the general statistics of the minimum temperature of the coldest month (TMIN), maximum temperature of the warmest month (TMAX) and mean annual temperature (MAT) on the Level I and II plots. Figure 3.1.7 shows the distribution of the TMAX, TMIN, MAT and the Level I plots whereas Figure 3.1.8 shows it on the Level II plots.

Table 3.1.7. General statistics of the TMIN, TMAX and MAT on the BioSoil⁺ Level I and II plots

	Level I			Level II		
	TMIN (°C)	**TMAX (°C)**	**MAT (°C)**	**TMIN (°C)**	**TMAX (°C)**	**MAT (°C)**
Minimum	21.7	9.2	-2.7	-21.4	14.8	-2.3
P_{25}	-9.0	20.5	5.1	-10.2	19.9	3.9
Median	- 5.4	21.9	7.4	-4.5	21.4	7.6
Mean	-5.5	22.6	7.5	-5.7	22.1	7.2
P_{75}	-1.3	24.1	9.8	-1.0	23.2	9.6
Maximum	18	36.2	22.3	7.2	36.0	21.9
N° NAs	2	2	2	0	0	0

On the BioSoil⁺ Level I plots, the TMIN, TMAX and MAT and is missing on two plots in the UK. TMIN ranges from -21.7 °C on one plot in Finland (15_3845) to 18 °C on the Canary Islands. The range of the TMAX is narrower than the TMIN. TMAX ranges from 9.2 °C on an Italian plot in the Alps (5_47) to 36.2 °C on a Spanish plot (11_1684). The MAT ranges from -2.7 °C on two Finnish plots (15_3881 and 15_3938) to 22.3 °C on the Canary Islands. The mean MAT is 7.5 °C and the median is 7.4 °C.

On BioSoil⁺ Level II the MAT, TMAX and TMIN is available for all 127 plots. TMIN ranges from -21.4 °C on a plot in Northern Finland (15_3) to 7.2 °C on a Spanish plot (11_10). The TMAX ranges from 14.8 °C on a Finnish plot (15_1) to 36.0 °C in Cyprus (plots 66_101 and 66_103). This range is again narrower than the TMIN. The MAT ranges from -2.3 °C in Finland (15_3) to 21.9 °C in Cyprus (plots 66_101 and 66_103).

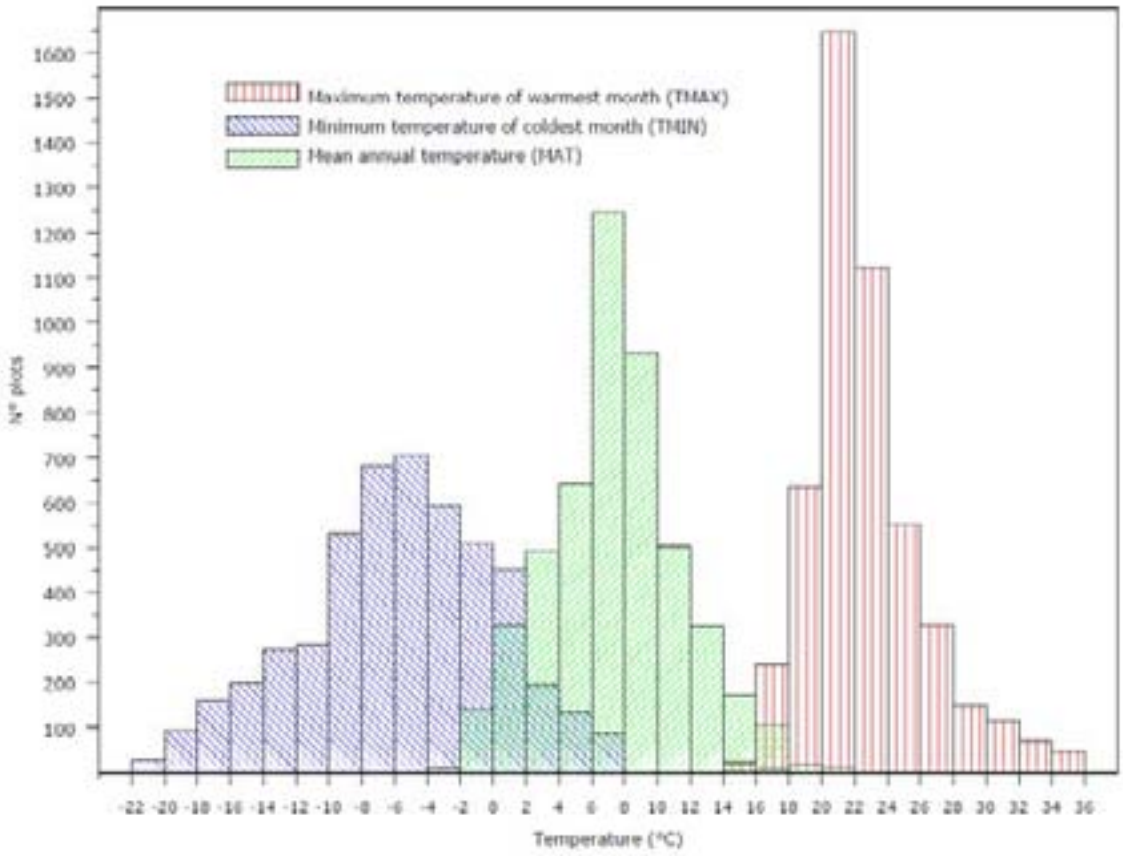


Figure 3.1.7. Distribution of the mean minimum, annual and maximum temperature on the Level I BioSoil plots

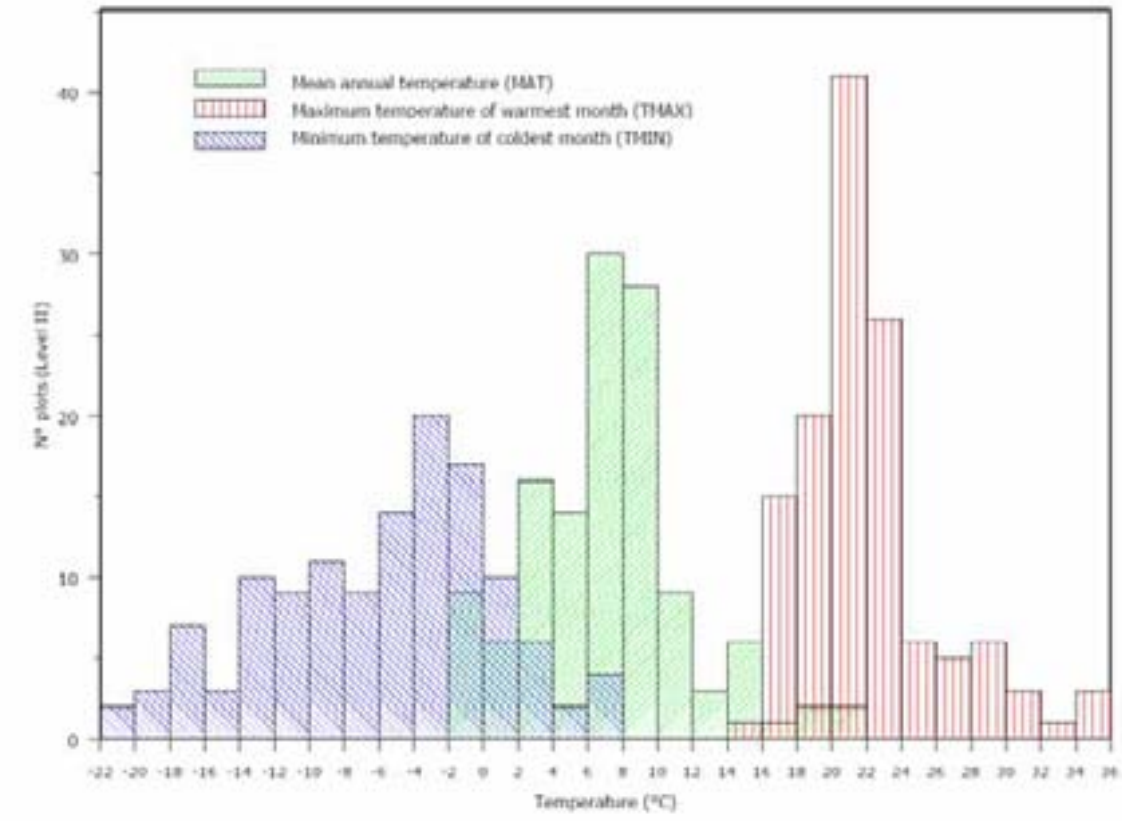
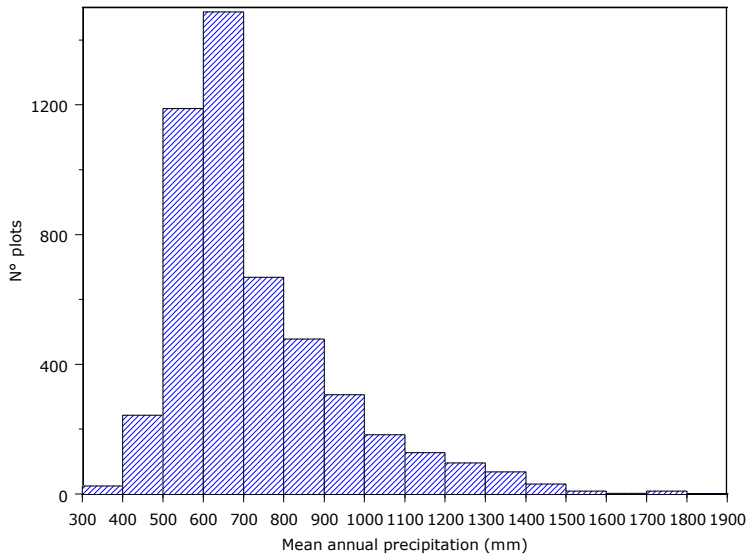


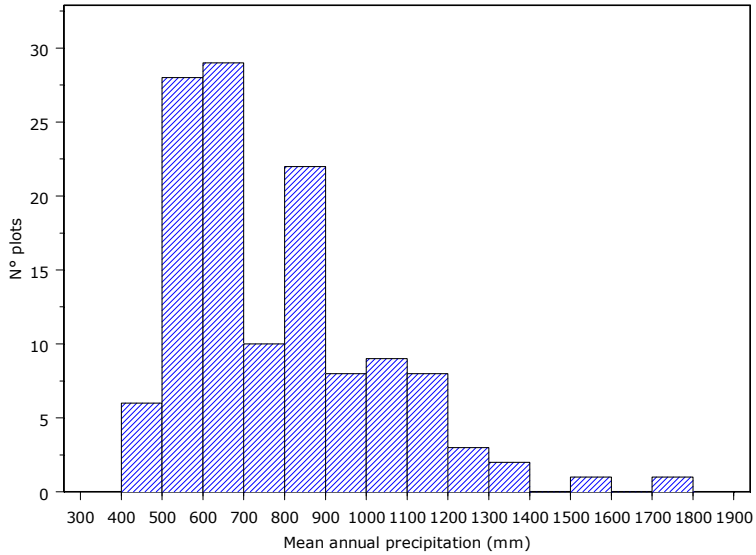
Figure 3.1.8. Distribution of the mean minimum, annual and maximum temperature on the Level II BioSoil plots

3.1.5 Mean annual precipitation



The mean annual precipitation on the BioSoil+ Level I plots ranges from 306 mm on one plot in the south of Spain to 1953 mm in western Scotland. The mean of all plots is 726 mm and the median 657 mm. Fifty percent of the plots receive between 586 and 816 mm annual precipitation. The distribution is left skewed.

Figure 3.1.9. Distribution of the mean annual precipitation on the 4928 Level I plots



The mean annual precipitation on the BioSoil+ Level II plots ranges from 405 mm on one plot in the north of Finland to 1773 mm in western Scotland. The mean of all plots is 778 mm and the median 706 mm. Fifty percent of the plots receive between 596 and 905 mm annual precipitation. On Level II there are insufficient observations to see a clear distribution pattern.

Figure 3.1.10. Distribution of the mean annual precipitation on the 127 Level II plots

3.1.6 Biogeographical regions and Ecoregions

Information on the Biogeographical regions could be derived for all BioSoil+ Level I and Level II plots and is shown in Figure 3.1.11. About 32 % of the Level I and 25 % of the Level II plots belong to the Boreal region and 29 % of the Level I and 22 % of the Level II belong to the Continental region. On Level I the third best represented region is the Mediterranean with 15.6 % of the plots, though on Level II it is the Atlantic region with 20.5 % of the plots followed by the Mediterranean region with 15.7 %. Fourth in row on Level I is the Atlantic region with 11.5 %. Fifth in row is the Alpine region with 9.4% of the Level I plots and 15.7 % of the Level II plots. The Pannonian region is represented by 105 plots (2.1 %) on Level I and only one Level II plot (0.8

%). The 13 plots belonging to the Macaronesian region are the 13 Level I plots on the Canary Islands.

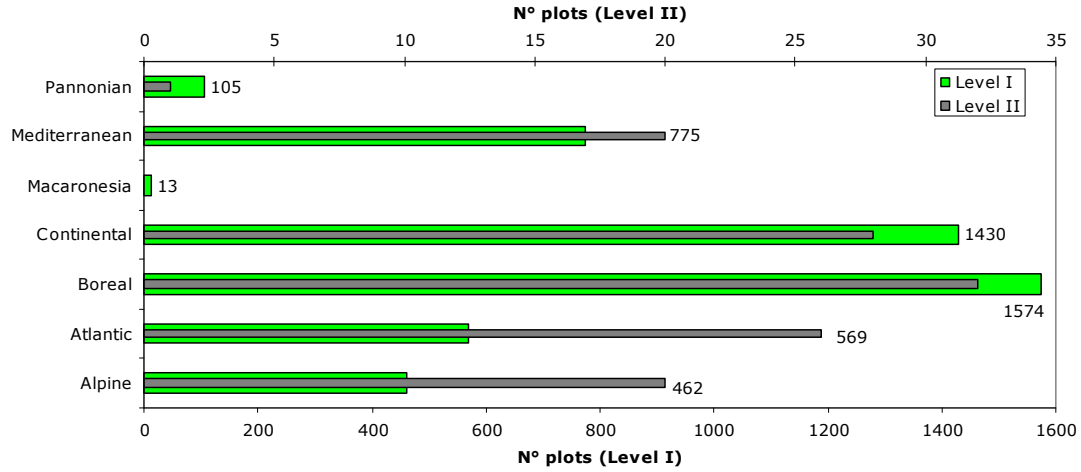


Figure 3.1.11. Distribution of the BioSoil+ Level I and Level II plots across the Biogeographical regions

Figure 3.1.12 shows the distribution according to the Ecoregions. Fifty percent of the BioSoil+ Level I plots are located in three Ecoregions: the Fenno-Scandinavian or Fennoscandian shield (19 %), the Central plains (18 %) and the Ibero-Macaronesian region (14 %). On Level II, the Fenno-Scandinavian shield seems to be over-represented by the 32 Finnish Level II plots. Also strongly represented on the BioSoil+ Level II plots are the Western plains, covering large parts of France, Belgium and a part of west Germany.

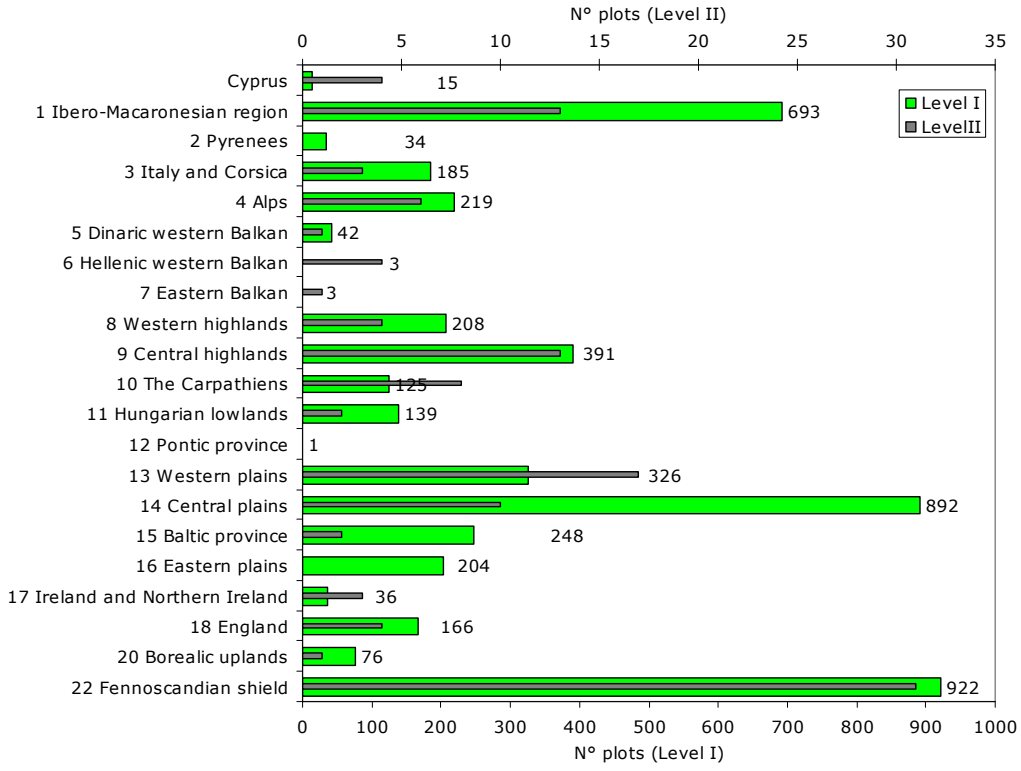


Figure 3.1.12. Distribution of the BioSoil+ Level I and Level II plots across the Ecoregions

3.1.7 Water availability for tree growth

The parameter 'water availability' is an estimate for the availability of water for tree growth. Three very rough classes were distinguished: insufficient, sufficient and excessive. On most plots (~ 80 %) there is sufficient water available (Figure 3.1.13). The information is missing on a number of Latvian and on the Danish Level I plots. Insufficient water availability is met on a number of Mediterranean, Boreal and Continental plots. The percentage of Level I plots where the water availability is excessive is limited to 4.7 %. On the Level II plots, the distribution is very similar.

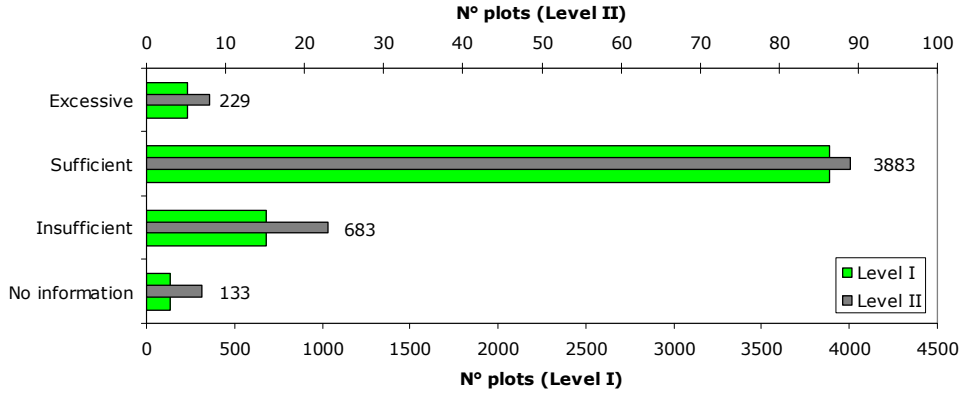


Figure 3.1.13. Water availability on the BioSoil$^+$ Level I and Level II plots

3.1.8 Tree species and tree species group

The main tree species was not asked in the BioSoil Soil module as the Biodiversity module asked for the tree species of all trees in measured subplots. As FSCC did not have access to the full BioSoil biodiversity database, the main tree species was based on the PCCDB for those plots that were in common. When the BioSoil plot did not overlap with the PCCDB, the tree species information was either obtained from the biodiversity component of the BioSoil project (Hessen, Niedersachsen, Saarland) or by asking the NFC for additional information (Poland, Finland) or both (Great Britain).

On Level I the most dominant main tree species is Pinus sylvestris (29.5 % of the plots) followed by Picea abies (21.0 % of the plots). So more than 50 % of the BioSoil$^+$ Level I plots are dominated by only two coniferous tree species. The third most important tree species is Fagus sylvatica (7 %). Figure 3.1.14 shows the distribution of the main tree species on both the Level I and Level II plots for those tree species that are dominant on more than 1 % of the plots.

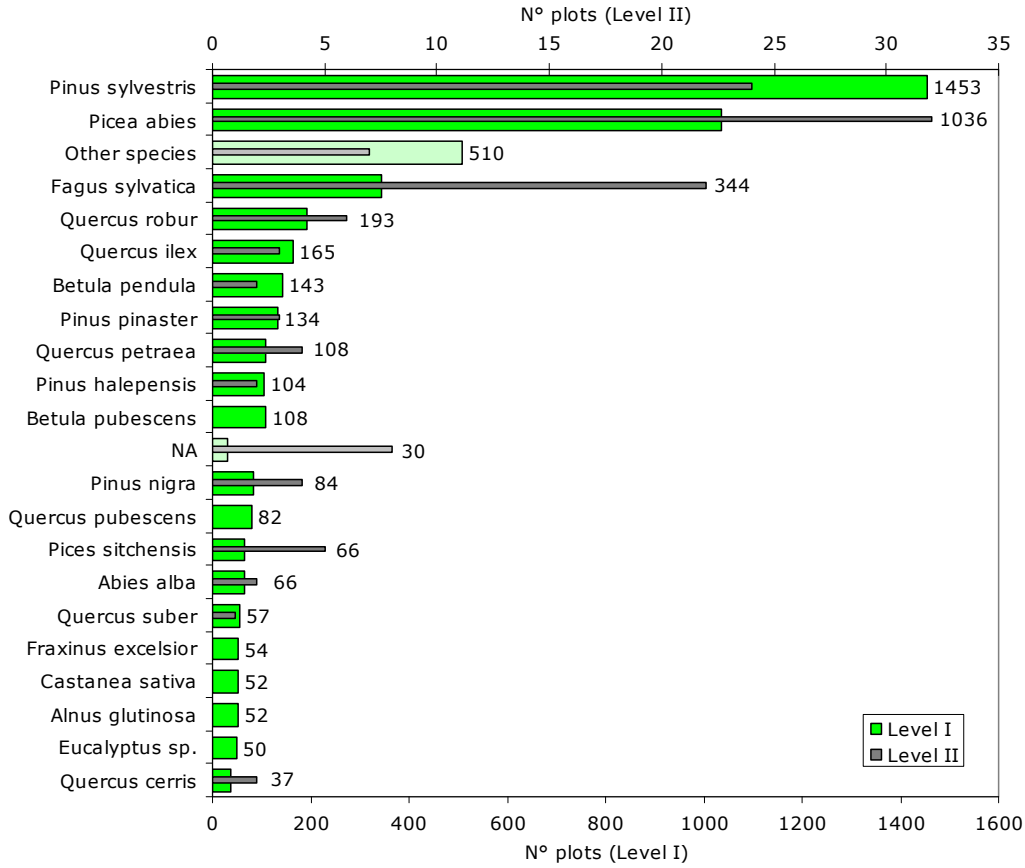


Figure 3.1.14. Distribution of the main tree species on the plots included in the BioSoil+ inventory

The distribution of the main tree species on Level II is different from the distribution on the Level I plots. While on Level I Pinus sylvestris is the most dominant main tree species, it is Picea abies on the BioSoil+ subset of the Level II (N° plots = 32 or 25.2 %). While Betula pubescens is the main tree species on more than 2 % of the Level I plots, it is absent from the subset of the Level II plots. Also Quercus pubescens is not present in the subset of the Level II plots. On the other hand, Quercus cerris is on only 0.8 % of the Level I plots the dominant tree species, while it is the main tree species on 2 Level II plots (1.6 %).

Concerning, the tree species group of the main tree species on Level I, the conifers are much more represented in the BioSoil+ database (63.8 %) compared to the broadleaves (35.6 %). These proportion on Level II are very similar (Figure 3.1.15).

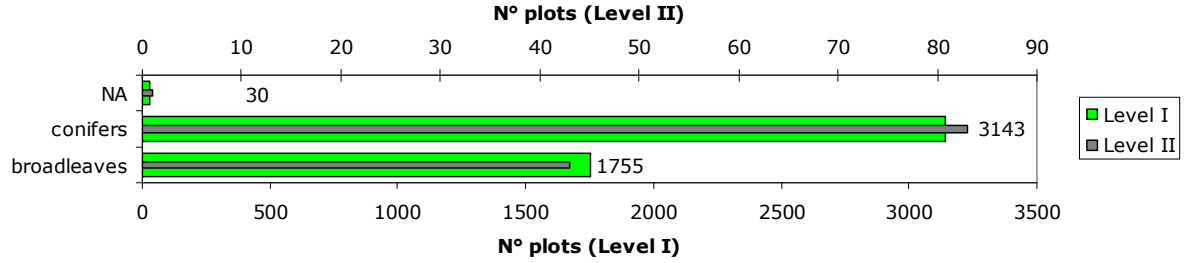


Figure 3.1.15. Distribution of the tree species groups on the BioSoil+ Level I and Level II plots

3.1.9 Stand type: broadleaved, coniferous, mixed

The countries reported whether the forest stand was either 'broadleaved', 'coniferous' or 'mixed' following the codes of the Corine land cover database. As this information was missing on 29 % of the plots, the data were complemented based on the Corine land cover database and if not available there, they were based on the main tree species code in the PCCDB. Note that the latter database does not contain any information on 'mixed' stands. About 36.1 % of the plots are coniferous, 34.1 % is mixed and 29.4 % is broadleaved (Figure 3.1.16). The number of mixed stands seems to be either underrepresented on the subset of the Level II plots or overestimated on the Level I plots (Figure 3.1.17).

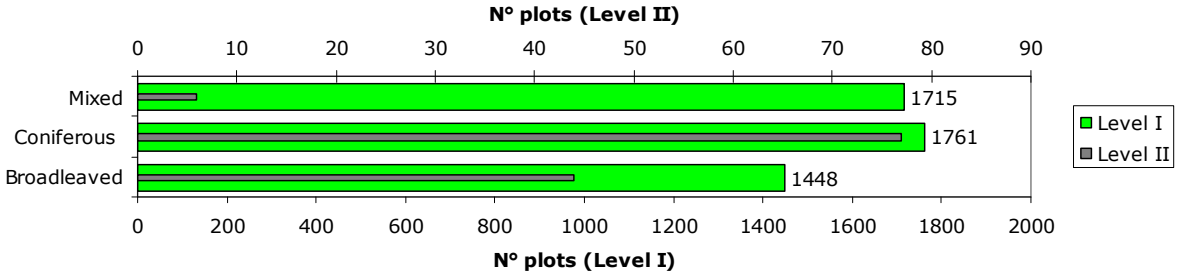


Figure 3.1.16. Distribution of the stand type (broadleaved, coniferous, mixed) on the BioSoil+ Level I and Level II plots

The distribution by country is given in Figure 3.1.17. Note that in Sweden, which is the country with the maximum amount of plots in the BioSoil+ database, all plots were reported as being mixed. This highly influences the distribution at the European level.

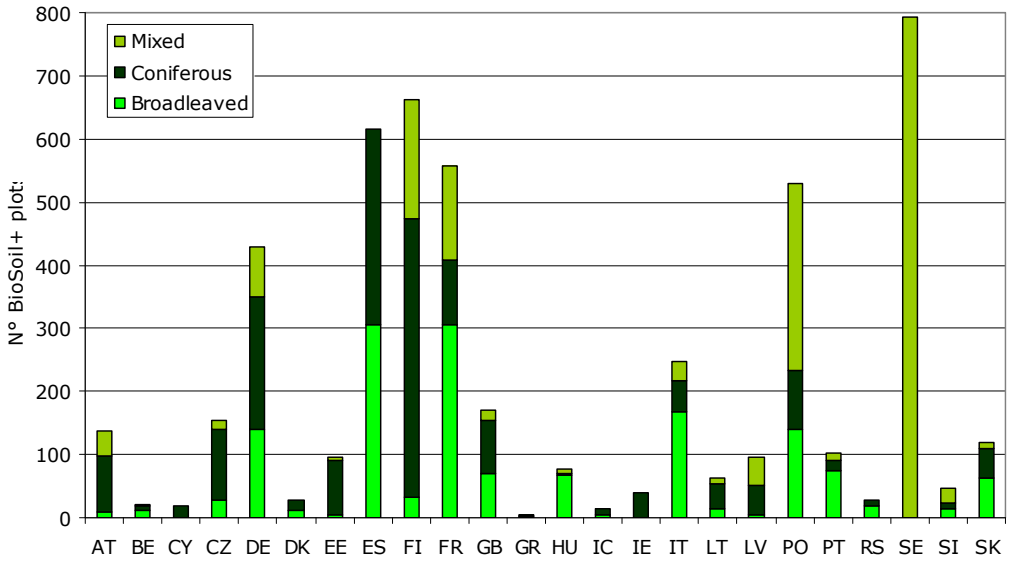


Figure 3.1.17. Number of broadleaved, coniferous and mixed stands by country included in the BioSoil+ inventory (Level I and II combined)

3.1.10 European Forest type Classification

European Forest types were only available for 1931 Level I (39.2 %) and 104 Level II (81.9 %) plots after overlay with the PCC databases. Figure 3.1.18 shows a picture which is clearly not representative for the whole dataset as the Swedish and Finnish Level I plots were not included in the classification which largely belong to the Boreal forest types.

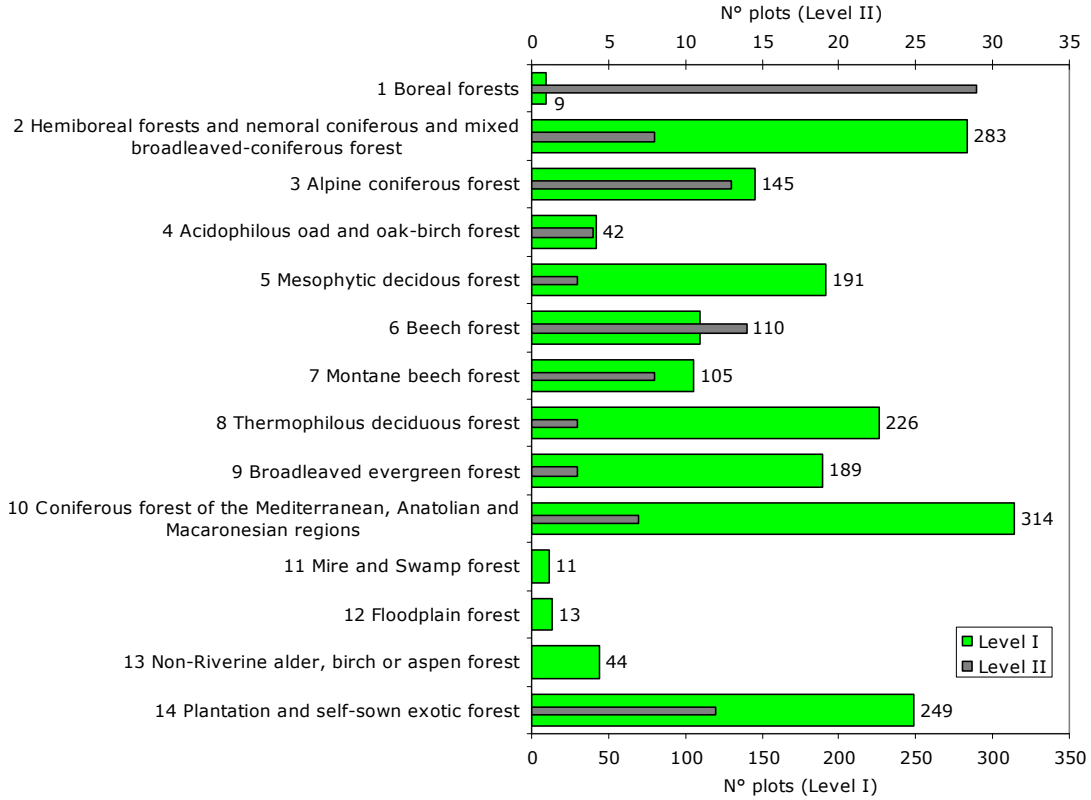


Figure 3.1.18. Distribution of the European forest types on 1931 Level I and 104 II BioSoil⁺ plots

3.1.11 Corine land cover

At the highest level of the Corine land cover classification system, 82.7 % of the BioSoil⁺ Level I plots and 89.9 % of the Level II plots fall within the category of 'Forests and semi natural areas' though a relatively large portion (11 % on Level I and 5.5 % on Level II) seems to fall within agricultural areas. The Corine land cover information is not available on Level I for Great Britain (166 plots) and is lacking on some plots in Spain (8), France (2), Portugal (1) and Hungary (1). On Level II it is lacking on 4 Sitka spruce stands in Great Britain (Figure 3.1.19).

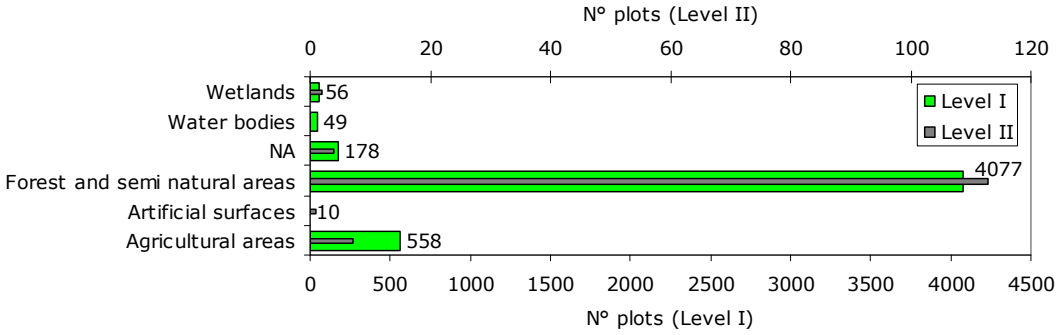


Figure 3.1.19. The distribution of the Corine land cover (first label) on the BioSoil⁺ Level I and II plots

While forests on wetlands are possible, the other 'wrong' classifications' can be due to scale differences. Corine works on a grid of 100 m resolution while a typical circular Level I plot has for example a radius of 25 m. Additionally there might be small deviations on the plot coordinates. Table 3.1.8 provides an overview of the distribution of the plots on the more detailed level of the Corine land cover classification. Concerning the plots classified within agricultural areas, a number

of forests can possibly resemble agricultural areas studied by remote sensing from space such as olive groves, agricultural land with significant areas of natural vegetation, fruit tree plantation.

Table 3.1.8. Distribution of the BioSoil+ Level I and II plots according to the Corine land cover database

CODE	LABEL1	LABEL2	LABEL3	N° plots	
				Level I	Level II
111	Artificial surfaces	Urban fabric	Discontinuous urban fabric	8	1
133		Mine, dump and construction sites	Construction sites	1	
142		Artificial, non-agricultural vegetated areas	Sport and leisure facilities	1	
211	Agricultural areas	Arable land	Non-irrigated arable land	177	3
222		Permanent crops	Fruit trees and berry plantations	3	
223			Olive groves	6	
231		Pastures	Pastures	71	1
241		Heterogeneous agricultural areas	Annual crops associated with permanent crops	4	
242			Complex cultivation patterns	66	
243			Land principally occupied by agriculture, with significant areas of natural vegetation	167	2
244			Agro-forestry areas	64	1
311	Forest and semi	Forests	Broad-leaved forest	893	28
312	natural areas		Coniferous forest	1954	68
313			Mixed forest	751	12
321		Scrub and/or herbaceous vegetation	Natural grasslands	22	
322		associations	Moors and heath land	17	1
323			Sclerophyllous vegetation	63	
324			Transitional woodland-shrub	368	4
332		Open spaces with little or no	Bare rocks	3	
333		vegetation	Sparsely vegetated areas	4	
334			Burnt areas	2	
411	Wetlands	Inland wetlands	Inland marshes	7	
412			Peat bogs	49	2
511	Water bodies	Inland waters	Water courses	4	
512			Water bodies	44	
523		Marine waters	Sea and ocean	1	
	No information			178	4
Total				**4928**	**127**

3.1.12 Natura 2000 areas

On Level I, 945 plots of the 4928 (19 %) fall within the premises of a Natura 2000 site (Figure 3.1.20). The 945 plots are situated in 714 different Natura 2000 areas. On Level II, 56 plots of the 127 (44 %) fall within a Natura 2000 area. They are located in 51 different Natura 2000 areas. Most of these Natura 2000 sites are combined Birds and Habitats Directive sites or Habitats Directive sites.

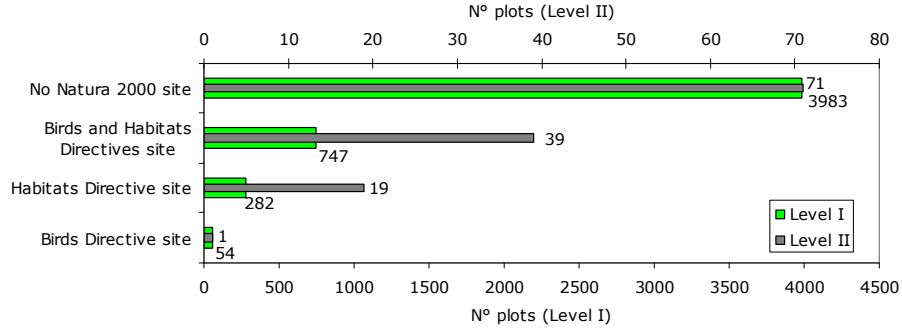


Figure 3.1.20. The distribution of Natura 2000 sites on the BioSoil+ Level I and II plots

3.2 Soil profile description

3.2.1 Soil parent material

Map 1 in Annex III shows the geographical distribution of the reported parent material classes on the BioSoil^{+} Level I and II plots and Figure 3.2.1 provides the frequency of the report parent material up to the level of the parent material group. On 519 of the 5061 BioSoil profiles (~10 %) the parent material was not reported and could not be retrieved based on the FSCDB (see chapter 2.6 on the data availability). In BioSoil it was only mandatory to report the parent material class. When no information on the group was provided, the profile was classified in 'no further specifications'.

The class of the unconsolidated glacial deposits and glacial drift is by far the most important parent material class (24 % of the profiles). The extent of this parent material corresponds largely with the extent of the ice cap(s) during the last ice-age and in the Alps. The second and third largest group of forest soils are formed in unconsolidated deposits (alluvium, weathering residuum and slope deposits ~ 15 %) and on igneous rocks (13 %). Note that most of the acid to intermediate Plutonic rocks have been described in Sweden which is indeed the dominant geological formation. However, the parent materials in which the soils are formed are, like in Finland, unconsolidated glacial deposits and glacial drifts. This shows that one should be careful in the interpretation of this classification as it seems that the original geological formation, which is shown on geological maps, and the (loose) parent material in which the soil horizons have developed, were in some countries wrongly considered as one and the same class.

The fourth group are the metamorphic rocks with 12 % abundance. These are any rocks formed from pre-existing rocks by solid state crystallisation driven by changes in temperature and pressure and by chemical action of fluids (Hamblin and Christiansen, 1998). While contact metamorphism is due to increased temperatures around igneous intrusions, regional metamorphism occurs over large areas due to tectonic processes. The 'weakly' metamorphic rocks comprise for example slate which is generally produced by a low-grade metamorphism due to pressure changes in shale or mudstone. Many of the plots with metamorphic rocks are found in the mountainous regions of Europe (Map 1 in Annex III).

The fifth group is formed in consolidated-clastic-sedimentary rock (10 %). These are rocks formed from fragments of other rocks. The sixth group are other sedimentary rocks (9 %) which are chemically precipitated, evaporated, or organogenic or biogenic in origin where calcareous rocks are dominant. So the sedimentary rocks make up 19 % of the parent material. A seventh group are the eolian deposits (4.8 %) where most countries specified the distinction between loess and eolian sand. An eighth group is formed in organic materials (2.8 %) which is dominantly peat. Forests soils of the BioSoil plots are rarely developed in anthropogenic deposits.

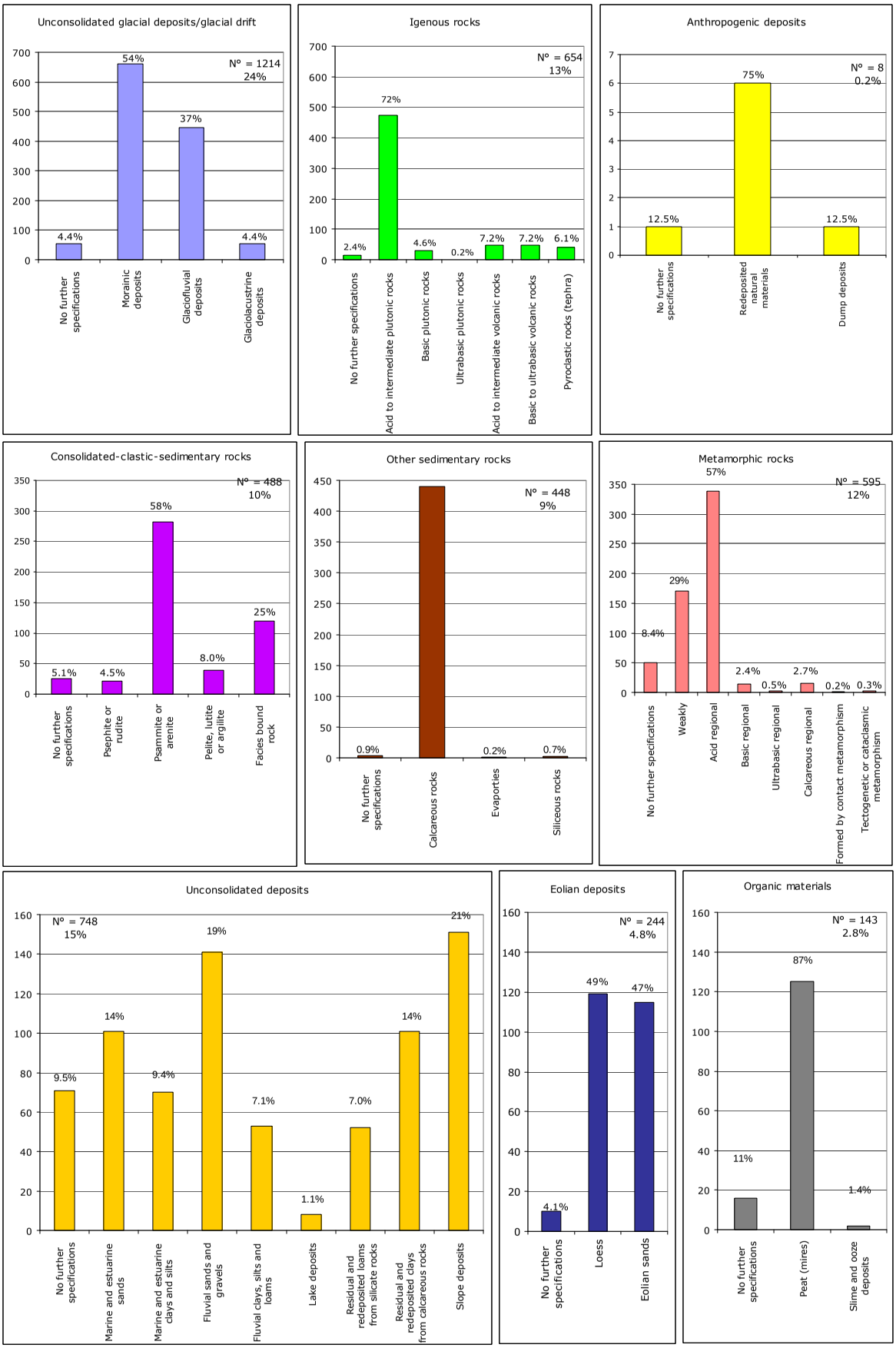


Figure 3.2.1. Frequency of the parent material classes and groups of the BioSoil+ soil profiles

3.2.2 Humus forms

Figure 3.2.2 shows the distribution of the humus forms by biogeographic region. About 85 % of the plots have terrestrial humus forms (Mull, Moder, Mor, Amphi) and 8.4 % have a semiterrestrial humus form (Anmoor, Histomull, Histomoder, Histomor or Histoamphi) as a consequence of water saturation during more than a few days per year. Mor is the dominant humus form, followed by Moder and Mull. Map 2 in Annex III shows the geographical distribution of the humus forms across Europe.

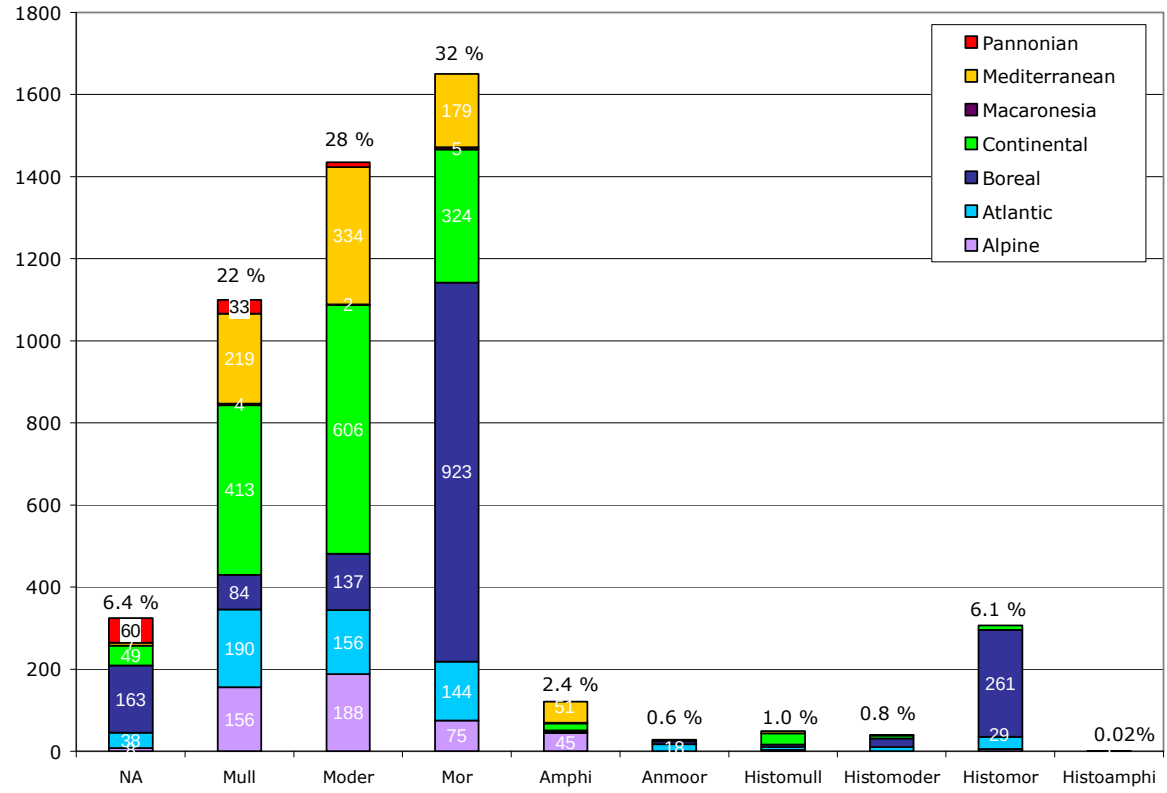


Figure 3.2.2. Distribution of the humus forms on the BioSoil Level I and Level II plots across the biogeographic regions

The Boreal region is dominated by Mor and Histomor. In the Mediterranean and Continental region the Moder forms are the dominant humus type. In the Atlantic region, there are no big differences in the occurrence of the three main terrestrial humus forms. The Amphi humus form is a typical humus form of the Alps and the Mediterranean. Macaronesia is represented by only 13 plots on the Canary Islands which is insufficient to fully represent this region. The semiterrestrial humus forms are also mainly encountered in the Boreal region. The Histoamphi form was only described on one plot in the Continental region.

3.2.3 Soil classification

All soil profiles were classified according to the World Reference Base for Soil Resources (WRB). Data were validated against the WRB 2006, update 2007 (IUSS Working Group WRB 2007). The WRB is a two tier system: on the first level there are Reference Soil Groups (RSGs), on the second level qualifiers. Within each level there is a fixed priority ranking. In this overview we will first study the distribution of the RSGs, secondly we will look at the most important qualifiers of the most frequently met RSGs.

3.2.3.1 The Reference Soil Groups (RSGs)

Of the 5061 records in the profile description dataset of the BioSoil$^+$ database, the WRB Reference Soil Group is available for 4876 profiles on both the Level I plots (4752 profiles) and Level II plots (124 profiles). Of the 32 major RSGs described at world scale, 26 have been described on the BioSoil$^+$ plots (Table 3.2.1 and Map 3 in Annex III).

Table 3.2.1. The distribution of the major WRB Reference Soil Groups on BioSoil$^+$ plots

Reference Soil Group	N° Profiles	%	Reference Soil Group	N° Profiles	%
Cambisols (CM)	1116	22.9	**Fluvisols (FL)**	31	0.64
Regosols (RG)	757	15.5	**Planosols (PL)**	30	0.62
Podzols (PZ)	685	14.1	**Lixisols (LX)**	29	0.59
Arenosols (AR)	563	11.7	**Albeluvisols (AB)**	28	0.57
Leptosols (LP)	353	7.24	**Andosols (AN)**	23	0.47
Luvisols (LV)	289	5.93	**Kastanozems (KS)**	23	0.47
Histosols (HS)	252	5.17	**Chernozems (CH)**	16	0.33
Gleysols (GL)	166	3.40	**Anthrosols (AT)**	14	0.29
Umbrisols (UM)	164	3.36	**Acrisols (AC)**	4	0.08
Stagnosols (ST)	140	2.87	**Vertisols (VR)**	4	0.08
Phaeozems (PH)	95	1.95	**Plinthosols (PT)**	1	0.04
Alisols (AL)	57	1.17	**Gypsisols (GY)**	1	0.02
Calcisols (CL)	34	0.70	**Technosols (TC)**	1	0.02

The dominant Reference Soil Groups on the BioSoil$^+$ plots are the Cambisols, followed by the Regosols and the Podzols. Together with the Arenosols, Leptosols, Luvisols, Histosols, Gleysols, Umbrisols, Stagnosols, Phaeozems and Alisols they make up 95 % of the profiles.

Cambisols (CM) are geographically widely spread across Europe. They are described in all countries participating in BioSoil. It is indeed the dominant RSG in temperate regions (ISSS Working Group RB 1998). They occur in areas with a humid climate mainly on younger landscapes where the processes of soil formation have had only a limited time to become effective. Consequently, many Cambisols occur on sandy outwash and loamy till deposits of Pleistocene age. They also occur on sandstones, shales and limestones in hilly and mountainous country. Cambisols are inherently fertile soils. About 26 % of the Cambisols in the database are situated in France. Other countries with a high occurrence of Cambisols are Germany, Spain and Italy, but they are also often found in the Boreal region.

The **Regosols** (RG) underlie one sixth of the BioSoil$^+$ plots. Approximately 70 % of these Regosols are located on the Scandinavian Peninsula. Regosols are typical soils formed in unconsolidated deposits with more than 100 cm in thickness. The largest extent of these weakly developed soils occur indeed in polar and boreal zones (ISSS Working Group RB 1998).

The **Podzols** (PZ) cover 14.1 % of the BioSoil$^+$ plots in Europe. These strongly acid soils contain an accumulation of organic matter, iron and aluminium within 200 cm of the soil surface. About 64 % of these Podzols are located on the Fenno-Scandinavian Peninsula.

Arenosols (AR) make up 11.5 % of the profiles. These are soils with a texture coarser than sandy loam to a depth of at least 100 cm from the mineral surface and having less than 35 % of rock fragments. They occur on deep eolian, marine, lacustrine and alluvial sands (ISSS Working Group RB 1998) mainly in the Continental and Boreal region. Other RSGs conditioned by the parent

material are **Andosols** (AN) (volcanic soils) and **Vertisols** (VR). Both are poorly represented in the BioSoil$^+$ database. Together they occur on less than 0.5 % of the plots.

Leptosols (LP) cover 7.2 % of the BioSoil plots. Leptosols are often found in mountainous areas. One third of the Leptosols on the BioSoil plots are found in Spain and hence in Mediterranean region. On the BioSoil$^+$ Level II no Leptosols have been described.

Luvisols (LV, 5.9 %) have been described in most countries of Western, Central and Southern Europe but not in Sweden, Finland, Ireland and Flanders. Together with other soils characterised by the presence of an Argic horizon (**Albeluvisols, Alisols, Lixisols and Acrisols**) they make up 8.4 % of the soil profiles in the BioSoil$^+$ database.

Histosols (HS) are described on 5.2 % of the BioSoil plots. The majority is situated in the Boreal region (Finland, Sweden, Estonia, Latvia, Lithuania) but HS are also found in the Continental region (Poland) and the Atlantic region (northern Germany, UK and Ireland) and occasionally in the Alpine regions (Germany, Austria, Northern Italy, Slovenia).

Soils that are largely under influence of the hydrology in the profile are Gleysols and Stagnosols. The **Gleysols** cover 3.4 %. **Stagnosols**, another new reference soil group, cover 2.9 % of the plots and are mainly found in Germany, France, Czech Republic and Poland.

Together with the Cambisols, Regosols and Arenosols, the **Umbrisols** (UM) make up a group of relatively young soils with little or no profile development. Umbrisols comprise typically shallow dark mountainous soils. They cover 3.4 % of the BioSoil$^+$ plots and have mainly been described in Poland, France, Portugal, Sweden, Spain and Austria.

Soils typical for steppic regions (**Phaeozems, Chernozems and Kastanozems**) have been described on 2.7 % of the profiles. The profiles formerly typified by FAO (1988) as Greyzems are mainly accommodated by the Phaeozems.

Although **Calcisols** and **Gypsisols** are typical for semi-arid and arid climates, 34 CL and 1 GY have been described in the Mediterranean and Pannonian region.

In summary, 30 % of the BioSoil$^+$ profiles are conditioned by the topography and/or physiography of the terrain (FL, GL, ST, LP, RG) and 23 % by the limited time of soil formation (CM). About 21 % is conditioned by the (sub)humid temperate climate (LV, AB, PL, PZ). The Umbrisols (3.4 %) are conditioned by both, a limited time of soil development and by cool and humid climatic conditions. The dominant influence of the parent material is evident in 12.1 % of the profiles (AR, AN, VR). Organic soils have been identified on 5.2 % of the described profiles (HS). About 2.7 % of the profiles is conditioned by organic matter accumulation in Steppic climate and $CaCO_3$ chemistry (CH, KS, PH). Anthropogenic influence of soil profiles seems not important on the BioSoil$^+$ plots and is only determining 0.3 % of the profiles (AT, TC).

3.2.3.2 The qualifier level

Introduction

On the second level of classification, the WRB makes a distinction between 'typically associated qualifiers', 'intergrades' and 'other qualifiers'. 'Typically associated qualifiers' are assigned to particular RSGs. An example is *Rustic* (rs) in Podzols meaning that in the spodic horizon, the ratio of the percentage acid oxalate extractable Fe to the percentage of OC is ≥ 6 throughout.

An 'intergrade' qualifier refers to important diagnostic criteria of another RSG. *Gleyic* (gl) and *Stagnic* (st) are intergrades related to the influence of the water table and *Histic* (hs) and *Folic* (fo) are intergrades referring to the thick organic layer on top of the mineral soil. *Leptic* (le) is an intergrade qualifier to the RSG of the Leptosols. 'Typically associated qualifiers' and 'intergrade qualifiers' constitute the prefix qualifiers. *Haplic* closes the list of the prefix qualifiers indicating that neither 'typically associated' nor 'intergrade qualifiers' apply.

Also the 'other qualifiers' follow a fixed ranking system. A first group relates to diagnostic horizons, properties or materials (e.g. *Albic*, *Humic, Calcaric*). A second group refers to chemical characteristics (e.g. *Dystric, Eutric, Alumic*). A third group refers to physical characteristics. A fourth group is related to mineralogical characteristics (e.g. *Cutanic*). A fifth relates to surface characteristics (e.g. *Escalic, Colluvic*). A sixth to textural characteristics (e.g. *Clayic, Siltic, Arenic*), including coarse fragments (e.g. *Skeletic*). A seventh relates to colour (e.g. *Chromic*) and an eight group with the remaining qualifiers.

In the BioSoil project it was not mandatory to report the qualifiers. However, most countries did report at least one qualifier, which should have been the most important qualifier. It is the first applicable qualifier of the priority lists in IUSS Working Group WRB (2006, 2007).

After validation and correction, *Haplic* (ha) is the most frequently applied qualifier (Table 3.2.4). As *Haplic* means 'having a typical expression of certain features', where typical is used in the sense that there is no further or meaningful characterisation, this qualifier should only be used if none of the other listed prefix qualifiers apply (IUSS Working Group WRB 2006). It has widely been applied on Cambisols, Arenosols and Regosols but less on Podzols.

In many cases, the '*Haplic RSG'* is further specified by suffix qualifiers. The qualifiers *Dystric* (dy) together with *Hyperdystric* (hd) and *Epidystric* (ed) refer to the low base saturation status and has been described for 1001 profiles. This is 30 % more than qualifiers *Eutric* (eu), *Endoeutric* (ne), *Epieutric* (ee) and *Hypereutric* (he) that have been reported on 756 profiles indicating exactly the opposite, namely referring to high base saturation status.

The qualifiers *Skeletic* (sk) and Hyperskeletic (*hk*), referring to the stoniness of the forest soil profile, have been attributed to 723 profiles. The *Leptic* (le) qualifier (including *Epileptic* and *Endoleptic*) has been given to 470 profiles.

Table 3.2.2. Qualifiers and number of times (N°) that they have been reported for at least 1 % of the profiles

Qualifier	Code(s)	N°	Qualifier	Code(s)	N°
Haplic	ha	2070	**Ruptic**	rp	124
Dystric, Epidystric, Hyperdystric	dy+ed+hd	1001	**Histic**	hi	121
Eutric, Endoeutric, Epieutric, Hypereurtric	eu+ne+ee+he	756	**Rustic**	rs	116
Skeletic, Hyperskeletic	sk+hk	723	**Clayic**	ce	106
Humic	hu	616	**Brunic**	br	99
Albic	ab	567	**(Nudi)Lithic**	li+nt	83
Leptic, Epileptic, Endoleptic	le+el+nl	470	**Carbic**	cb	87
Siltic	sl	398	**Rendzic**	rz	78
Folic	fo	362	**Sodic**	so	77
Calcaric	ca	311	**Entic**	et	76
Gleyic, Endogleyic	gl+ng	277	**Hemic**	hm	73
Stagnic	st	225	**Calcic**	cc	71
Chromic	cr	209	**Cambic**	cm	71
Alumic	au	191	**Fibric**	fi	71
Cutanic	ct	153	**Umbric**	um	71
Drainic	dr	151	**Mollic**	mo	63
Arenic	ar	150	**Sapric**	sa	57

Albic is a very important qualifier for the Podzols. It can be found in Arenosols, Stagnosols, Luvisols and a number of other RSGs but it is unlikely to be described in Regosols although the BioSoil^{+} database contains 40 Regosols where this qualifier was given.

The qualifier *Gleyic* (gl) shows the presence of reducing conditions and a gleyic colour pattern. *Endogleyic* is used when *Gleyic* applies to a layer of at least 25 cm thick between 50 and 100 cm from the mineral soil surface. While *Gleyic* refers to the influence of a moving groundwater table, *Stagnic* refers to the influence of a stagnating water table on top of an impermeable soil layer.

Folic refers to the presence of a folic horizon, so an organic layer of more than 10 cm thick, within 40 cm from the soil surface. Such an organic layer can be found in a wide range of forest soils but is most frequently met on Podzols with Mor humus forms.

Siltic (si), *Arenic* (ar) and *Clayic* (ce) refer to the texture in a layer of 30 cm or more thick within 100 cm of the soil surface.

In the following the first order qualifiers and the second order qualifier in case the first qualifier is *Haplic* is discussed for the reference soil groups occurring in more than 1 % of the profiles.

CAMBISOLS

A total of 1116 profiles have been classified as Cambisols (1096 on Level I and 20 on Level II). About 95 % of the Cambisols were given a classification name at lower level by reporting a first qualifier. The most dominant qualifier is *Haplic* (Figure 3.2.3). In the WRB 2006 classification system *Haplic* is much more applied than in the classification system used in the first forest soil condition inventory, namely the FAO Revised Legend of the Soil map of the world (FAO-UNESCO-ISRIC 1988). This is due to the prefix-suffix priority system. In WRB 2006, there should always be a prefix qualifier. If none of the prefix qualifiers apply, the prefix *Haplic* is used. This implies that the often reported *Eutric* Cambisols, *Dystric* Cambisols, *Calcaric* Cambisols, *Chromic* Cambisols etc. do not longer exist as such in WRB 2006. These soils have become *Haplic* Cambisols (*Eutric*), *Haplic* Cambisols (*Calcaric*), *Haplic* Cambisols (*Dystric*) and *Haplic* Cambisols (*Chromic*) and are all a lower level unit of the *Haplic* Cambisols.

Figure 3.2.3 shows also that the *Humic* (hu) qualifier, indicating a content of more that 1 % OC till a depth of 50 cm from the mineral soil surface, is described on 10 % of the Cambisols. Humic Cambisols did already exist in FAO soil legend (FAO-UNESCO-ISRIC 1988) though a number of them have moved into the WRB RSGs of the Umbrisols (ISSS Working Group RB 1998).

Interesting is the relatively high occurrence of *Haplic* Cambisols *Alumic* within the BioSoil^{+} database as this combination of RSG and qualifier was not yet described before. This qualifier shows a high Al-saturation on the exchange complex of the soil and is a possible indicator for forest soil acidity. While the qualifiers *Alumic, Dystric* and *Hyperdystric* refer to a low base saturation, *Eutric, Hypereutric* but also *Calcaric* refer to a high base saturation.

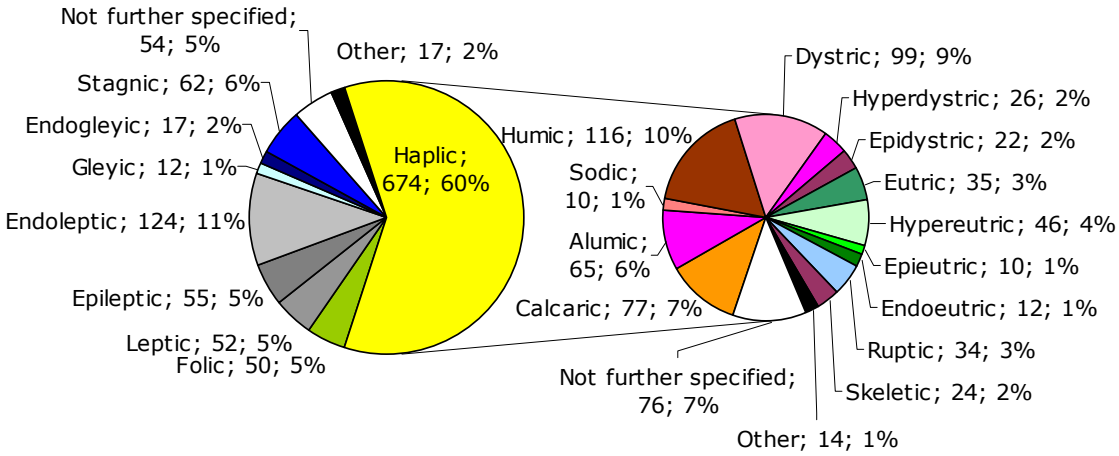


Figure 3.2.3. Absolute and relative distribution of the 1st qualifier within the Cambisols and of the second qualifier (suffix) when the first qualifier is Haplic

Other 1st qualifiers refer to the stoniness of the profile (*Leptic, Epileptic, Endoleptic*) or to the soil hydrology (*Endogleyic, Gleyic, Stagnic*). *Gleyic* Cambisols are only possible when these occur as *Endogleyic* Cambisols though it was not mandatory to determine up to specifier level. On a number of Cambisols, a thick aerated organic layer was described and these soils were classified as *Folic* Cambisols.

REGOSOLS

A total of 757 profiles have been classified as Regosols (749 level I and 8 Level II). The RSG of the Regosols is the second largest RSG in the BioSoil^{+} database, though the least differentiated. Classified according to WRB 2006 (update 2007), 75 % of the profiles received the *Haplic* qualifier of which a total of 385 profiles did not receive any additional second qualifier. The distribution of the first qualifier and the second qualifier (if the first is *Haplic)* is shown in Figure 3.2.4.

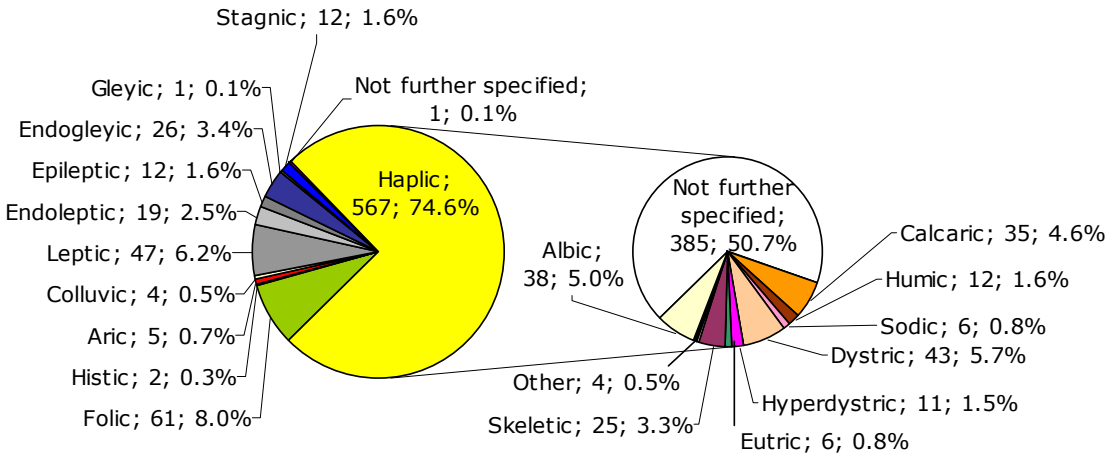


Figure 3.2.4. Absolute and relative distribution of the 1st qualifier within the RSG of the Regosols and of the second qualifier (suffix) when the first qualifier is Haplic

Approximately 8 % of the Regosols are *Folic* Regosols. The other prefix qualifiers refer again to the stoniness or the hydrology of the profile. Remarkable in the pie chart showing the second level qualifiers when the first is *Haplic*, is the *Albic* qualifier which is not included in the qualifier list of the Regosols. It may be criticized whether the presence of an Albic horizon is possible in a Regosol, as Regosols are very weakly developed mineral soils formed in unconsolidated materials showing no profile development. An Albic horizon is rather the result of an advanced profile development. It usually occurs in association with illuvial horizons such as argic or spodic horizons, which it overlies. This indicates that these 38 profiles are probably wrongly classified as Regosols and should have keyed out earlier as Podzols, Cambisols or Luvisols. So the coverage of the Regosols in the BioSoil^{+} database is possibly overestimated.

PODZOLS

A total of 685 profiles have been classified as Podzols (651 on Level I and 34 on Level II). The Podzols have a relatively high number of typically associated qualifiers which receive high priority in ranking and have indeed frequently been described: *Placic, Ortsteinic, Carbic, Rustic, Entic* and *Albic*. Of the 685 Podzols, 24 profiles were not given a first qualifier and 68 were given the qualifier *Haplic* of which 63 were not further specified by a second qualifier (Figure 3.2.5). In a large portion of the Podzols (430 profiles), the presence (or absence) of an Albic horizon was specified by the qualifiers *Albic* or *Entic* (by either the first, second or third qualifier). In three profiles, the qualifier 'Humic' was added as first qualifier. This qualifier is not included in the priority list, probably because of the partial redundancy of information. Also the qualifier *Dystric* in the Haplic Podzols can be considered redundant.

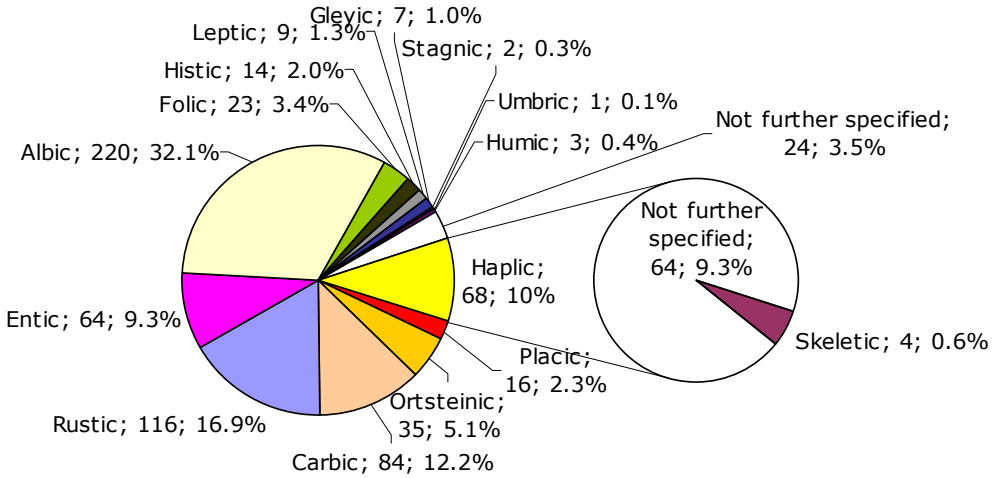


Figure 3.2.5. Absolute and relative distribution of the 1st qualifier within the RSG of the Podzols and of the second qualifier (suffix) when the first qualifier is Haplic

ARENOSOLS

A total of 563 profiles have been classified as Arenosols (537 on Level I and 26 on Level II) (Figure 3.2.6).

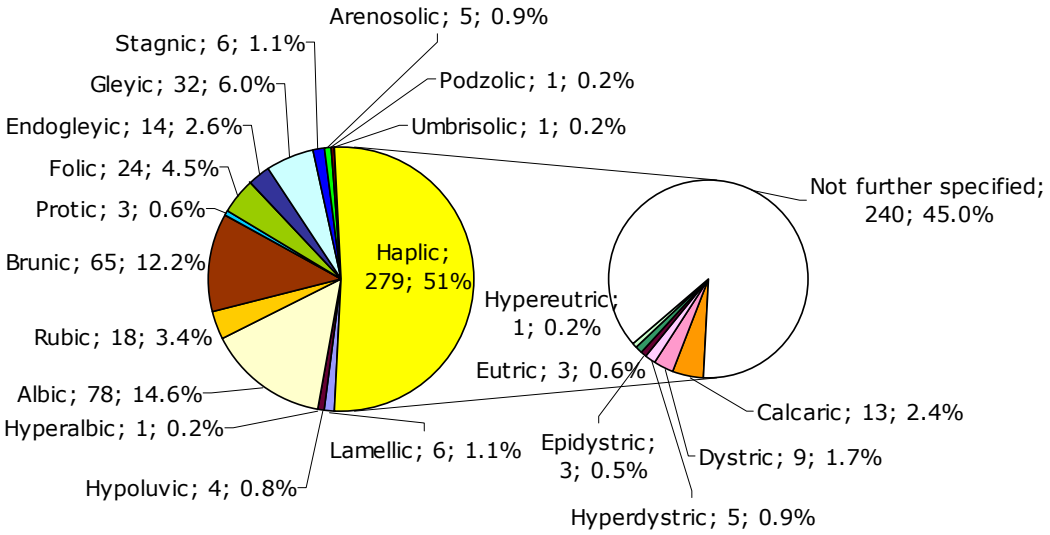


Figure 3.2.6. Absolute and relative distribution of the 1st qualifier within the RSG of the Arenosols and of the second qualifier (suffix) when the first qualifier is Haplic

The three prefix qualifiers with highest importance (*Lamellic, Hypoluvic* and *Hyperalbic*) have only been described on a very limited number of plots. The most frequently used qualifiers – after *Haplic* – are *Albic, Rubic* and *Brunic*. Although *Brunic* is not a typically associated qualifier, it mainly occurs in Arenosols. Related to water stagnation, it is rather unexpected to find *Gleyic* and *Stagnic* Arenosols, as sandy soils are expected to drain well. WRB only acknowledges *Endogleyic* and *Endostagnic* in the list of prefix qualifiers when the Gleyic and/or Stagnic properties occur at greater depth. *Protic* is a typically associated qualifier expressing that the Arenosol does not show any horizon development at all.

Arenosolic, Podzolic and Umbrisolic in WRB 2006 refer to the fact that the considered Arenosol is overlying a buried other Arenosol, Podzol or Umbrisol. These qualifiers are not any longer used in

WRB 2006, update 2007. Instead, the name of the buried soil is placed after the name of the overlying soil adding the word "over" in between.

A relatively large portion of the Arenosols ~51 % or 279 profiles were described as *Haplic* Arenosols and 240 of these profiles did not receive an additional qualifier. In case they were described, the next qualifier in row refers to the base saturation of the soil (*Calcaric, Eutric, Hypereutric*) on the side of the high base saturation and *Dystric, Epidystric* and *Hyperdystric* on the side of the low base saturation.

LEPTOSOLS

A total of 353 profiles have been classified as Leptosols, all on Level I. Exactly 346 profiles received at least one qualifier (Figure 3.2.7).

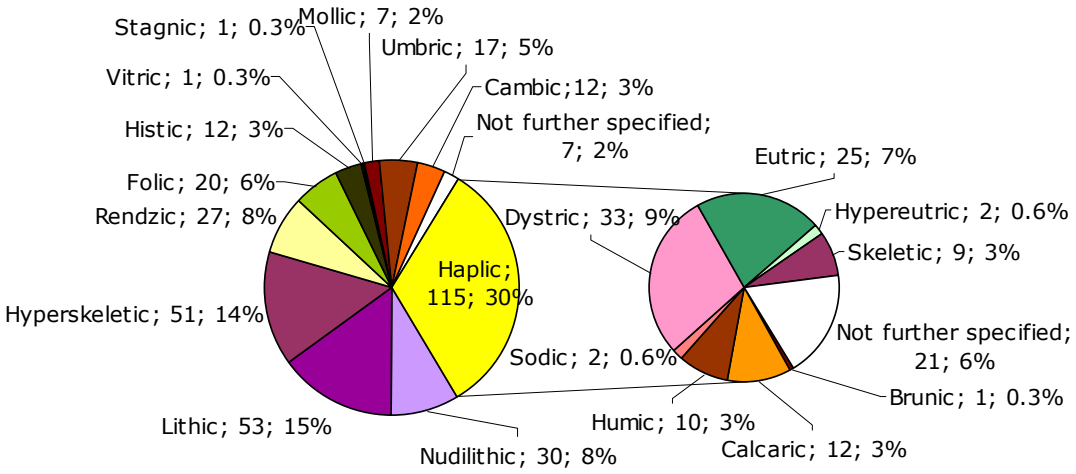


Figure 3.2.7. Absolute and relative distribution of the 1st qualifier within the RSG of the Leptosols and of the second qualifier (suffix) when the first qualifier is Haplic

The three qualifiers of highest priority refer to the depth and/or the stoniness of the Leptosols and have exclusively been used at the level of the first qualifier: *Nudilithic* Leptosols are soils with continuous rock at the soil surface which in forests would mean that it is a soil where a thin organic layer (< 10 cm) immediately overlays rock. These Leptosols have been described in Sweden only. *Lithic* Leptosols can have a soil thickness of up to 10 cm. *Hyperskeletic* Leptosols have maximum 20 % fine earth averaged over a depth till 75 cm from the soil surface or to continuous rock whichever is shallower.

The next qualifier in the priority is *Rendzic*. *Rendzic* implicitly includes the qualifier *Mollic* and nearly always *Calcaric* and *Eutric*. As strictly seen a *Mollic* horizon can overly calcareous material without itself being calcareous, the *Calcaric* qualifier was allowed in combination with *Rendzic* but if the qualifiers *Mollic* or *Eutric* were reported in *Rendzic* Leptosols, they were considered redundant and removed from the dataset. In total 50 *Rendzic* Leptosols were described, of which 27 with the *Rendzic* qualifier as the first qualifier. In Germany, Estonia and Slovenia *Mollic* Leptosols *Calcaric* have been described. On these profiles it can be questioned whether they should not have been classified as *Rendzic* Leptosols. At the level of the first qualifier, *Mollic* was reported on seven profiles and *Umbric* on 17 profiles.

Folic and *Histic* are two qualifiers that indicate that either a Folic or a Histic horizon starts within 40 cm from the soil surface but not meeting the thickness requirements to key out as Histosols. In total 20 Leptosols received *Folic* as first or second qualifier and 12 received as first qualifier *Histic*.

The next qualifier is *Vitric* which could be applied to one Leptosol in Italy. Also the qualifier *Stagnic* was only applicable on one profile. No *Gleyic* Leptosols were identified. *Cambic* has been applied on 17 profiles where on 12 profiles it was the most important qualifier.

The *Haplic* qualifier was attributed to 115 profiles. Of these, 21 profiles were not given a second qualifier so no additional information is available. Brunic is ranked first in the list of the suffix qualifiers. *Brunic* is closely related to *Cambic*, although it only meets 2 – 4 criteria of the cambic horizon. While *Calcaric, Eutric* and *Hypereutric* refer to high base saturation, *Dystric* refers to low base saturation. In case a profile was given both the qualifiers *Calcaric* and *Eutric*, the *Eutric* qualifier was removed as it becomes redundant in combination with *Calcaric*. The *Humic* qualifier is applicable on 10 profiles. *Sodic* means that the soil has 15 % or more exchangeable Na plus Mg on its exchange complex.

LUVISOLS

A total of 289 profiles have been classified as Luvisols (280 on Level I and 9 on Level II) (Figure 3.2.8). Like Alisols, Lixisols, Albeluvisols and Acrisols, the Luvisols have a higher clay content in the subsoil than in the topsoils as a result of pedogenetic processes (especially clay migration) leading to an argic subsoil horizon. Of these five RSGs, the Luvisols are best represented in the BioSoil^{+} database as Luvisols have high-activity clays and a high base saturation at certain depth. The low activity clays, seen in Acrisols and Lixisols, are rather typical for wet tropical or monsoonal, subtropical or warm temperate climate on old land surfaces. Alisols also have high-activity clays but have a low base saturation at some depth. A minor occurrence of Alisols have been reported from around the Mediterranean sea (Italy, Spain and Portugal) and also occur in humid temperate regions (Belgium, Denmark and Germany).

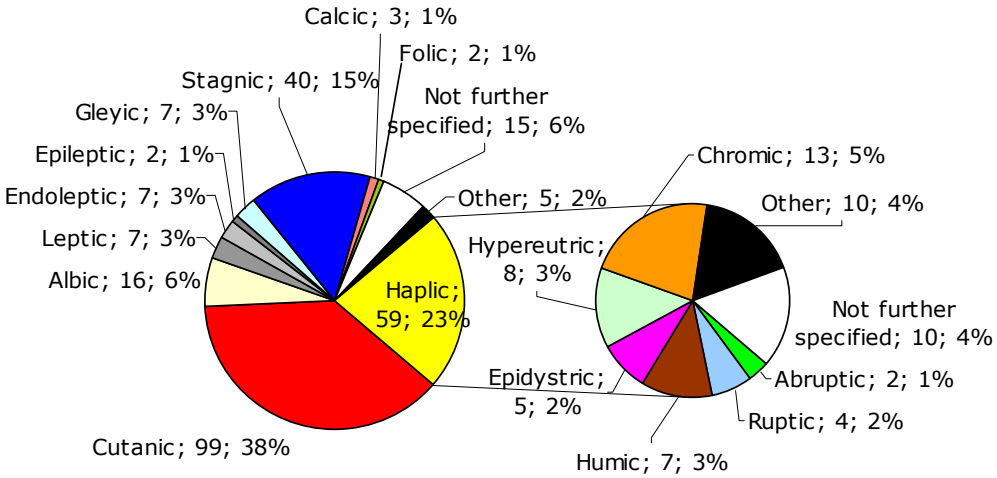


Figure 3.2.8. Absolute and relative distribution of the 1st qualifier within the RSG of the Luvisols and of the second qualifier (suffix) when the first qualifier is Haplic

Cutanic was in WRB 1998 typically associated with Luvisols. In WRB 2006 it can also be given to other soil profiles with an Argic horizon such as Acrisols, Lixisols, Alisols and Albeluvisols which is indeed the case. The class 'Other' are qualifiers that have only been described once.

HISTOSOLS

A total of 252 profiles have been classified as Histosols (247 on Level I and 5 on Level II) (Figure 3.2.9).

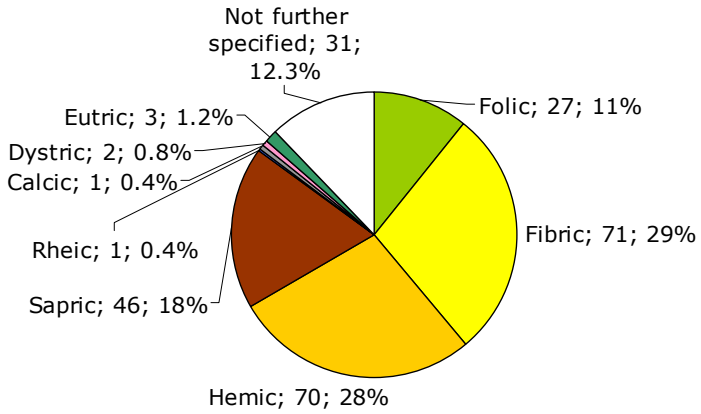


Figure 3.2.9. Absolute and relative distribution of the 1st qualifier within the RSG of the Histosols

At the qualifier level, two redundant qualifiers have been reported *Haplic* and *Histic*. *Haplic* is not defined for Histosols as always one of the three typically associated qualifiers *Fibric, Hemic or Sapric* should be applicable. *Histic* is a second redundant qualifier which does not add any information to the classification name Histosol. In the corrected datafile *Haplic* has been removed on eight and *Histic* on two Swedish plots.

The *Folic* qualifier has highest ranking priority within the Histosols. It refers to the presence of a Folic horizon which is a horizon existing of organic material and saturated with water for less than 30 consecutive days in most years and having also a thickness of 10 cm or more. So 11 % of the described Histosols in the BioSoil^{+} database fulfil these criteria.

The qualifiers *Fibric, Hemic and Sapric* provide information on the degree of decomposition of the organic material. Taking the two plots into account where these qualifiers were reported as the second qualifier, this information is available on 191 (75.8 %) of the Histosols. On 15.9 % of the Histosols the classification was only conducted till the level of the RSG. So on 8.3 % of the described Histosols, the designation of the first level qualifier is not following the rules of IUSS Working Group WRB (2006, 2007).

In total 5 *Rheic* Histosols have been identified. In one case, *Rheic* appears as the first qualifier. It is a typically associated qualifier and means that the Histic horizon is saturated predominantly with groundwater or flowing surface water starting within 40 cm of the soil surface. Further one *Calcic* Histosol was found in Poland. *Dystric* and *Eutric* should not have been defined at the level of the first qualifier as these are suffix qualifiers. But as they were the next in order to report, they have been added to Figure 3.2.9.

Interesting remark is that Slovenia defined twice the *Skeletic* qualifier in their Histosols. This qualifier was not included in the priority list of WRB 2006. The updated version of WRB 2007 however took this qualifier on board.

The qualifier *Drainic* (dr), referring to an artificially drained *Histic* horizon starting within 40 cm of the soil surface, is mainly described in Histosols but not exclusively as *Histic* horizons may also occur in other RSGs.

GLEYSOLS

A total of 166 profiles have been classified as Gleysols (161 on Level I and 5 on Level II) and their distribution is represented in Figure 3.2.10. In 30 % of the Gleysols, the water stagnation in the soil profile reaches the surface during some period of the year as the decomposition of the organic layer is limited by the temporarily water saturation, indicated by the *Histic* qualifier. A high number of Gleysols are rich in organic matter indicated by the qualifiers *Folic, Histic, Mollic, Umbric* and *Humic*.

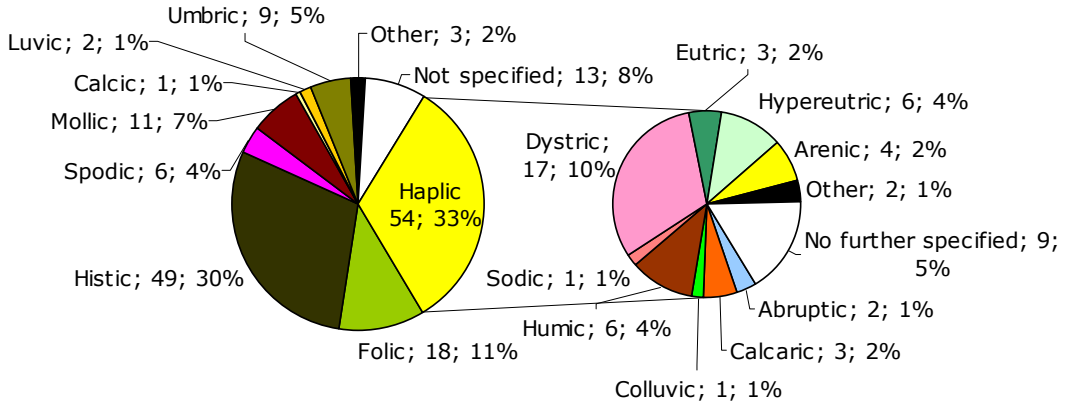


Figure 3.2.10. Absolute and relative distribution of the 1st qualifier within the RSG of the Gleysols and of the second qualifier (suffix) when the first qualifier is Haplic

UMBRISOLS

A total of 164 profiles have been classified as Umbrisols (159 on Level I and 5 on Level II) (Figure 3.2.11).

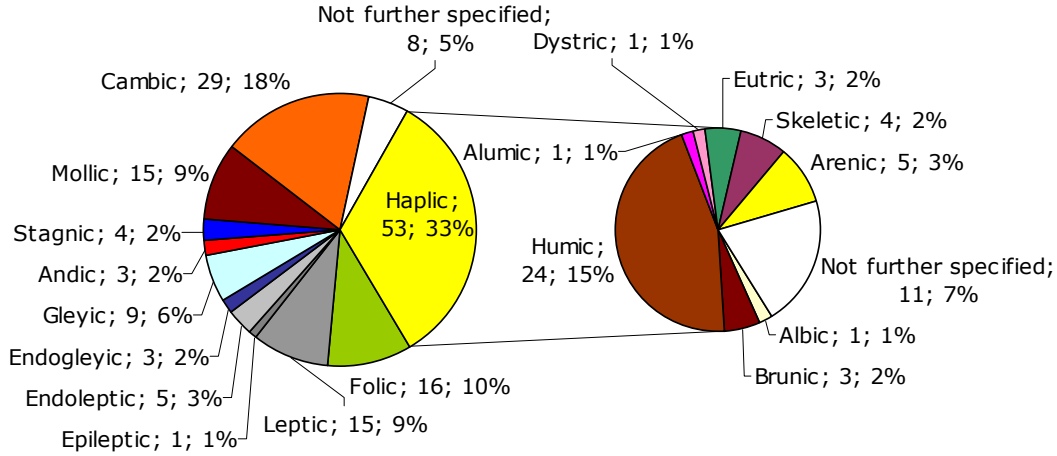


Figure 3.2.11. Absolute and relative distribution of the 1st qualifier within the RSG of the Umbrisols and of the second qualifier (suffix) when the first qualifier is Haplic

The Umbrisols accommodate soils where organic matter has accumulated within the mineral surface soils, in most cases with low base saturation. They are the logical counterpart of the Kastanozems, Chernozems and Phaeozems which have a high base saturation throughout (IUSS

Working Group WRB 2007). In the previous classification systems of the FAO (FAO-UNESCO-ISRIC 1988) they were not recognised at such a high taxonomic level and many of these soils were classified as *Humic* Cambisols or *Umbric* Regosols. The former *Humic* Cambisols receive the *Cambic* qualifier to indicate the presence of a cambic horizon and they become *Cambic* Umbrisols. When the accumulation of organic matter is down to 50 cm, the *Humic* qualifier is added as a suffix qualifier.

STAGNOSOLS

A total of 140 profiles have been classified as Stagnosols (138 on Level I and 2 on Level II), which are represented in Figure 3.2.12. Stagnosols are soils with a perched water table showing redoximorphic features caused by surface water. They are periodically wet and are mottled in the topsoil and subsoil, with or without concretions and/or bleaching. A common name in many national classification systems is *pseudogley* (IUSS Working Group WRB 2007). The bleaching is indicated by the *Albic* qualifier.

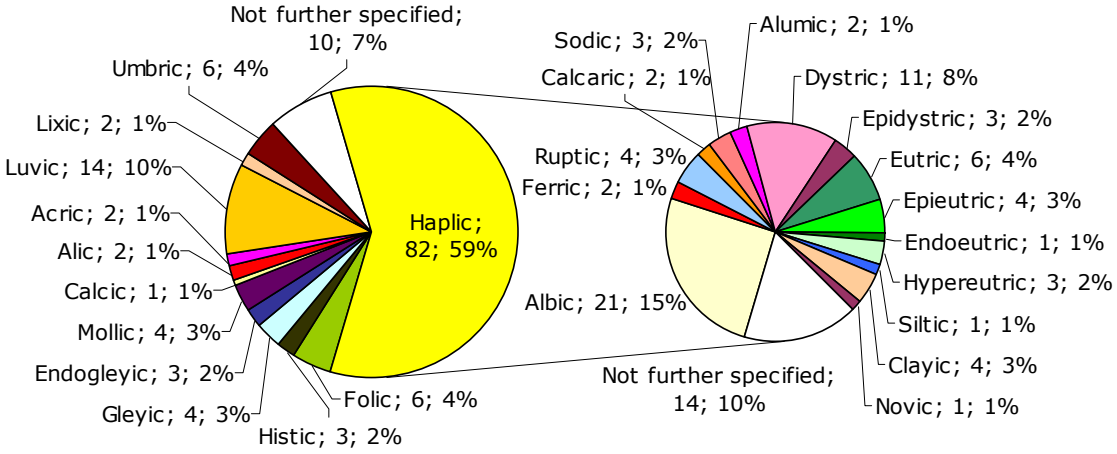


Figure 3.2.12. Absolute and relative distribution of the 1st qualifier within the RSG of the Stagnosols and of the second qualifier (suffix) when the first qualifier is Haplic

As Stagnosols key out after the Gleysols, the *Gleyic* qualifier should refer to gleyic properties in the 50 – 100 cm layer and so the qualifier is then better referred to as *Endogleyic*. A number of qualifiers indicate the presence of an argic horizon (*Alic, Acric, Luvic, Lixic*).

PHAEOZEMS

A total of 95 profiles have been classified as Phaeozems, all on Level I (Figure 3.2.13). No PH were described on Level II plots. The RSG of the Phaeozems accommodate soil of relatively wet grasslands and forests in moderate continental climates. They are much like Chernozems and Kastanozems but are leached more intensively due to higher rainfall. Consequently they have dark, humus-rich surface horizons, that are, in comparison with Chernozems and Kastanozems, less rich in bases. They may or may not have secondary carbonates (indicated by the qualifier *Calcic*) but have a high base saturation in the upper meter (IUSS Working Group WRB 2007).

The *Rendzic* qualifier means that the mollic horizons either contain or directly overlay calcaric material containing 40 % or more calcium carbonate equivalent. When the $CaCO_3$ is present in lower amounts, the Calcaric qualifier is applied.

Although *Folic* is not recognised as a prefix qualifier in the Phaeozems, it can be applicable on six profiles. While the *Pachic* qualifier means that the mollic horizon is 50 cm or more thick, *Humic* indicates a content of organic matter of at least 1 % in the upper 50 cm of the mineral soil.

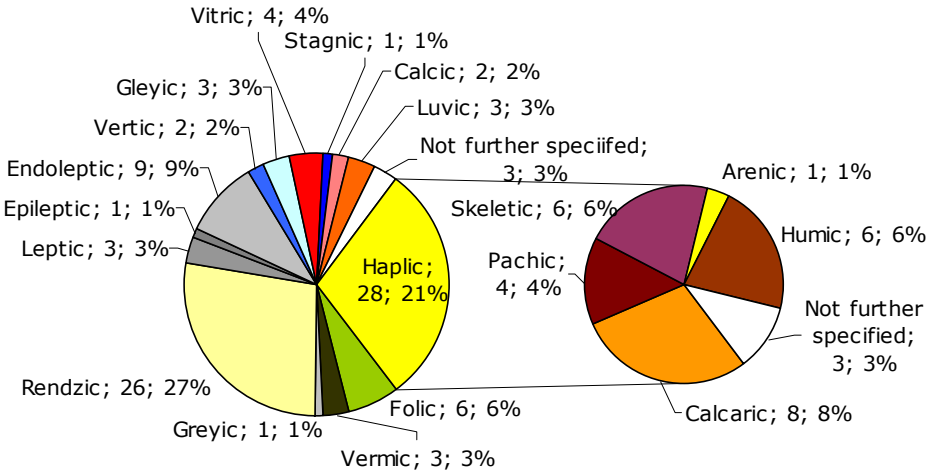


Figure 3.2.13. Absolute and relative distribution of the 1st qualifier within the RSG of the Phaeozems and of the second qualifier (suffix) when the first qualifier is Haplic

3.2.4 Type of water table

The type of water table was not reported for 18 % of the described profiles and was not observed in another 51 % of the profiles (Table 3.2.3). Indeed, this proves how difficult it is to determine this factor during a soil survey.

Table 3.2.3. Type of water table reported in the 5061 BioSoil+ profiles

Type of water table	N° profiles	%
No water table observed	2593	51
Perched water table	389	8
Permanent water table	1182	23
Not reported	897	18

A perched or stagnating water table was observed in 8 % of the profiles. On 23 % a permanent groundwater table was present.

3.2.5 Mean highest, mean lowest groundwater level

On 20 % of the plots, no mean depth of the groundwater level was reported and on another 51 % no groundwater table was observed or was not known at the time of the assessment (Table 3.2.4). This means that the information on the highest and lowest level of the water table is only available on 30 % of the profiles.

Table 3.2.4. Mean highest (HGWL) and mean lowest (LGWL) groundwater level reported in the 5061 BioSoil+ profiles

	HGWL		LGWL	
	N° profiles	**%**	**N° profiles**	**%**
No groundwater table observed or unknown	2557	51	2563	51
Groundwater table between 0 - 50 cm	308	6	132	3
Groundwater table between 50 - 100 cm	561	11	176	3
Groundwater table between 100 - 150 cm	235	5	247	5
Groundwater table between 150 - 200 cm	112	2	451	9
Groundwater table between below 200 cm	258	5	512	10
Not reported	1030	20	980	19

3.2.6 Rooting depth, rock depth and depth to obstacle

Finland, Greece, Latvia and Portugal reported these three variables on a high number of plots. But Finland reported for most of the rock and obstacle depth, a default value of 101 cm, which probably means 'more than 1 meter'. Also Portugal reported a default value of 100 cm in case rock or obstacle were not defined in the first meter of the soil profile. Latvia reported obstacle depths till 2 meter but often reported a 0 value for rock depth, which would mean the soils are *Nudilithic* Leptosols which is however not the case. These 0 values have been removed from the database. The roots reach depths of more than 2 meter on plots in Germany, France, Hungary, Latvia and Lithuania. The parameter 'rock depth' has mainly been used to validate the profile classification. Table 3.2.5. gives an overview of average and range of the reported depths per country.

Table 3.2.5. Rooting depth, rock depth and depth to obstacle (Level I and II)

	Rooting depth (cm)				Rock depth (cm)				Depth of obstacle (cm)			
Country	**Total**	**Mean**	**Min**	**Max**	**Total**	**Mean**	**Min**	**Max**	**Total**	**Mean**	**Min**	**Max**
AT	131	75	30	100	115	74	30	100	1	100	100	100
BE	21	137	60	195	-	-	-	-	-	-	-	-
CY	19	46	20	80	19	40	20	72	-	-	-	-
CZ	154	76	28	125	1	39	39	39	-	-	-	-
DE	388	99	0	260	194	90	0	200	175	79	0	200
DK	10	86	26	140	-	-	-	-	-	-	-	-
EE	96	65	20	140	3	37	21	65	18	41	20	65
ES	-	-	-	-	-	-	-	-	-	-	-	-
FI	662	49	3	80	662	96	3	101	662	93	3	101
FR	249	73	8	210	269	63	8	180	534	50	0	210
GB	166	75	5	110	-	-	-	-	-	-	-	-
GR	4	113	100	130	4	133	110	145	-	-	-	-
HU	69	139	2	240	37	192	70	200	33	163	60	240
IC	-	-	-	-	-	-	-	-	-	-	-	-
IE	38	58	27	90	7	79	40	120	-	-	-	-
IT	240	74	6	170	87	52	2	110	124	49	10	100
LT	64	119	22	212	2	208	205	210	64	149	35	220
LV	95	126	5	319	95	33	0	205	95	146	44	250
PO	530	88	21	98	52	123	45	200	-	-	-	-
PT	103	68	15	120	103	82	15	130	103	71	15	125
RS	-	-	-	-	-	-	-	-	-	-	-	-
SE	80	39	7	99	763	88	0	99	3	65	63	68
SI	46	80	33	150	5	66	38	90	46	80	33	188
SK	78	75	35	120	6	82	57	100	7	64	35	110
Total	**3243**	**77**	**0**	**319**	**2424**	**85**	**0**	**210**	**1865**	**80**	**0**	**250**

3.2.7 Depth for stock calculations

Map 4 in Annex III shows the effective solum depth of each BioSoil^{+} plot in the upper 1 m of the soil profile. In case the soil was deeper than one meter, the default value of 100 cm has been used. These depths will be applied in Volume II for the calculations of organic carbon and other forest soil stocks.

3.3 Soil horizon description

3.3.1 Thickness of horizons, layers and profile depth

In forest soils, usually an organic forest floor has been described on top of the profile. The mean thickness of this organic layer (when present) is 10.2 cm (ranging from 0 cm till 375 cm). When the organic layer is well aerated, it received the master symbol 'O'. When the layer is water saturated, it received the master symbol 'H'. The mean thickness of the O layers is 5.5 cm (ranging from 0 till 92 cm) and the mean thickness of the H layer is 49 cm (ranging from 2 till 370 cm).

Not all participating countries made the soil horizon description at the same level of detail. Belgium described on average the highest number of horizons per profile. On the other extreme, Sweden, with only three horizons per profile and without specification of subordinate symbols, provided the least detailed information. In Denmark, Hungary, Latvia and Poland the mean thickness of the described horizons at Level I was 25 cm or more (Table 3.3.1). Lithuania and Poland described the soil horizons till a depth of more than 150 cm while Spain, the Canary Islands and Sweden rather reported shallow soil profiles. Soil horizon information for Serbia is missing as Serbia followed - in the survey year 2004 - the manual of 2003 when no reporting of soil horizon descriptions was foreseen.

Table 3.3.1. Mean N° of described horizons, mean N° of horizons with subordinate symbol(s), mean thickness and mean max. depth of the described profiles by country.
The numbers before the slash refer to Level I; the numbers behind the slash to Level II.

Country	Mean N° of horizons	Mean N° of horizons with subordinate symbol(s)	Mean thickness of described horizon (cm)	Mean max depth of profile (cm)
AT	6/7	2/3	10/8	49/48
BE	11/11	5/6	14/18	138/165
CY	4/5	-/-	12/15	38/61
CZ	5/5	3/3	21/15	109/58
DE	7/6	4/3	17/23	114/111
DK	6/6	3/2	25/22	142/120
EE	6/-	2/-	20/-	108/-
ES	4/-	2/-	16/-	42/-
FI	4/5	1/1	19/19	72/74
FR	5/10	1/3	18/15	86/107
GB	6/7	2/3	18/16	90/92
GR	-/7	-/2	-/19	-/116
HU	6/-	3/-	26/-	147/-
IC	4/-	1/-	10/-	23/-
IE	7/7	2/1	13/13	79/78
IT	6/6	2/2	13/16	74/84
LT	7/9	3/2	22/24	151/208
LV	8/-	4/-	25/-	162/-
PO	6/8	2/2	31/26	179/190
PT	5/-	2/-	15/-	70/-
SE	3/-	-/-	14/-	29/-
SI	7/9	3/7	13/21	82/180
SK	6/8	2/3	16/15	92/98

3.3.2 Horizon designations

3.3.2.1 Master horizon symbol

In total 114 different combinations of master horizon symbols have been used to name the 24440 described horizons. A limited number of combinations of master horizons symbols seem unlikely as for example 'AEB' or 'BRC'. Assuming that the first master symbol is the most important one, Table 3.3.2 gives an overview of the most important described horizons.

Table 3.3.2. Number of horizons described in the soil horizon dataset of the BioSoil+ database

Main master horizon symbol	N° of horizons described
O - horizons	6637
H - horizons	778
A - horizons	4221
E - horizons	1602
B - horizons	7165
C - horizons	3689
R - horizons	348
Total	**24440**

3.3.2.2 Subordinate symbol

In total 197 different combinations of subordinate symbols have been reported on 7709 of the 23618 described horizons on Level I and on 288 of the 852 described horizons on Level II. So only one third of the horizons did receive a subordinate symbol. The full list of reported subordinate symbols is provided in Table 3.3.3.

Table 3.3.3. The frequency of reported subordinate symbols

Subordinate symbol	N°	Description
a	11	Evidence of cryoturbation
b	109	Buried horizon
c	90	Concretions or nodules
d	99	Dense horizon (physically root-restrictive; not used in combination with m)
f	2	Frozen soil (not used in combination with I)
g	1675	Strong gleying
h	2859	Accumulation of organic matter
i	25	Slickensides
k	476	Accumulation of pedogenetic carbonates
m	76	Strong cementation or induration (pedogenetic, massive)
n	2	Pedogenetic accumulation of exchangeable sodium
o	123	Residual accumulation of sesquioxides
p	441	Ploughing or other artificial disturbance
q	76	Accumulation of pedogenetic silica
r	396	Strong reduction
s	980	Illuvial accumulation of sesquioxides
t	796	Illuvial accumulation of clay
u	17	Urban and other man-made materials
v	12	Plinthite
w	1644	Development of colour or structure in B (only used with B)
x	11	Fragipan
y	2	Pedogenetic accumulation of gypsum
Total	**9922**	

The by far most widely applied subordinate symbol is 'h' (accumulation of organic matter) followed by 'g' (strong gleying) and 'w' (development of colour or structure in B).

3.3.3 Soil structure

On about 50 % of the horizons, the soil structure has been reported. Horizons without any structure (single grain) have been described in 30% of the cases. This is followed by the subangular blocky structure (27 %) and the typical granular structure (15 %) of the organic rich top soil. Then comes the angular blocky structure (12 %), the massive structure (6 %) and the crumbly structure (5 %). Structures like platy, prismatic, columnar and wedge-shaped have only been described in a limited number of soil horizons. The granular structure is mainly described for A horizons. The subangular structure mainly on B horizons. The majority of the E horizons and of the C horizons are characterised by a single grain structure.

Table 3.3.4. N° of reported structure types grouped by main master horizon symbols

Master horizon	Platy	Pris-matic	Colum-nar	Angular blocky	Subangular blocky	Gra-nular	Crum-bly	Massive	Single grain	Wedge-shaped
O	104	0	0	27	52	107	37	23	16	0
H	10	0	0	11	19	30	1	16	3	0
A	23	11	4	191	1000	995	334	76	780	0
E	12	8	5	88	224	141	33	45	266	0
B	53	215	19	909	1585	464	152	307	1344	1
C	38	52	7	255	400	152	23	296	1243	1
R	0	6	1	7	11	6	0	17	10	0
Total	**240**	**292**	**36**	**1488**	**3291**	**1895**	**580**	**780**	**3662**	**2**

3.3.4 Soil colour

Most of the reported soil colours are displayed in the Munsell Soil Color Charts (2000) where they are arranged by three dimensions that combine to describe all colours and are known in the Munsell system as Hue, Value and Chroma. The countries Portugal, Italy and Flanders did define a number of additional hue codes, though still using the Munsell colour notations. The Hue notation of a color indicates its relation to Red (R), Yellow (Y), Green, Blue and Purple. Figure 3.3.1 shows the reported Hues. More than 50 % of the colours have the Hue '10 YR'. When considering only the Hues described on at least 100 horizons, we see that they are limited to 10 YR, 2.5Y, 2.5YR, 5Y, 5YR and 7.5YR. The Value notation indicates the colour lightness with increasing lightness with increasing Value. Figure 3.3.2 shows the reported Values where the soil in moist condition clearly show lower Values. The Chroma notation indicates the colour strength or the departure from a neutral colour of the same lightness (Figure 3.3.3).

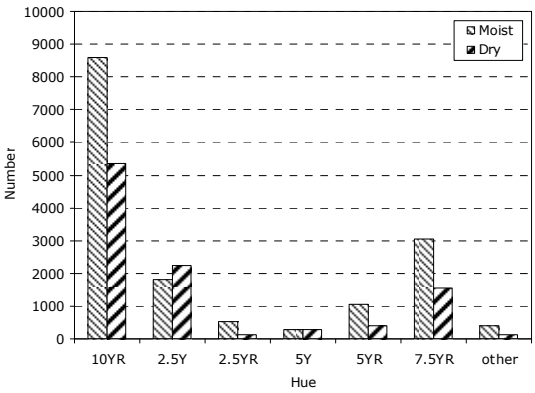


Figure 3.3.1. Frequencies of reported Hues (moist and dry colours)

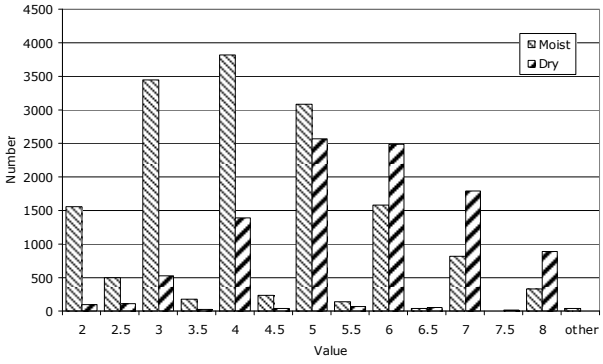


Figure 3.3.2. Frequencies of reported Values (moist and dry colours)

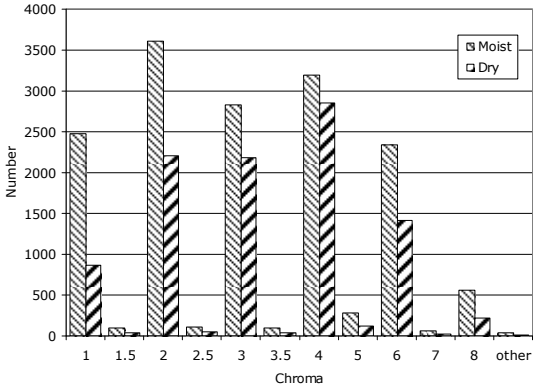


Figure 3.3.3. Frequencies of reported Chromas (moist and dry colours)

Table 3.3.5 shows the distribution of the frequencies of the colours with Hue 10 YR. For the moist colours, the highest frequencies are located in the lower left corner of the 10YR chart and decrease when going towards the upper right corner. The highest frequencies of the dry colours are more located in the centre of the 10YR chart.

Table 3.3.5. Frequencies of reported colour with Hue 10 YR (moist colours on the left and dry colours on the right)

Moist colour

10YR		1	2	3	4	6	8
	8/	24	43	29	18	10	1
	7/	45	54	74	100	78	37
	6/	44	79	126	304	223	90
	5/	71	172	269	485	483	166
	4/	156	443	415	453	397	
	3/	221	692	505	261	112	
	2/	707	382				

Dry colour

10YR		1	2	3	4	6	8
	8/	16	47	63	52	13	2
	7/	35	122	162	311	192	24
	6/	57	239	231	460	289	54
	5/	87	330	302	529	232	61
	4/	85	294	231	132	58	
	3/	43	109	42	20	10	
	2/	37	31				

For the A horizon the most frequently described colour is very dark brown (10YR 3/2). The most frequently described colours of the B horizons are 10YR 5/6 and 4/6 and are lighter than the most frequently described colour of the E horizons (10YR 4/2 or 3/2). The colour of the C parent material is usually lighter than the B horizon. The colours of the O and the H horizon are very similar and on average darker than the A horizon (10 YR 2/1 or 2/2).

The most frequently described value of moist soils is '4' and of dry soils is '5' or '6'. The most frequently described Chroma for moist soils is '2' and for dry soils is '4'. On 9300 horizons, both the moist and dry colour was available. For those horizons there is an average shift to the darker colours (lower values of Value and Chroma) upon wetting the soil as shown in Figures 3.3.4 and 3.3.5. Table 3.3.6 shows that he shift in the Values and the Chromas is statistically significant different from 0 as shown by the paired t-tests.

Table 3.3.6. Comparison of the reported Chroma and Value codes between moist and dry colours

Variable	Moist Mean value	Dry Mean value	Mean difference	95% CI
Chroma	3.440	3.495	-0.06	[-0.089; -0.034]**
Value	4.405	6.695	-1.29	[-1.310; -1.269]**

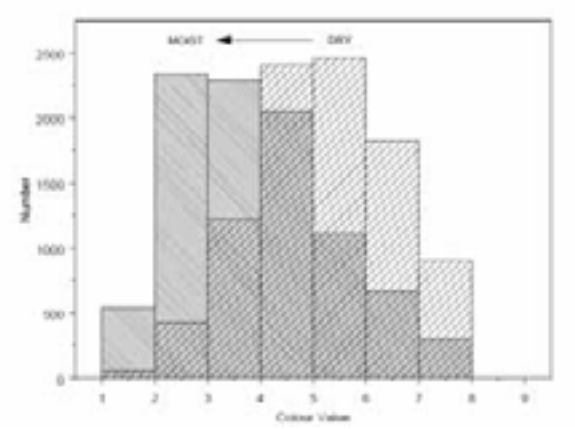


Figure 3.3.4. Distribution of the colour Value when dry and when moist

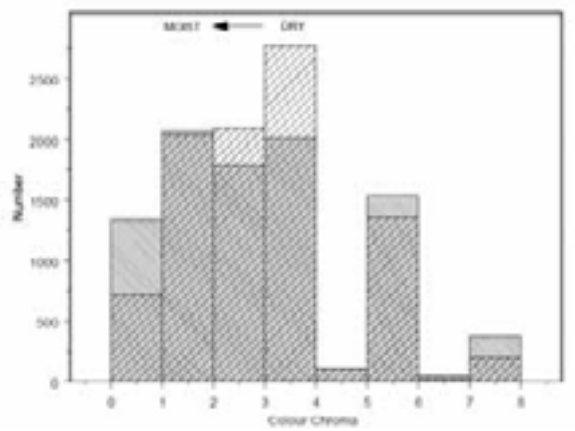


Figure 3.3.5. Distribution of the colour Chroma when dry and when moist

3.3.5 Textural class

Analytical data on soil horizons have within the BioSoil survey often been derived from the analyses conducted on the samples taken at fixed depths. As the statistics on the laboratory results will be discussed in detail in Section 3.4.1.1, they are not described here. Below a number of general patterns in the textural data are visualised and discussed. Figures 3.3.6 till 3.3.13 show the reported textural class for 8 important reference soil groups in the European forests. Leptosols are not shown as textural data on these shallow soils are rather limited. The textural data on all soil horizons (these are all described depths per profile) are included.

The texture of Cambisols is often siltloam, loam or sandy loam (Figure 3.3.6). The distribution pattern of the soil textures within the Cambisols corresponds well to the overall pattern (Section 3.4.1.1). The texture of the Arenosols is dominantly sand and a bit of loamy sand but other soil texture are as good as non existing. The textures of the Podzols are mainly sand, sandy loam and loamy sand. Regosols are formed in a wide range of soil textures but with a strong presence of soils with low clay content.

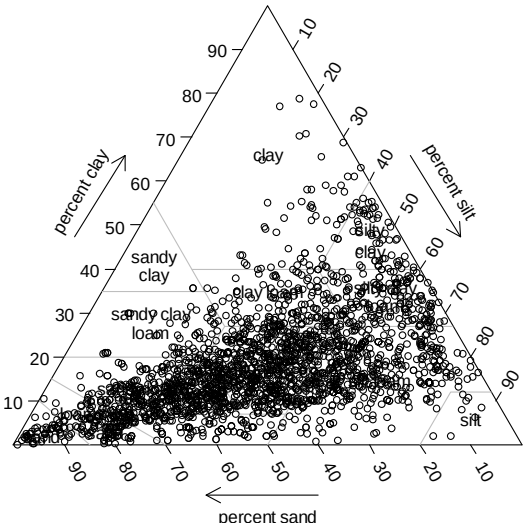


Figure 3.3.6. Textures described in Cambisols

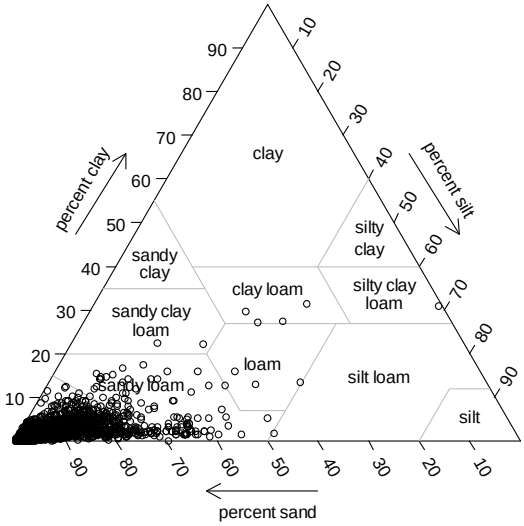


Figure 3.3.7. Textures described in Arenosols

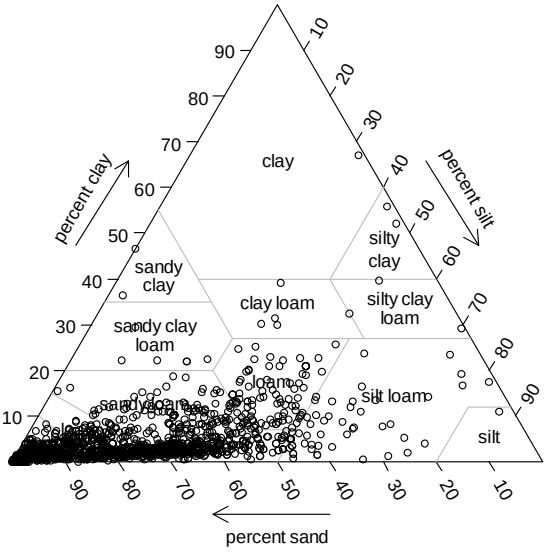


Figure 3.3.8. Textures described in Podzols

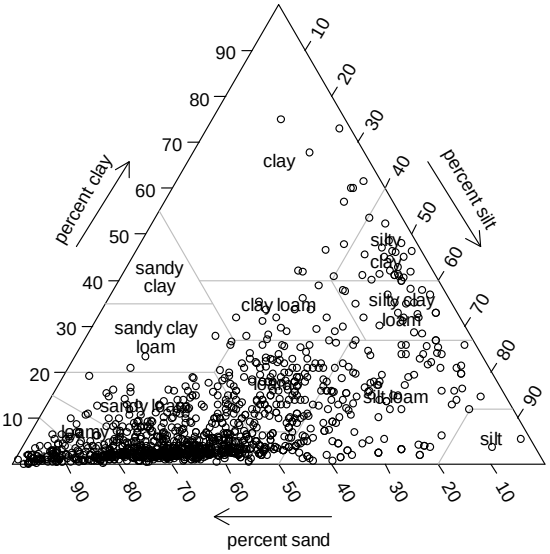


Figure 3.3.9. Textures described in Regosols

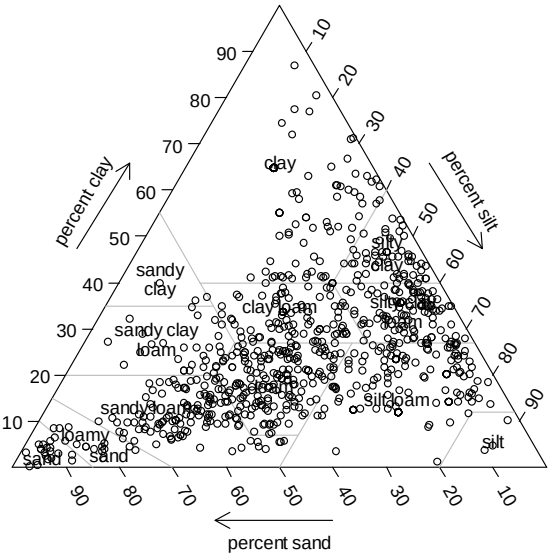


Figure 3.3.10. Textures described in Luvisols

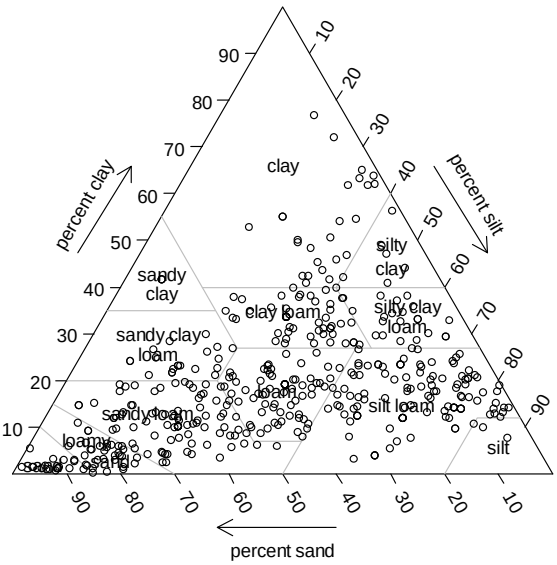


Figure 3.3.11. Textures described in Stagnosols

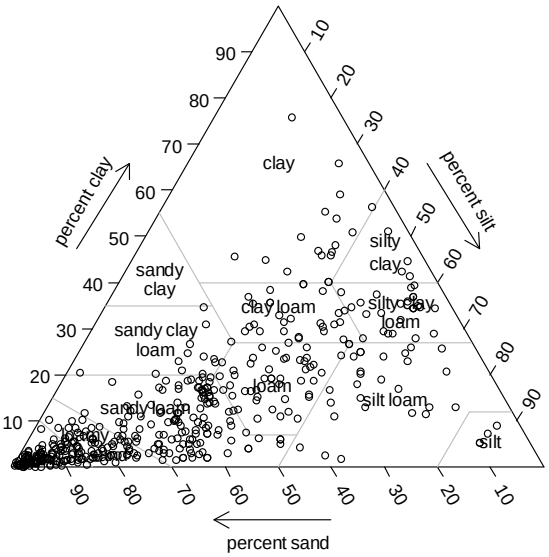


Figure 3.3.12. Textures described in Gleysols

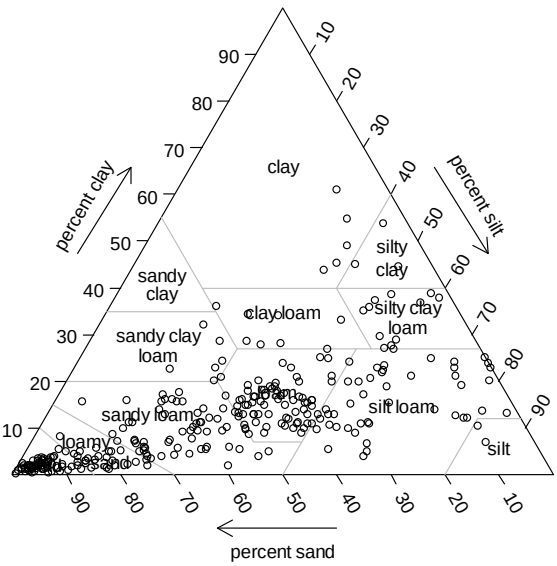


Figure 3.3.13. Textures described in Umbrisols

The Luvisols are characterised by a high number of loam and siltloam textures. Stagnosols are characterised by a high number of silt loam textures while the Gleysols are rather characterised by a high number of sand, loamy sand and sandy loam textures. Umbrisols show a high number of sandy loam and loamy horizons.

3.3.6 Coarse fragments code

The abundance of the coarse fragments has been reported according to the codes shown in Table 3.3.7. Coarse fragment volume contents have mainly been estimated during the profile description. Stratified according to the main master horizons, the reported coarse fragments contents are shown in Figures 3.3.14 till 17.

Table 3.3.7. Classes limits of coarse fragments volumes

Code	Description	Volume %
0	No coarse fragments	0 %
1	Very few	Less than 5 %
2	Few	Between 5 and 15 %
3	Frequent or many	Between 15 and 40 %
4	Very frequent, very many	Between 40 and 80 %
5	Dominant or skeletal	More than 80 %

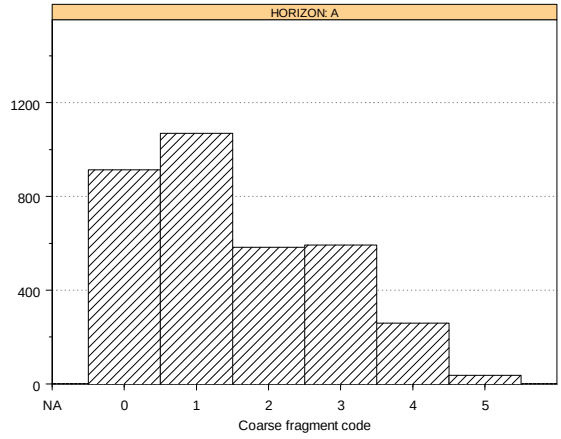


Figure 3.3.14. Frequency of coarse fragments in the A horizons

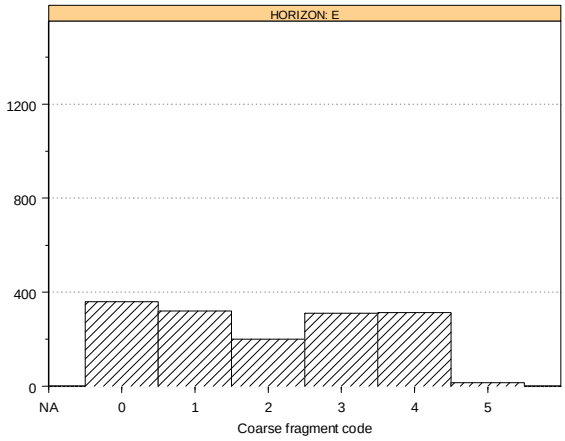


Figure 3.3.15. Frequency of coarse fragments in the E horizons

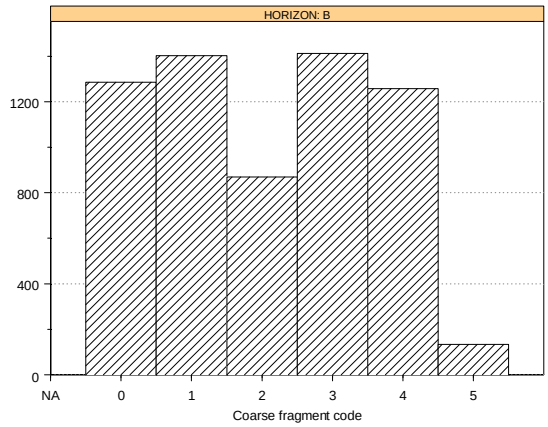


Figure 3.3.16. Frequency of coarse fragments in the B horizons

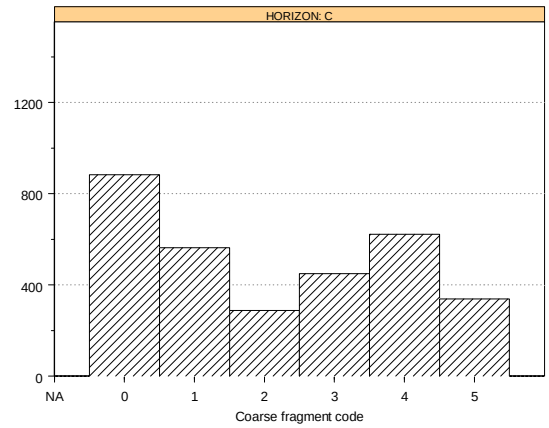


Figure 3.3.17. Frequency of coarse fragments in the C horizons

The coarse fragment content in the A horizon is low compared to the other genetic horizons, as shown by relative high bars for the codes 0 and 1. The highest volumes of coarse fragments have mainly been described in the C horizon. Remarkable in the distribution is the relative low proportions of soil horizons with 'few' coarse fragments' (code 2, between 5 and 15%) in the E, B and C horizons.

3.4 Univariate analysis of the fixed depth samples

3.4.1 Particle size distribution

3.4.1.1 Mineral layers

Clay, Silt and Sand fraction

The clay fraction (0 - 2 µm) is one of the major characteristics of soil. The distribution of clay percentage (% of mass) in forest soils for each investigated layer is given in Figure 3.4.1. Clay content ranges from 0 to 88 %, but 97.5 % of all values are below 51 %. We set the LOQ at 0.5 %, which is close to 0.6 % as reported by the labs (De Vos 2008). Between 2 and 6 % of the observations are left censored (below LOQ).

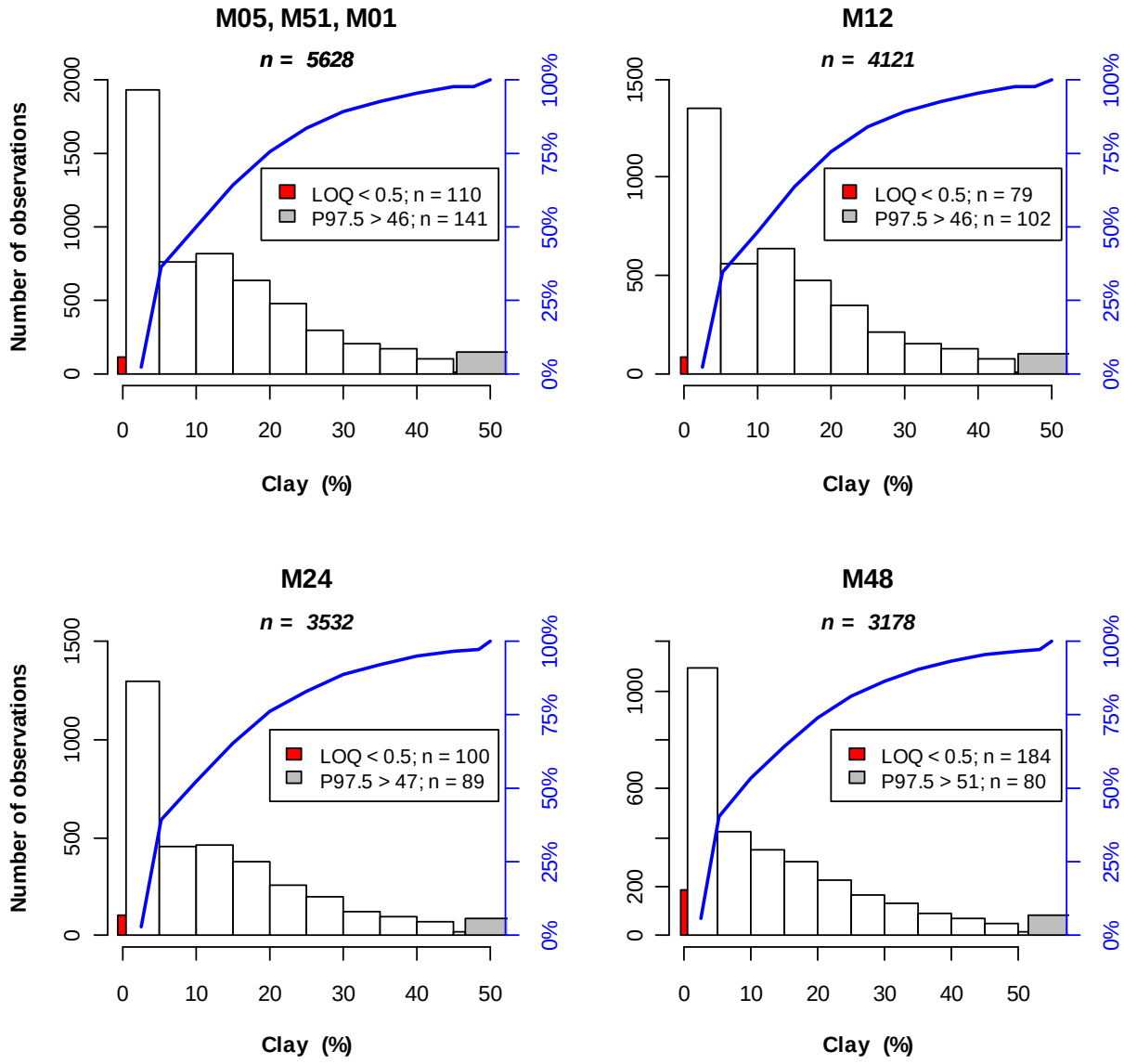


Figure 3.4.1. Absolute and cumulative frequency distribution of clay (%) in mineral soil layers of all BioSoil^{+} plots (Level I and Level II). The red bars indicate observations below LOQ, the grey bars indicate extreme observations, including those above the 97.5 percentile as indicated in the legend. Percentiles are indicated in blue.

For all layers, the 0 – 5 % class is best represented and less than half of the observations are situated in the consecutive classes. Soil samples holding more than 50 % of clay rarely occur (< 2.5 % chance). As may be derived from the cumulative frequency curve, the median clay content of European forest soils is ~ 10 % (mean: 13 %).

The distribution of the silt fraction (2 – 63 µm) is shown in Figure 3.4.2. This distribution is more evenly spread than clay and ranges from 0 to 100 %, but values above 73 % silt are seldom observed (< 2.5 % chance). Upon setting the LOQ at 0.5 %, the percentage of the left censored values is less than 1.8 %, as is the case for M48.

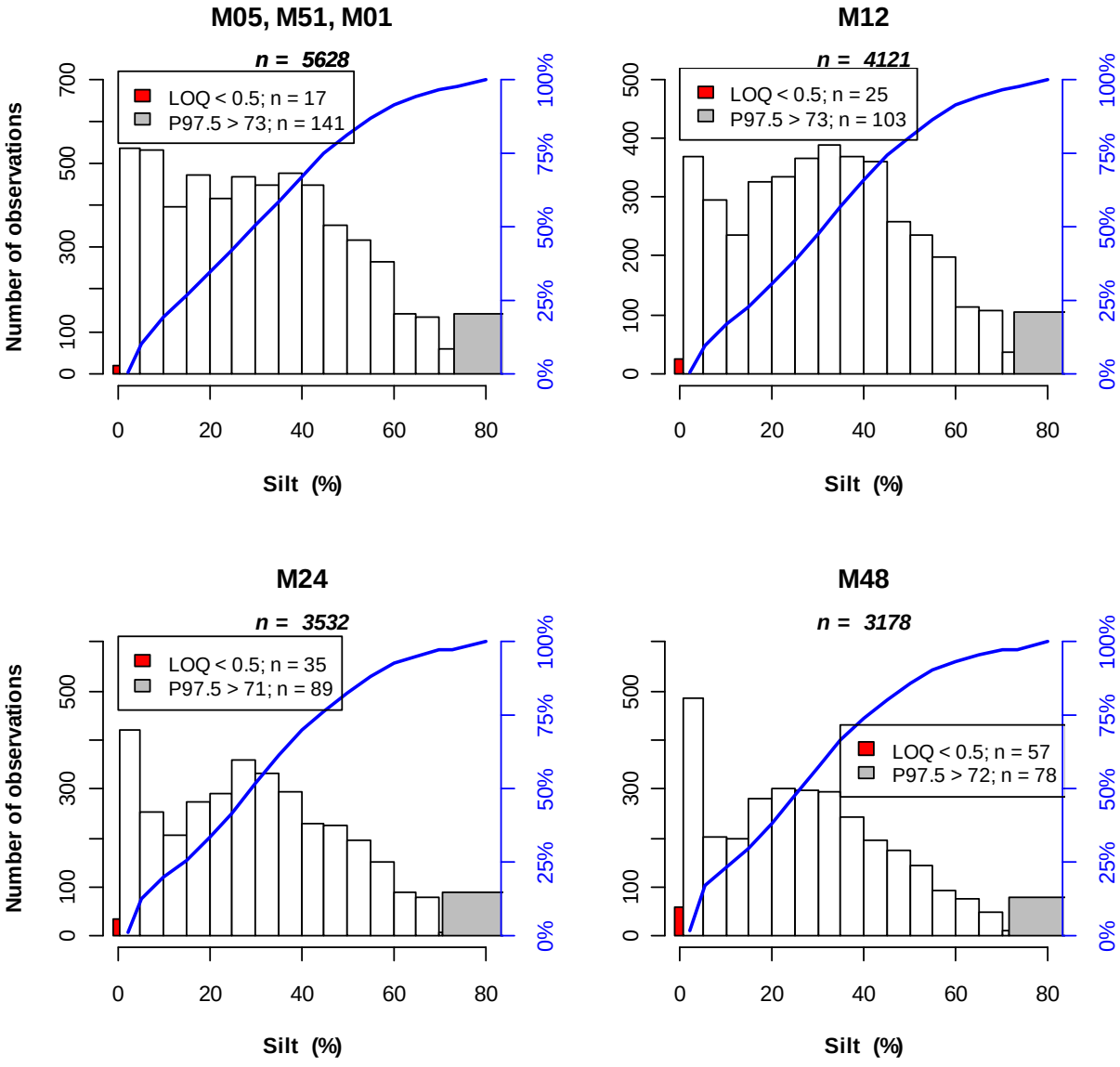


Figure 3.4.2. Absolute and cumulative frequency distribution of silt (%) in mineral soil layers of all BioSoil⁺ plots (Level I and Level II). The red bars indicate observations below LOQ, the grey bars indicate extreme observations, including those above the 97.5 percentile as indicated in the legend. Percentiles are indicated in blue.

The distribution follows a slight bimodal pattern with a higher number of observations within the range 0 - 10 % and around 20 - 35 % silt. Median values are situated around 30 % (mean: 31 %) for all layers until 40 cm of depth and around 26 % (mean: 28 %) for the M48 layer. More data on general statistics are given in Annex II.

Just as the silt fraction, sand (63 µm - 2 mm) is well distributed across all bins between 0 and 100 %, illustrated by a quite straight cumulative distribution line (Figure 3.4.3). However, relatively more observations are noticeable above 90 % of sand. Less than 0.1 % of all observations reported have less than 0.5 % sand (LOQ), but many are comprised in the highest class evidenced by very high 97.5 percentile values (96 % sand and more). Median sand content is between 57 and 62 % (mean: 54 – 59 %). On average, the M12 layer shows the lowest sand content whereas the M48 layer the greatest, mainly by its large contribution of pure sands (95 - 100 % sand fraction).

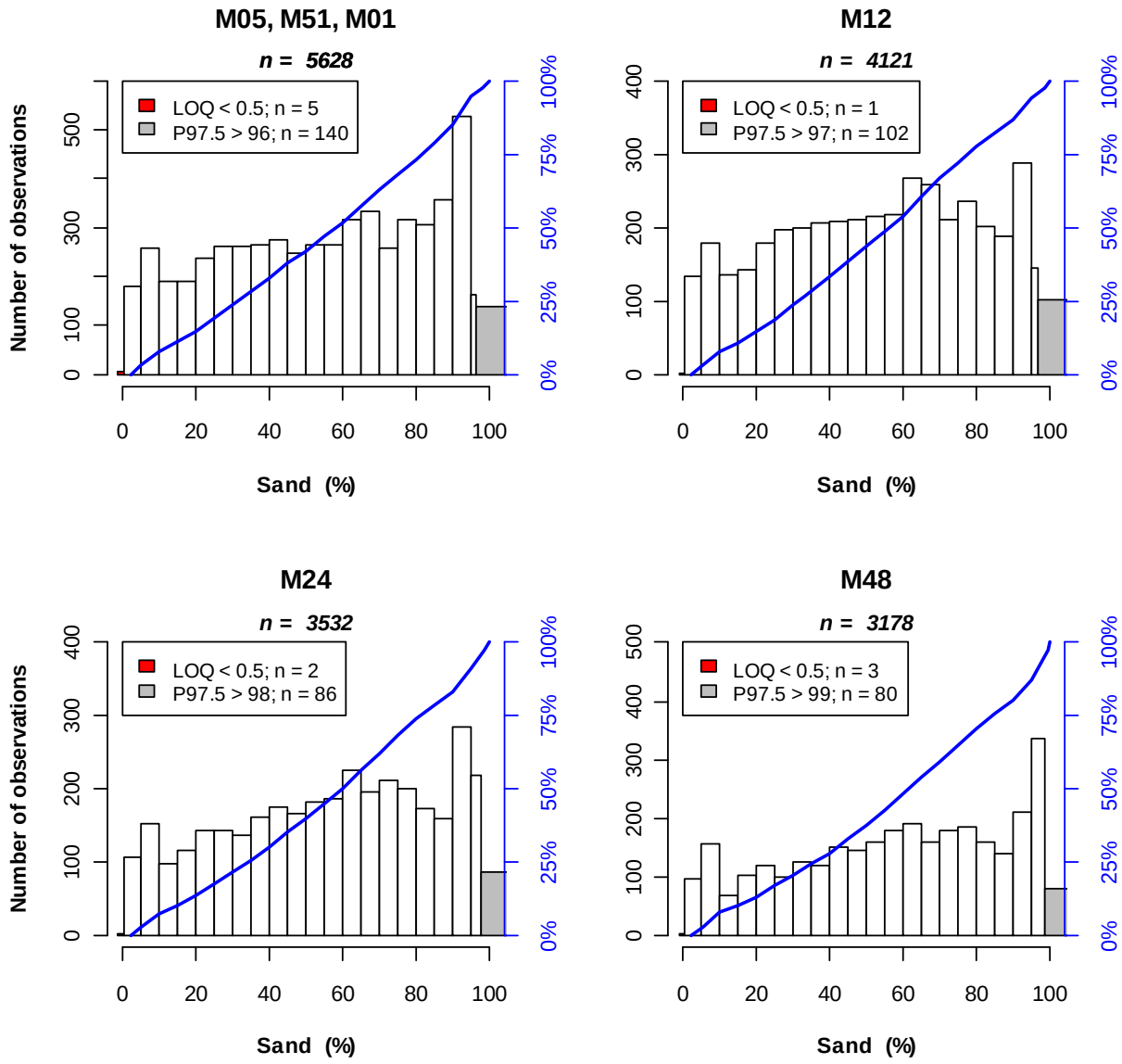


Figure 3.4.3. Absolute and cumulative frequency distribution of sand (%) in mineral soil layers of all BioSoil⁺ plots (Level I and Level II). The red bars indicate observations below LOQ, the grey bars indicate extreme observations, including those above the 97.5 percentile as indicated in the legend. Percentiles are indicated in blue.

Textural classes

The mineral soil samples are graphed in the USDA/FAO (1951) texture triangle (Figure 3.4.4) and the frequency of observations in each textural class is reported in Table 3.4.1. The scatterplots in the texture triangles show for all fixed depths that the highest density is situated in the sand area:

classes Sand (S), Loamy Sand (LS) and Sandy Loam (SL), and then spread towards the textural classes Silty Clay (SiC), Silty Clay Loam (SiCL) and Silt Loam (SiL).

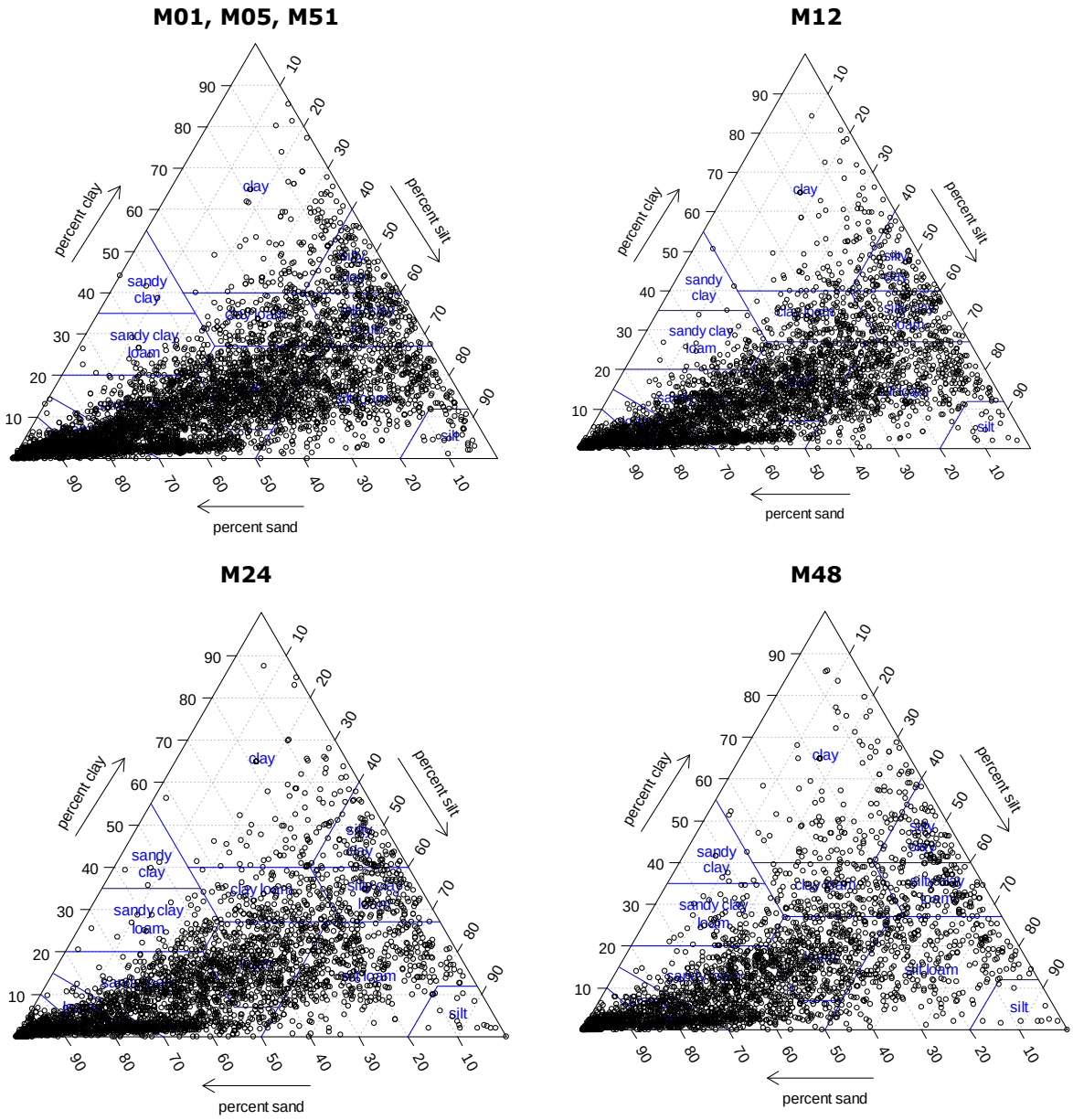


Figure 3.4.4. USDA (1951) texture triangles of mineral layers at 4 depths of all BioSoil+ plots (Level I and Level II combined).

Sandy Clay (SC), Sandy Clay Loam (SCL), Silt (Si) and Clay (C) are much less represented, each with generally less than 2.5 % of all observations for that layer. Some points fall exactly on the borderline between adjacent classes, but they comprise no more than 0.5 % of the observations (Table 3.4.1). Sandy Loam (SL) appears to be the dominant textural class for the M01, M12 and M24 layers with nearly one quarter of all observations. Secondly, Sand (S) is very well represented with about one fifth of all observations and the most dominant in the M48 layer. Next is Loam (L) with about 15 % of all observations, Silt Loam (SiL) with ~13 % and Loamy Sand (LS) with ~12 %. The remaining classes hold less than 5 % of the observations. Hence, the dominance in decreasing order is: SL > S > L > SiL > LS >> CL ≈ SiCL > C >SiC > SCL > Si > SC.

Table 3.4.1. Frequency (numbers and percentages) of USDA/FAO classified soil textures according to mineral soil layer; borderline cases separated by a slash are also given.

Textural Class	M01		M12		M24		M48		Total	
	N°	%	N°	%	N°	%	N°	%	N°	%
C	118	*2.1*	88	*2.1*	91	*2.6*	129	*4.1*	426	*2.6*
SiC	130	*2.3*	88	*2.1*	86	*2.4*	82	*2.6*	386	*2.3*
SC	3	*0.1*	2	*0.0*	4	*0.1*	6	*0.2*	15	*0.1*
CL	247	*4.4*	170	*4.1*	143	*4.0*	149	*4.7*	709	*4.3*
SiCL	257	*4.6*	181	*4.4*	146	*4.1*	117	*3.7*	701	*4.3*
SCL	87	*1.5*	66	*1.6*	67	*1.9*	80	*2.5*	300	*1.8*
L	855	*15.1*	670	*16.2*	501	*14.2*	412	*13.0*	2438	*14.8*
SiL	773	*13.7*	600	*14.5*	432	*12.2*	306	*9.6*	2111	*12.8*
SL	1326	*23.5*	1058	*25.6*	891	*25.2*	727	*22.9*	4002	*24.3*
Si	34	*0.6*	18	*0.4*	18	*0.5*	12	*0.4*	82	*0.5*
LS	712	*12.6*	484	*11.7*	430	*12.2*	406	*12.8*	2032	*12.3*
S	1087	*19.2*	683	*16.6*	711	*20.1*	731	*23.0*	3212	*19.5*
C/CL	0	*0.0*	2	*0.0*	2	*0.1*	1	*0.0*	5	*0.0*
C/SiC	0	*0.0*	2	*0.0*	0	*0.0*	1	*0.0*	3	*0.0*
SiL/Si	2	*0.0*	0	*0.0*	0	*0.0*	0	*0.0*	2	*0.0*
SiL/SL	1	*0.0*	1	*0.0*	3	*0.1*	2	*0.1*	7	*0.0*
SiC/SiCL	1	*0.0*	3	*0.1*	1	*0.0*	3	*0.1*	8	*0.0*
SL/LS	3	*0.1*	1	*0.0*	2	*0.1*	0	*0.0*	6	*0.0*
SCL/SL	2	*0.0*	1	*0.0*	3	*0.1*	3	*0.1*	9	*0.1*
LS/S	0	*0.0*	1	*0.0*	0	*0.0*	0	*0.0*	1	*0.0*
L/SiL	7	*0.1*	4	*0.1*	5	*0.1*	5	*0.2*	24	*0.1*
L/SL	1	*0.0*	2	*0.0*	0	*0.0*	2	*0.1*	5	*0.0*
C/SiC/CL/SiCL	1	*0.0*	1	*0.0*	0	*0.0*	0	*0.0*	2	*0.0*
Total	5647	*100*	4126	*100*	3536	*100*	3174	*100*	16483	*100*

In all, the proportions of each textural class do not differ substantially among soil layers. If some deviance is observed, it is mostly between the M48 and the other layers.

Map 5 in Annex III shows the geographical distribution of the textural classes across the European forests in the upper 10 cm of the mineral soil. The dominant textural class of Sandy Loam is found in Finland and central and southern Europe. The distribution of the Sandy soil textures corresponds well with the distribution of the eolian sands (Map 1) in northern Flanders, northern Germany and Poland. South of this region, the loess belt can be distinguished by the presence of textures such as Sandy Loam, Loam and Silt Loam.

3.4.1.2 Peat layers

Texture was rarely reported for peat layers. Most countries did not determine granulometry when layers were designated H05, H51, H01, H12, H24 or H48, although this is not clearly stated in the soil manual. Moreover, some layers changed designation (e.g. from M01 to H01) based on lab results. In any case, texture was reported for 15 topsoil H-layers (H05, H51, H01), three H12 layers, no H24 layers and only one H48 layer. For the topsoil H layers, a wide range in clay (2.5 – 40 %), silt (6 – 68 %) and sand (2 – 90 %) is stored in the BioSoil^{+} database.
The textural classes are Sand, Loamy Sand, Sandy Loam, Loam, Silt Loam, Silty Clay Loam and Silty Clay.

3.4.2 Organic layer mass and thickness

3.4.2.1 Organic layer mass

Forest Floor

Organic layer dry mass (DM, kg m^{-2}) was determined for aerated and hydromorphic humus types. The dry mass of the litter layer (OL) ranges from 0 (OL is absent) to some kg. Ninety five percent of all observations are comprised within the 0.07 – 2.78 kg m^{-2} range and the median value is 0.62 kg m^{-2} (Figure 3.4.5*).*

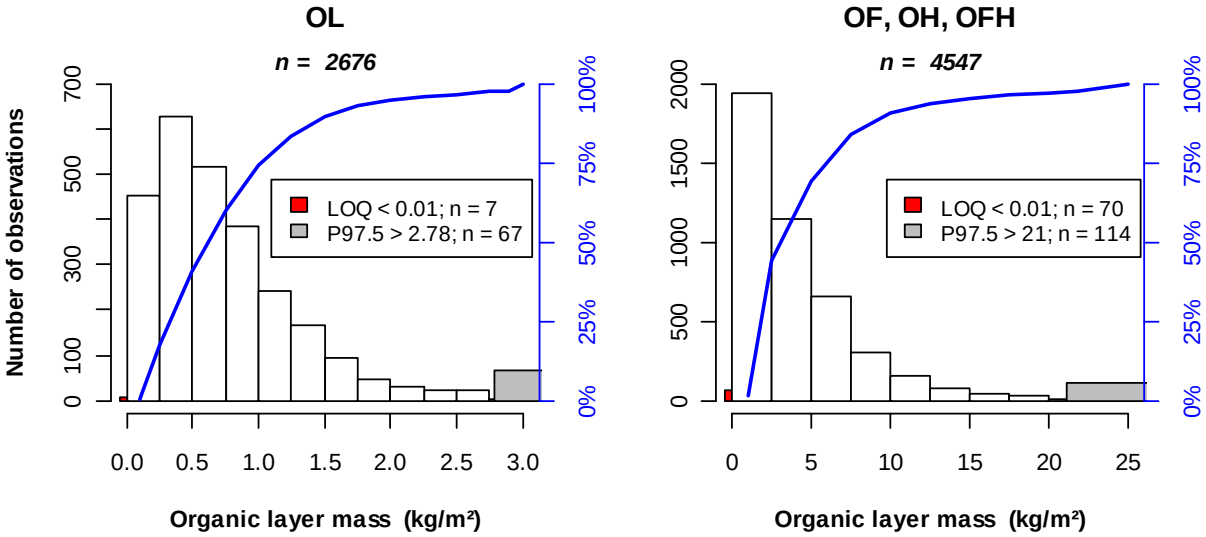


Figure 3.4.5. Absolute and cumulative frequency distribution (in blue) of organic layer mass in forest floor layers of all BioSoil+ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above the 97.5 percentile.

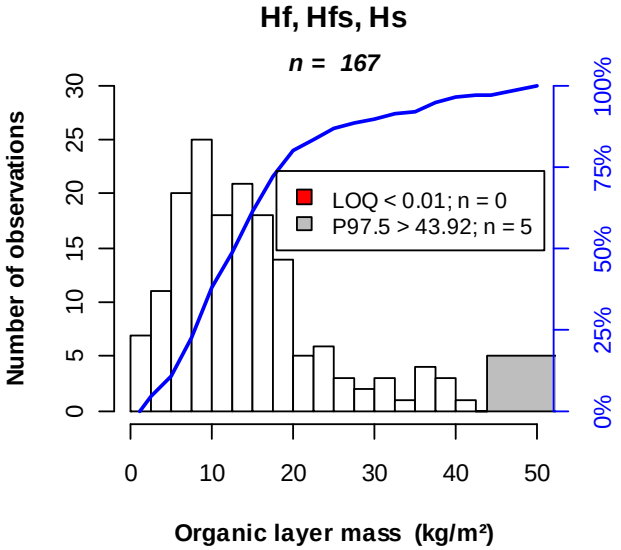


Figure 3.4.6. Absolute and cumulative frequency distribution (in blue) of organic layer mass in hydromorphic forest floor layers of all BioSoil+ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above the 97.5 percentile.

We set the limit of quantification to 0.01 kg m^{-2}, which is also the minimum numerical precision that could be reported. About 0.3 % of all OL observations and 1.5 % of OFH masses were zero-values, considered as left censored values for the statistical calculation. Both distributions are clearly positively skewed (skewness 41.7 and 7.1 respectively). The dry mass of 95 % of all measured OFH layers ranges from 0.17 to 21.1 kg m^{-2}, and the median mass (i.e. 3.00 kg DM m^{-2}) is almost 5 times larger than for OL. Less than 2.5 % of all OFH observations show masses greater than 21.1 kg m^{-2}, up to 135 kg m^{-2} in an extreme situation.

In hydromorphic forest floors (H layers), organic matter is accumulated under reduced conditions due to very slow

decomposition. This is clearly illustrated in Figure 3.4.6 compared to Figure 3.4.5. The 95 % range for H layers is between 1.03 and 43.9 kg m^{-2} which is double as wide as for OL and OFH layers. The median value is 12.7 kg m^{-2}, over 4 times greater than for OFH layers.

The geographical distribution of the forest floor mass is shown in Map 6 in Annex III. The maps include the mass of the OL layer when available. Masses of more than 10 kg m^{-2} are mainly found in the Southern part of Sweden but also in central Europe high forest floor mass has been recorded. Masses of lower than 1 kg m^{-2} are mainly found in Southern Europe.

Peat soils

Some countries reported the dry mass of their peat layers. It is evident that the dry mass is strongly related with the layer thickness: H24 layers are expected to have twice as much dry mass as M12, at least when the bulk density of these layers is comparable.

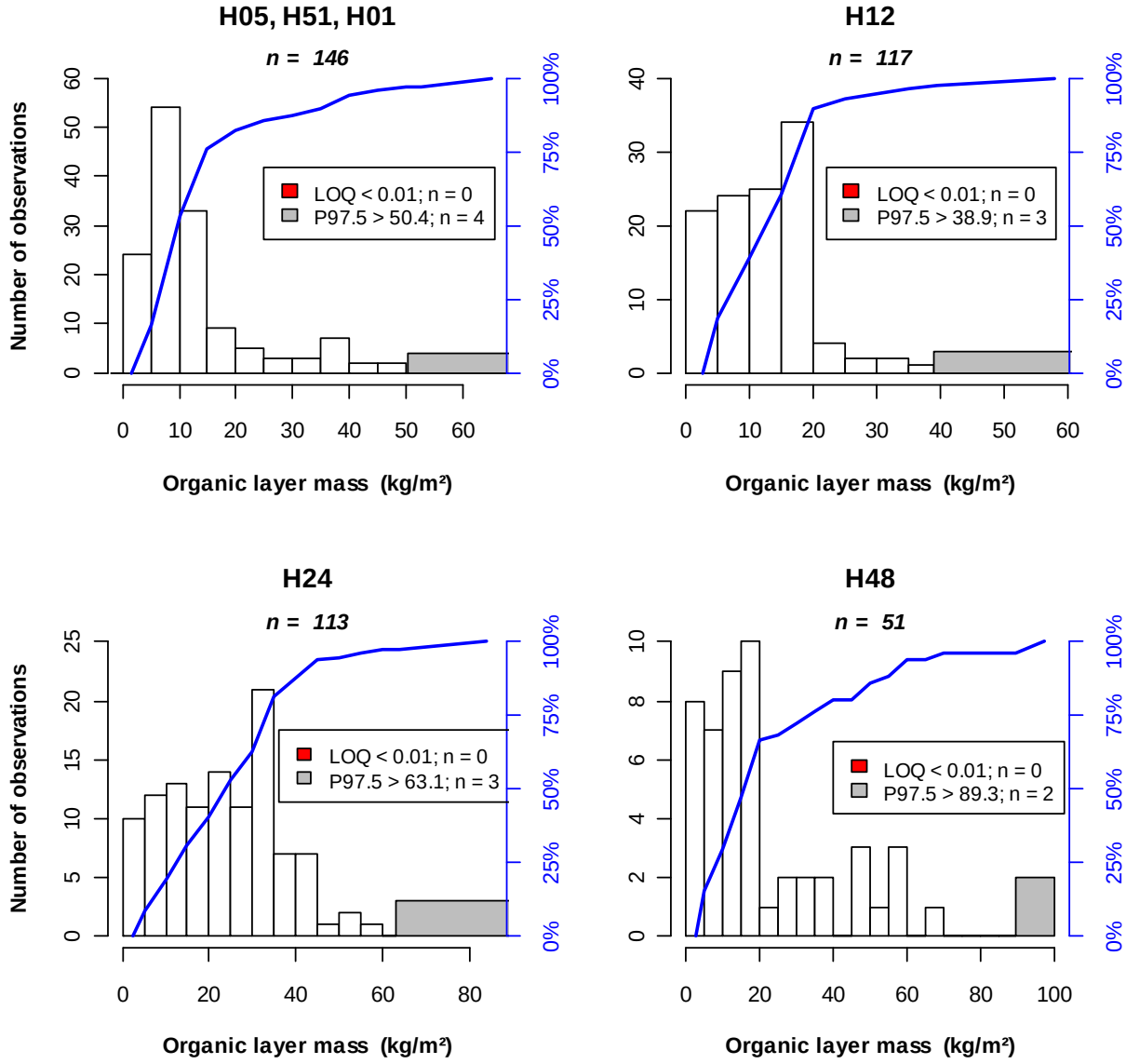


Figure 3.4.7. Absolute and cumulative frequency distribution (in blue) of organic layer mass in peat layers of all BioSoil⁺ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above the 97.5 percentile.

Histograms of the dry mass for the reported H layers are presented in Figure 3.4.7. The 95 % range of the H01 layer dry mass ranges from 1.61 to 50.4 kg DM m^{-2}, with a median value of 9.46

kg DM m^{-2}. So, per cm of peat, mass is about 0.95 kg m^{-2}. From 10 to 20 cm of depth, the median is 13.0 kg m^{-2}, suggesting a slightly higher density (1.30 kg m^{-2} cm^{-1} thickness or equivalent to a bulk density of 130 kg m^{-3}). The 95 % range is 1.37 to 38.9 kg DM m^{-2}. In the H24 layer, the 95 % range is comprised within 2.74 – 63.0 kg DM m^{-2}, and the median value is 23.5 kg m^{-2}. Per cm of thickness this is 1.18 kg m^{-2}, which is in line with the H01 and H12 estimates. For the H48 layer, 95 % of the rather limited set of observations (n = 51) is between 2.39 and 89.3 kg m^{-2} with median value of 15.3 kg DM m^{-2}. Surprisingly, the dry mass per cm thickness for this layer is just 0.38 kg m^{-2} which deviates strongly from the other layers. A possible reason might be the fact that this layer is often water-saturated which makes accurate sampling (gathering material) very difficult. This is also reflected in a strongly reduced number of reported values compared to the other H layers.

3.4.2.2 Organic layer thickness

Forest Floor

The thickness distribution is only reported here for forest floors, since for mineral and peat layers fixed depths were applied. The histograms for terrestrial layers is given in Figure 3.4.8. For OL layers, thickness has been recorded mainly in steps of 1 cm, except for layers thinner than 1 cm, where sometimes a millimetre scale was applied. Ninety five percent of all OL thicknesses are between 0.1 and 2.8 cm, with a median value of 0.6 cm and a mean of 1.7 cm. One centimetre is indeed most frequently observed. For OF, OH or OFH layers, thickness ranges from 0.2 to 21.1 cm in 95 % of all instances. Still 101 layers thicker than 19 cm were recorded up to 64 cm thick. The median value is 3 cm and the mean 4.3 cm. However, most frequently, a thickness of 1 cm was reported. The frequency decreases rapidly till 10 cm above which less than 10 % of the observations are found.

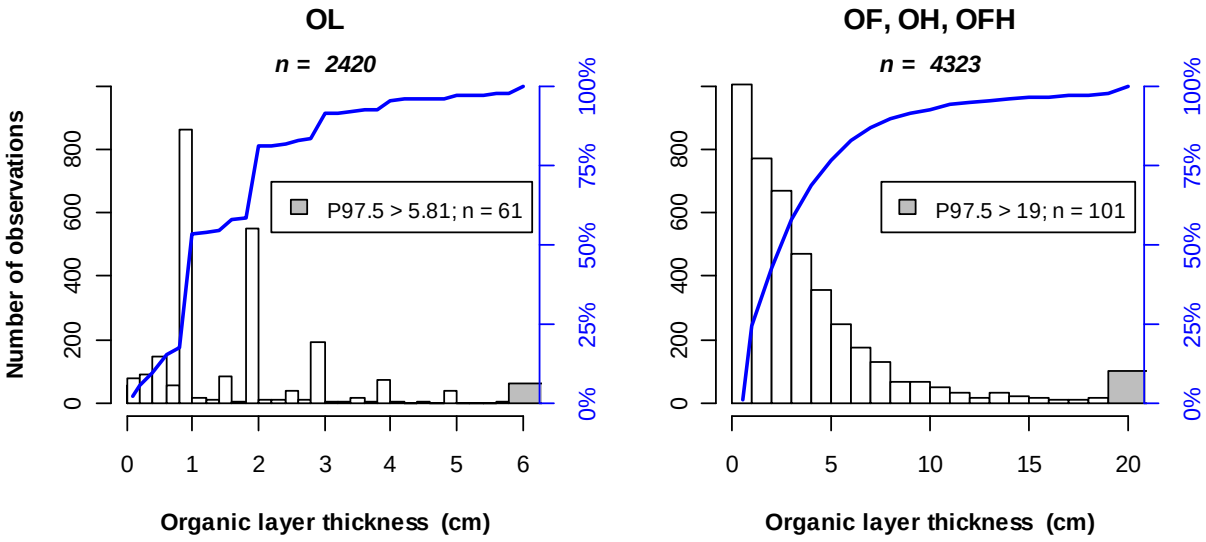


Figure 3.4.8. Absolute and cumulative frequency distribution (in blue) of organic layer thickness in forest floor layers of all BioSoil^{+} plots (Level I and Level II). Grey bars indicate observations above the 97.5 percentile.

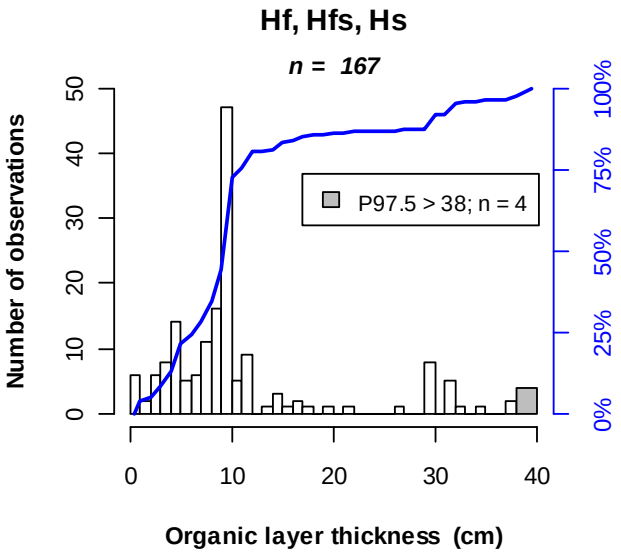


Figure 3.4.9. Absolute and cumulative frequency distribution (in blue) of organic layer thickness of hydromorphic forest floor layers of all BioSoil^{+} plots (Level I and Level II). Grey bars indicate observations above the 97.5 percentile.

In the hydromorphic forest floors, anaerobic conditions retard degradation of organic matter causing thick forest floors. Figure 3.4.9 indicates that ~10 cm thick floors are the most frequently reported ones, while this thickness was rarely observed in well aerated floors. The 95 % range of all observations is in between 1 and 38 cm thickness. The estimated median value is 10 cm and mean 11.8 cm which is about double of the OL and OFH layers combined.

Although thickness was measured for 167 H layers only, it clearly shows their capacity to store significant amounts of carbon and other elements.

3.4.3 Bulk density

3.4.3.1 Measured bulk density

Bulk density (BD) was reported for peat and mineral soil layers. As illustrated in Figure 3.4.10 there is distinct difference between the bulk density of organic (here peat) and mineral matrices. The former show median values around 150 kg m^{-3} and the latter above 1000 kg m^{-3}. The figure also indicates opposite distributions: negatively skewed for mineral layers and positively skewed for peat layers.

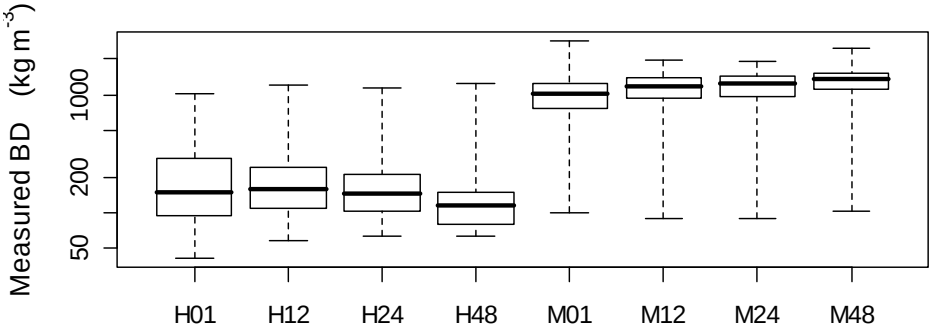


Figure 3.4.10. Box plot of measured bulk density for peat and mineral soil layers. The Y-axis is logarithmic.

Forest Floor

Although not required, bulk density of OFH layers was reported by Bavaria (Germany) for 49 samples only. The BD values ranged from 51 to 269 kg m^{-3}, the median was 145 kg m^{-3} and the mean 149 kg m^{-3}. No BD was reported by any country for OL, Hf, Hs nor Hfs layers. However, bulk density of these layers may be estimated using their properties dry mass and thickness, as discussed in Volume II of this report.

Mineral layers

The distribution of measured fine earth BD values for the soil mineral layers is given in Figure 3.4.11. Contrary to most other soil variables, BD shows left skewed distributions, and skewness to the left seems to increase with depth (from M01 to M48: -0.08, -0.39, -0.65 and -0.71). Extreme values are 88 kg m^{-3} at the lower end and 2847 kg m^{-3} at the high end. Theoretically, bulk density values exceeding 2600 kg m^{-3} are mainly bedrock (Poesen and Lavee 1994) and higher BD_{fe} values are questionable. Bulk density values below 100 kg m^{-3} are usually highly organic layers, which may occur on top of mineral soil or in between mineral layers. For 95 % of the observations however, BD of the topsoil (M01) ranges from 385 to 1561 kg m^{-3}; the median is 1015 kg m^{-3} and the mean 1007 kg m^{-3}. The most frequently observed class (modus) is 1100 - 1200 kg m^{-3}, and some M01 layers show BD lower than 500 kg m^{-3}, all considered as mineral particles intensively mixed with large amounts of organic matter. The number of observations below 500 kg m^{-3} readily decreases with depth, as does the organic matter content. Hence, BD increases with depth. The median increases from M01 to M48 in the order: 1015 < 1180 < 1248 < 1354 kg m^{-3}. Also the 95 % range increases: in the M12 layer BD ranges from 506 to 1645 kg m^{-3}, in M24 from 462 to 1651 kg m^{-3} and in M48 from 583 to 1728 kg m^{-3}. In the M48 layer, BD values around 1500 kg m^{-3} are frequently found. Observations greater than 1800 kg m^{-3} are only found in 0.4 % of all sampled layers, mostly in the subsoil. More statistical data are tabularised in Annex II.

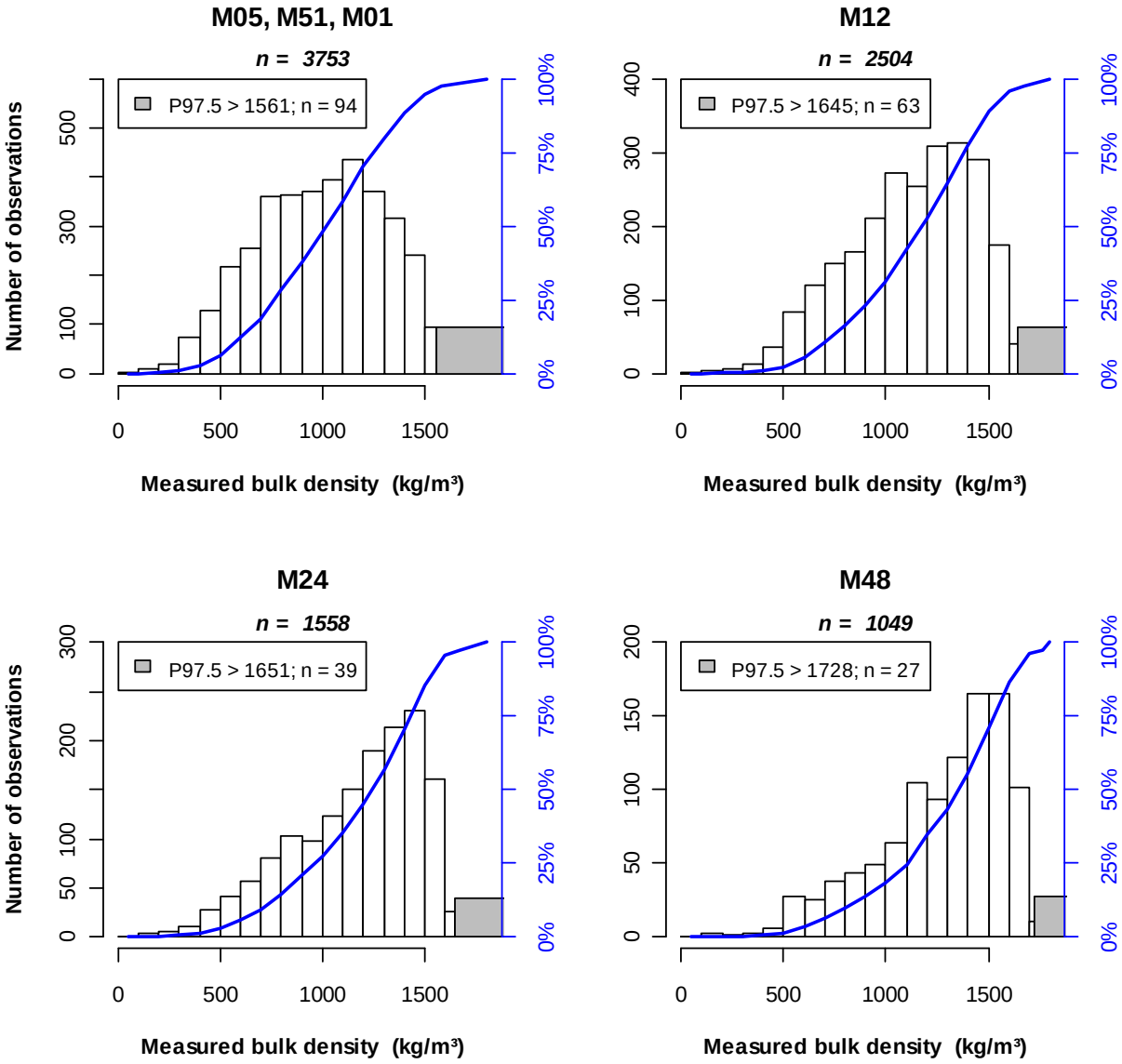


Figure 3.4.11. Absolute and cumulative frequency distribution (in blue) of measured bulk density in mineral soil layers of all BioSoil⁺ plots (Level I and Level II). The grey bars indicate observations above the 97.5 percentile.

Peat soils

Few peat layers were sampled for BD, although these data are essential for stock calculations and are often lacking in soil databases. From their histograms given in Figure 3.4.12 it is clear that positively skewed distributions appear (skewnesses from 2.2 to 3.8), opposite to those of mineral soils as mentioned above. Here, peat and other organic materials with BD typically around 150 kg m^{-3} occur in various mixtures with mineral particles which may increase the BD accordingly.

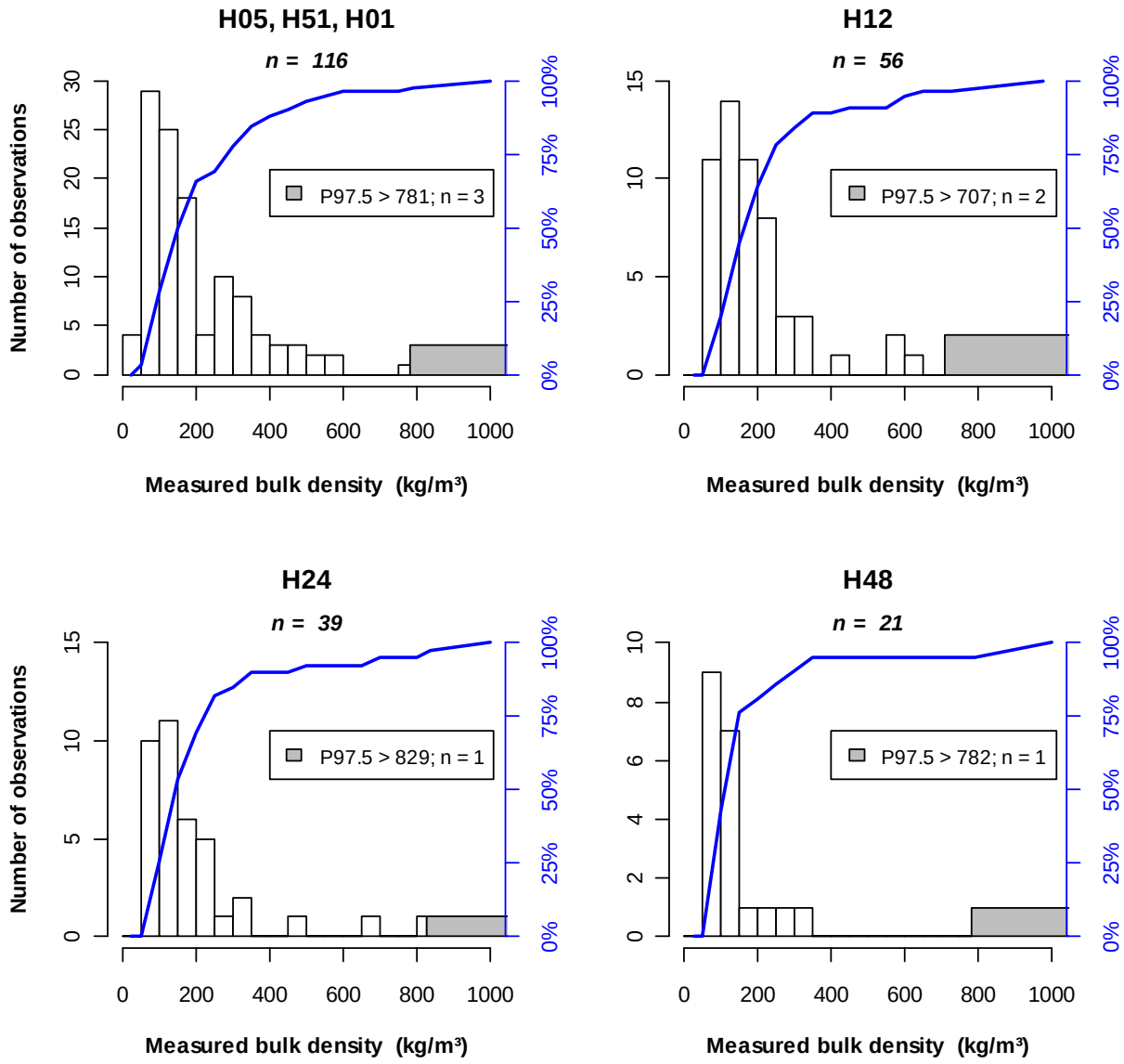


Figure 3.4.12. Absolute and cumulative frequency distribution (in blue) of measured bulk density in peat layers of all BioSoil⁺ plots (Level I and Level II). The grey bars indicate observations above the 97.5 percentile.

Based on the restricted dataset, 95 % ranges are similar for all depths, varying from ~50 kg m^{-3} to 830 kg m^{-3}, but measurements between 400 and 800 kg DM m^{-3} are rarely reported. Median values range from 117 to 158 kg m^{-3}.

3.4.3.2 Estimated bulk density

For Level I it was accepted to estimate BD using pedotransfer functions, for Level II assessments BD may have been estimated based on previous observations. Both approaches yield 'estimated' BD values an their distributions are reported here. In case both measured and estimated BD were reported for the layers, their correspondence is analysed in Volume II of this report.

Forest Floor

Latvia reported estimated BD values for 69 OFH layers and Sweden for 14 OH layers. No country reported estimated BD data for OL, Hf, Hs or Hfs layers. For the OH and OFH layers combined, minimum BD is 60 kg m^{-3} and maximum 1004 kg m^{-3}, whereas the 95 % range is comprised within 84 – 923 kg m^{-3}. The median is 150 kg m^{-3} and mean 281 kg m^{-3}. Although the median is close to the one found for measured BD, the range is much wider towards the higher end.

Mineral layers

In deeper soil layers (M24 and M48), bulk density is more estimated than measured. This justifies the analysis of the distributions of the estimated values (Figure 3.4.13). Again, left skewed distributions were found for each fixed depth layer. Skewness is highly comparable with measured BD distributions for all layers, unlike for M01 where skewness is -0.36 compared to -0.08 for measured BD. However, for a given layer, the median values are similar between the measured and estimated datasets, for instance 1015 and 1052 kg DM m^{-3} for the M01 layer. The 2.5-percentiles (399 - 739 kg m^{-3}) are slightly higher than for measured values whereas the 97.5-percentiles (1531 – 1701 kg m^{-3}) are slightly lower. In all, no substantial deviances between measured and estimated distributions were found.

The geographical distribution of the bulk density in the upper 10 cm of the soil is shown in Map 7 in Annex III. Low bulk densities are found in those regions where soils with organic rich topsoils have been described, such a the north of Europe, Ireland and Scotland where peat soils occur, in Galicia where Umbrisols are found and in the Alps. Relatively high bulk densities are mainly described in the sandy regions such as Poland or the Landes in France, along with some areas in Hungary. Also in large areas of Spain high values have been measured.

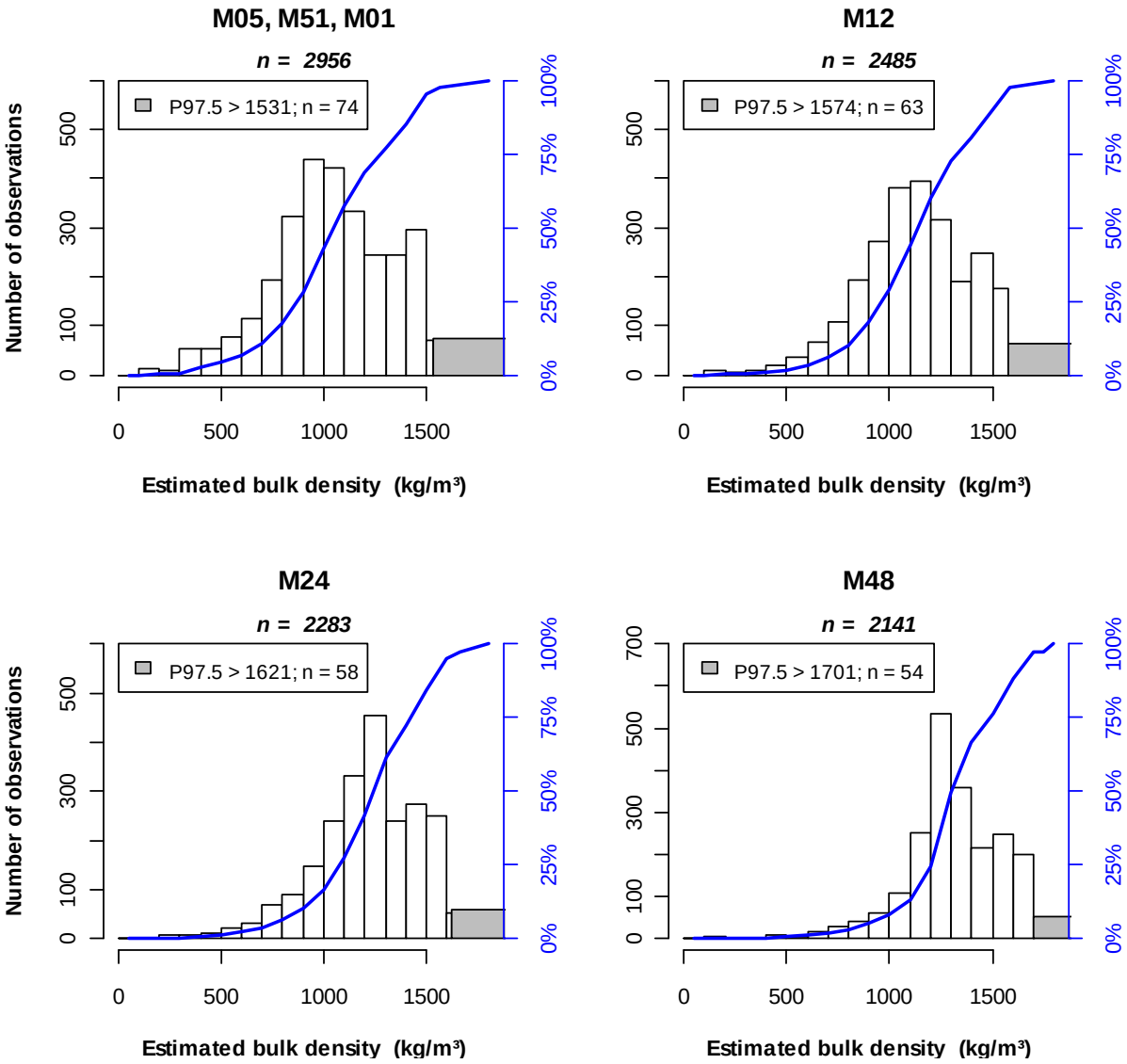


Figure 3.4.13. Absolute and cumulative frequency distribution (in blue) of estimated bulk density in mineral soil layers of all BioSoil⁺ plots (Level I and Level II). The grey bars indicate observations above the 97.5 percentile.

Peat soils

Very few (n = 65) estimated BD values for peat soil layers were reported. Minimum value over all layers is 79 kg m^{-3} and the maximum BD is 860 kg m^{-3}. The 95 % range for all layers is from 88 to 758 kg DM m^{-3} and does not vary substantially among layers. The median BD slightly decreases with depth, from 250 kg m^{-3} in M01 to 159 kg m^{-3} in M48, but these might be biased by the sampled subset. No inference may be made on its vertical distribution. The medians of estimated BDs are generally greater than the median of measured BDs for each layer.

3.4.4 Coarse fragments

Analysis of coarse fragments was mandatory for mineral soil layers. Sporadically some countries reported coarse fragments in forest floors and peat soils too, but mostly the reported value is 0 % (indicating no coarse fragments observed), or rarely admixtures up to 30 % by volume or 70 % by mass are given. Overall, the number of observations for organic layers is too low for inference of proper distribution patterns. Coarse fragments for mineral soils are reported based on percentage of mass and/or volume. Mass percentage of coarse fragments in mineral soils ranges from 0 % (absent, occurs in maximally 24 % of the observed samples) to 100 % (pure gravel or bedrock). Ninety-five percent of the samples comprise coarse fragments between 0 % and 76.1 % DM (Figure 3.4.14*).* For all depths, by far most samples hold coarse fragments in the 0 - 5 % class while the frequency strongly decreases in higher classes drawing a right tailed distribution. The median values vary from 3.72 to 7.11 %.

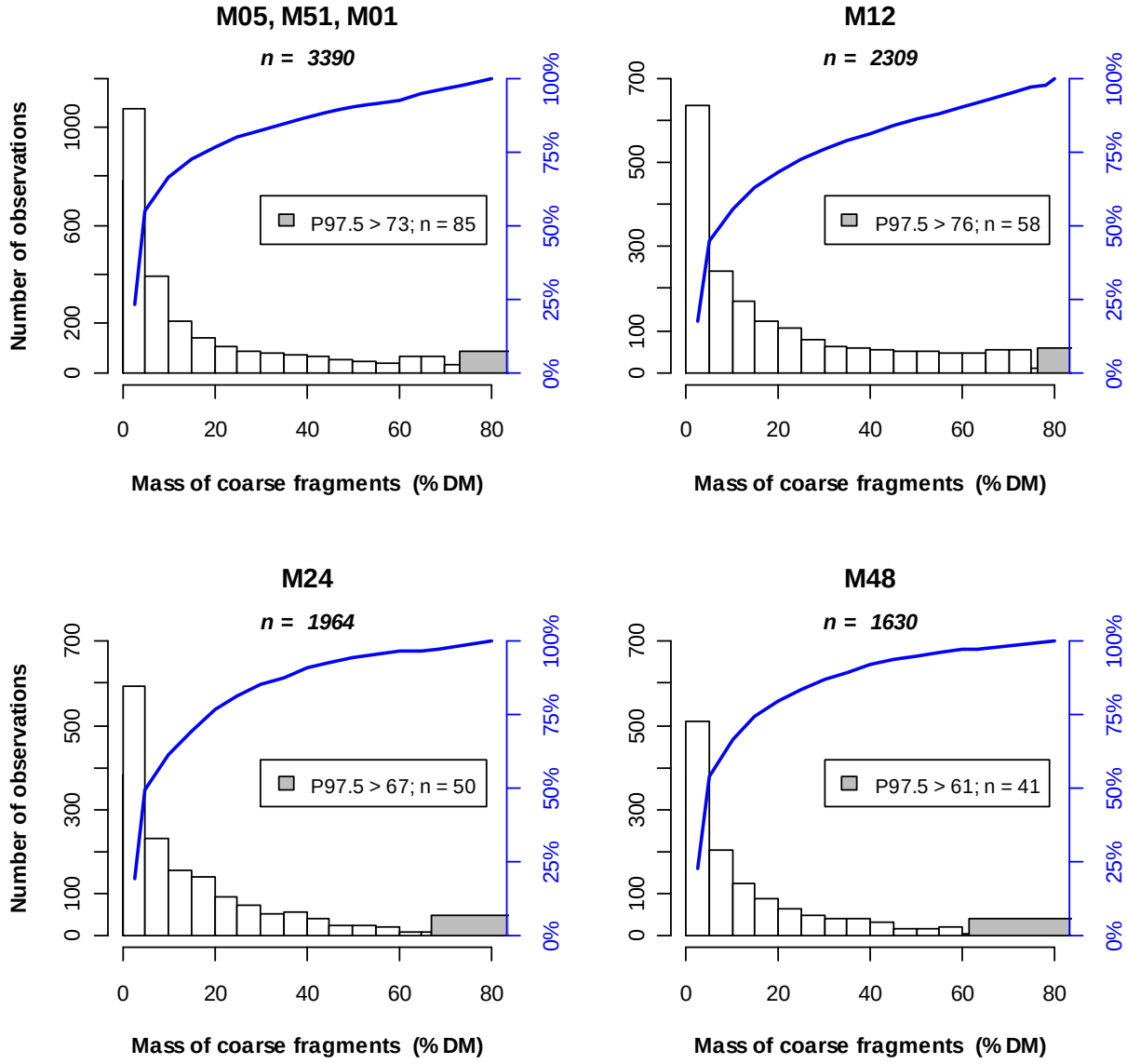


Figure 3.4.14. Absolute and cumulative frequency distribution (in blue) of mass based coarse fragments in mineral soil layers of all BioSoil⁺ plots (Level I and Level II). The grey bars indicate observations above the 97.5 percentile.

The distributions of volume based content of coarse fragments are given in Figure 3.4.15. Again, the smallest class (0 - 5 vol %), holds most observations. The median values are 16.5 % for M01, ~20 % for M12 and M24 and 30 % by volume for M48. The 95 % range for all layers varies from 0 % to 85 % of the soil volume occupied by coarse fragments, and apart from the first two classes (< 10 vol %), classes up to 30 vol % are quite evenly represented and then decrease for layers till 40 cm. Conversely, in the M48 layer, observations of very gravely substrates (40 – 80 vol % of coarse fragments) are reported. More statistics are tabularized in Annex II.

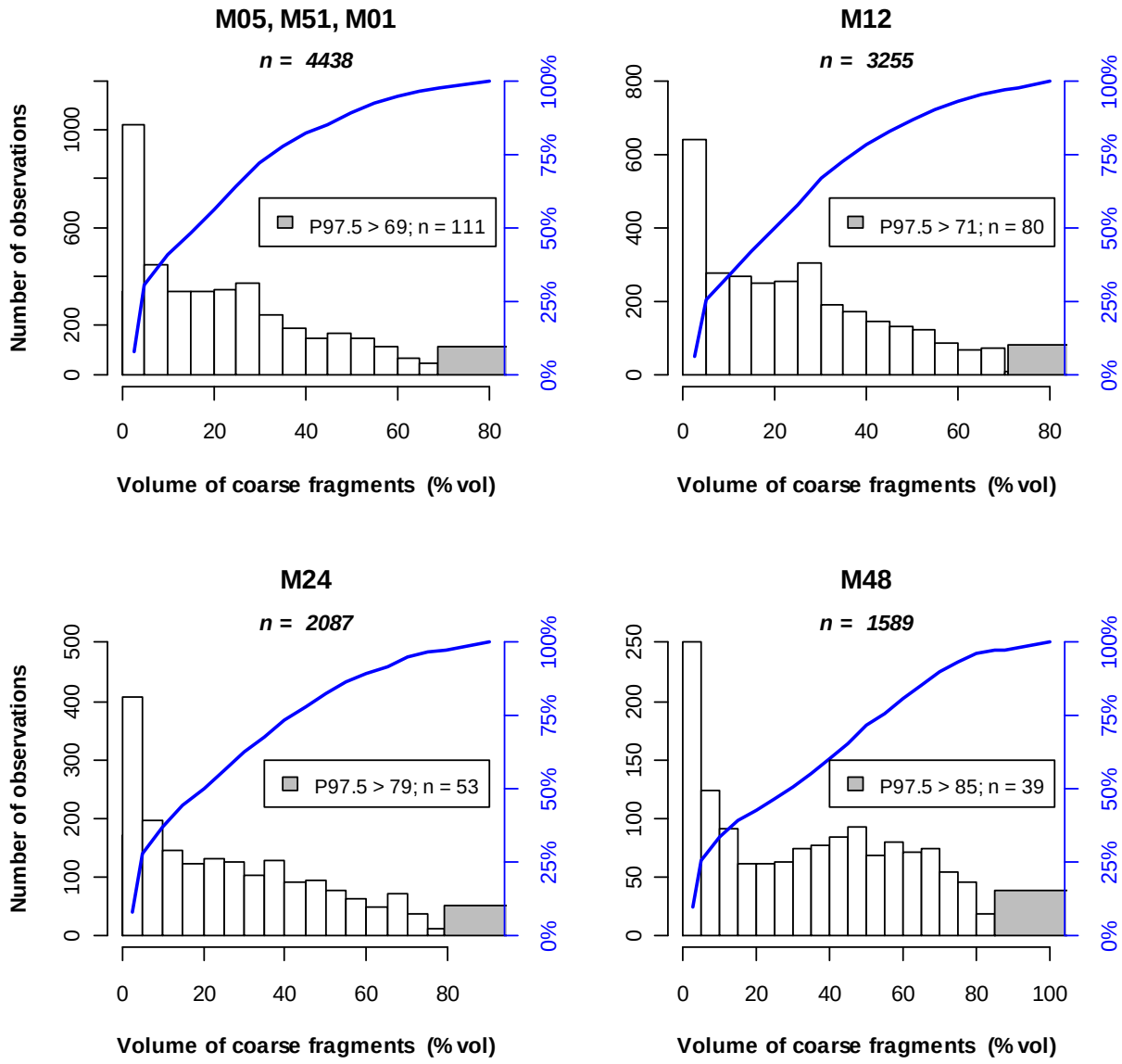


Figure 3.4.15. Absolute and cumulative frequency distribution (in blue) of volume based coarse fragments in mineral soil layers of all BioSoil⁺ plots (Level I and Level II). The grey bars indicate observations above the 97.5 percentile.

The geographical distribution of the volumetric percentage of coarse fragments in the upper 10 cm of the soil is shown in Map 8 in Annex III. Data of the extended dataset have been used, which means that when only mass % was available the volume coarse fragments were estimated based on the mass %. None or very few coarse fragments are found in large areas in the Baltic states, Denmark, northern Germany, Poland, the Landes in France, Great Britain and Flanders. Note that the kriged maps shows many blank areas indicating missing values. Abundant stone contents in the topsoil are mainly concentrated in Finland and Spain.

3.4.5 Soil reaction

Soil reaction, measured both as pH-$CaCl_2$ (potential pH) and pH-H_2O (actual pH), is determined in forest floor, mineral soil and peat layers. The distributions for pH-$CaCl_2$ are summarized in Figure 3.4.16. The peat layers (H01 to H48) are clearly most acid. In the mineral layers, median pH increases with depth whereas it decreases in the forest floor profile. The box plot pattern for pH-H_2O is similar. The respective distributions and general statistics are described in next sections and tabularized in Annex II.

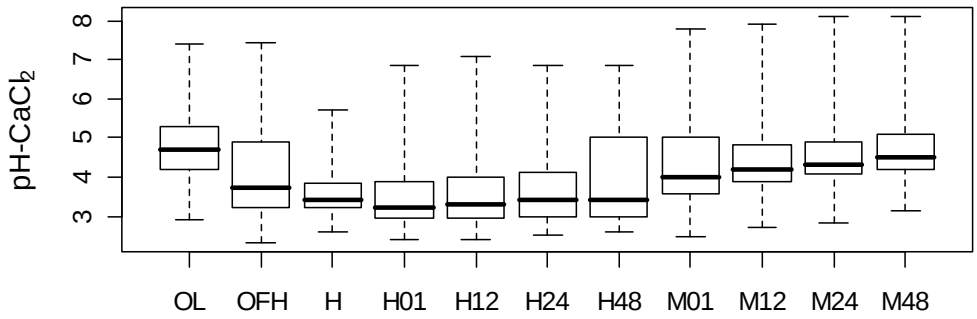


Figure 3.4.16. Box plot of potential pH (pH-$CaCl_2$) for all investigated layers

3.4.5.1 pH-$CaCl_2$

Forest Floor

In the litter layer (OL), pH-$CaCl_2$ ranges from 2.9 to 7.4, with median value 4.7 and mean 4.8. The nearly unimodal distribution (Figure 3.4.17) centred around the mean is complemented with 62 values (~8 %) above 6. Ninety-five percent of all observations range from 3.4 to 6.9.

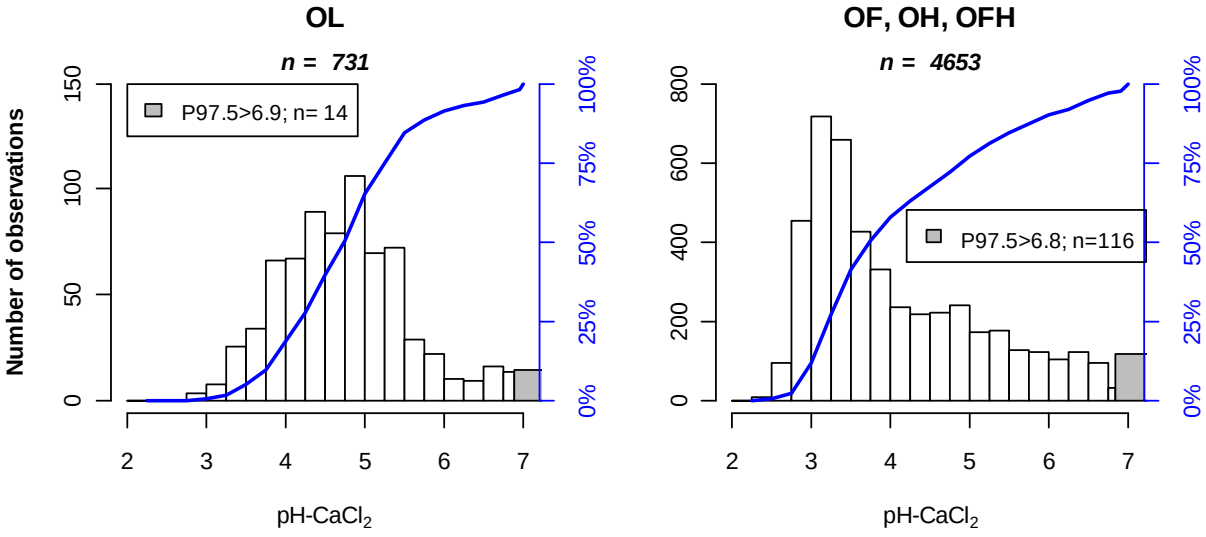


Figure 3.4.17. Absolute and cumulative frequency distribution (in blue) of pH-$CaCl_2$ in forest floor layers of all BioSoil$^+$ plots (Level I and Level II). The grey bars indicate observations above the 97.5 percentile.

In contrast, the pH-$CaCl_2$ distribution of the fragmentation (OF), humus (OH) or combined (OFH) layers is more complex. The pH-$CaCl_2$ min - max range is 2.3 – 7.5. The frequency pattern shows that class 3.0-3.25 is most dominant and that the number of observations in subsequent classes

decreases gradually. The median value of 3.7 is exactly one unit lower than for the OL layer. The mean pH-$CaCl_2$ is 4.15 and the 95 % range is 2.77 - 6.83. It shows that the potential pH of OF and OH layers is generally lower than the pH-$CaCl_2$ of the OL layers.

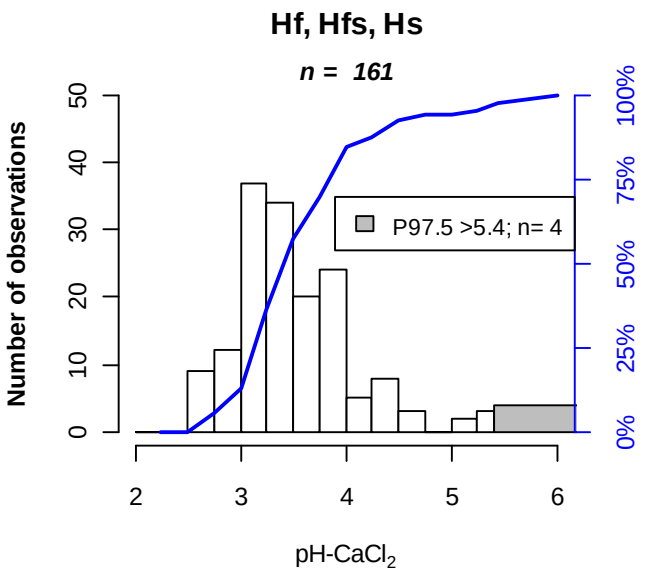


Figure 3.4.18. Absolute and cumulative frequency distribution (in blue) of pH-$CaCl_2$ in hydromorphic forest floor layers of all BioSoil+ plots (Level I and Level II). The grey bars indicate observations above the 97.5 percentile.

In hydromorphic (semiterrestrial) forest floor layers (Hf, Hfs, Hs) the observed pH-$CaCl_2$ range is more narrow: 2.6 - 5.7 and indicates also much more acidified conditions than in terrestrial layers. Most frequent values are within the pH-$CaCl_2$ 3 – 3.25 range (Figure 3.4.18) and very few observations are found exceeding pH 5.5. The calculated median pH-$CaCl_2$ value is 3.4 and the mean is 3.6. Note that the number of reported observations (n = 161) is rather low compared to the OL (n = 731) and OFH (n = 4653) layers. Hence, generalisation for the soil reaction of these layers across Europe is rather tentative.

Mineral layers

The frequency distributions for mineral layers at four depth intervals are given in Figure 3.4.19. In the 0 - 10 cm layer, pH-$CaCl_2$ ranges from 2.5 to 7.8 but the 95 % range is 3.0 - 7.4. The median value is 4.0 and mean 4.5, although most observations are situated within the 3.75 – 4.0 class. In this bimodal distribution, calcareous soils exhibit a second peak within the pH 7.0 – 7.5 range which is visible at all depths. Figure 3.4.19 also shows that the distribution clearly shifts to the right with increasing depth. It confirms that pH generally increases with depth (or acidity decreases). The median and mean values increase: median 4.2 (mean 4.6) in M12 < median 4.3 (mean 4.7) in M24 < median 4.5 (mean 4.9) in M48. The $P_{97.5}$ level also increases but the number of exceeding observations decreases probably due to much less M48 samples compared to for instance M01. Al these numerical data are given in Annex II.

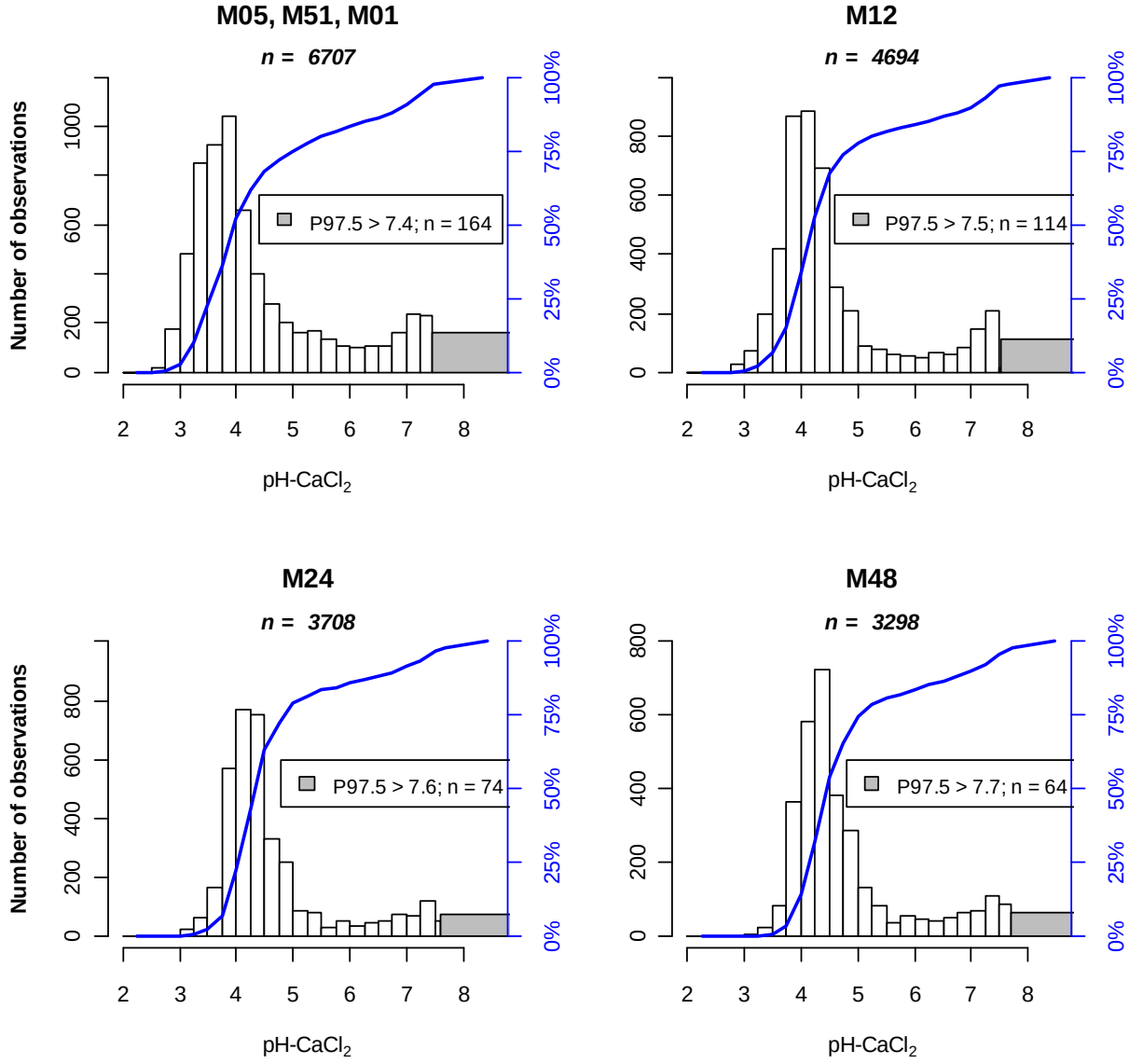


Figure 3.4.19. Absolute and cumulative frequency distribution (in blue) of pH-$CaCl_2$ in mineral layers of all BioSoil$^+$ plots (Level I and Level II). The grey bars indicate observations above the 97.5 percentile.

Peat soils

The pH-$CaCl_2$ distribution of peat soils is displayed in Figure 3.4.20. In contrast to the mineral soil, distributions do not clearly shift here with increasing depth. Most observations remain in the pH class 2.5 - 3.5, indicating very acidified conditions. Apparently, relatively more observations are found in the pH 4 – 6 range for M48 than for the other layers. The kurtosis of the M48 distribution (kurtosis = 2.03) is much lower than for the other distributions (kurtosis > 3.9). Median values slightly raise with increasing depth: 3.20, 3.30, 3.40, 3.43 just like the mean values (i.e. 3.56, 3.65, 3.74, 4.05) for M01, M12, M24 and M48 respectively. The $P_{97.5}$ value remains rather stable not exceeding 6.5.

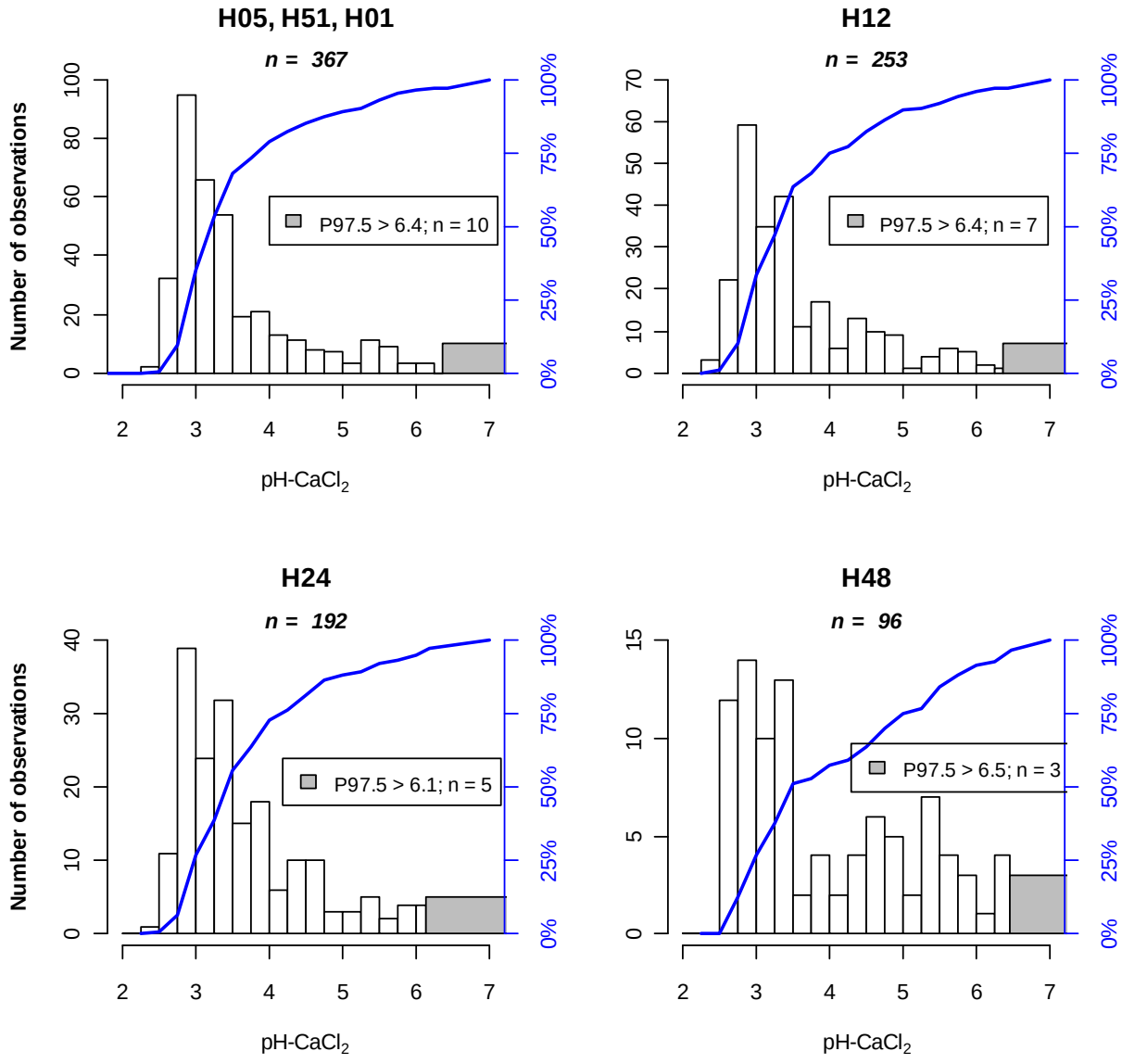


Figure 3.4.20. Absolute and cumulative frequency distribution (in blue) of pH-$CaCl_2$ in peat layers of all BioSoil⁺ plots (Level I and Level II). The grey bars indicate observations above the 97.5 percentile.

Map 9 in Annex III shows the geographical distribution across Europe of the pH-$CaCl_2$ in the upper 10 cm of mineral and peat soils based on the BioSoil⁺ Level I and II data. There is a clear gradient of increasing pH from Northwest to Southeast except for some slightly calcareous areas in Estonia and Latvia.

3.4.5.2 pH-H_2O

Forest Floor

In the litter layer (OL), pH-H_2O ranges from 3.7 to 7.2, with both median and mean value equal to 5.1. The distribution is unimodal (skewness = 0.24) with clearly most observations in class 5 - 5.25 (Figure 3.4.21). Ninety-five percent of all pH observations are within 4.0 – 6.4.

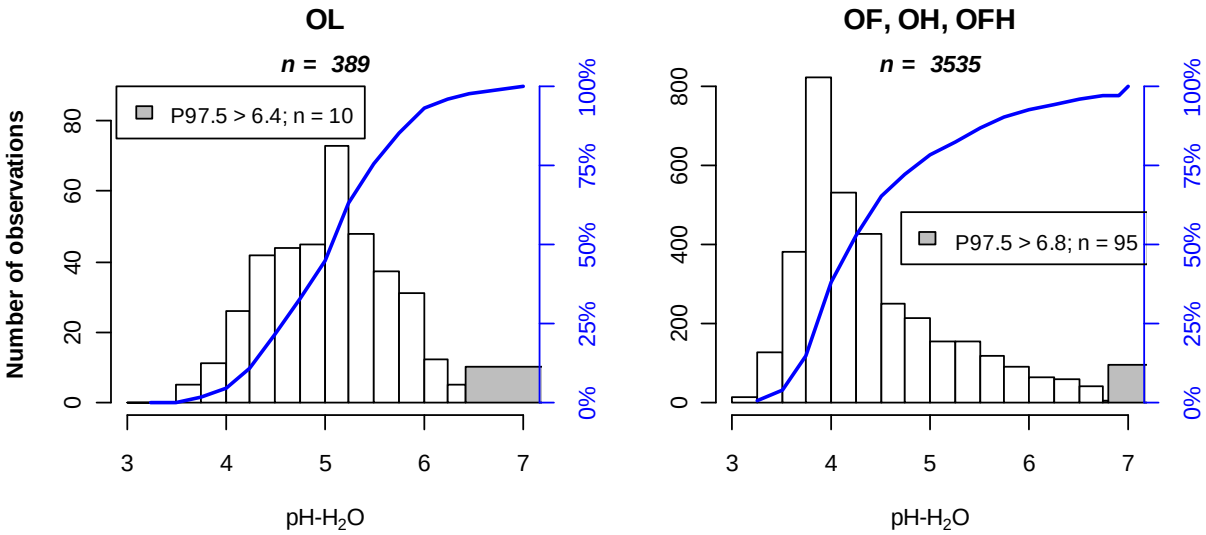


Figure 3.4.21. Absolute and cumulative frequency distribution (in blue) of pH-H_2O in forest floor layers of all BioSoil$^+$ plots (Level I and Level II). The grey bars indicate observations above the 97.5 percentile.

In contrast, the pH-H_2O distribution of the fragmentation (OF), humus (OH) or combined (OFH) layers is skewed to the right (skewness = 4.34). The pH-H_2O min - max range is 3.1 – 7.9.

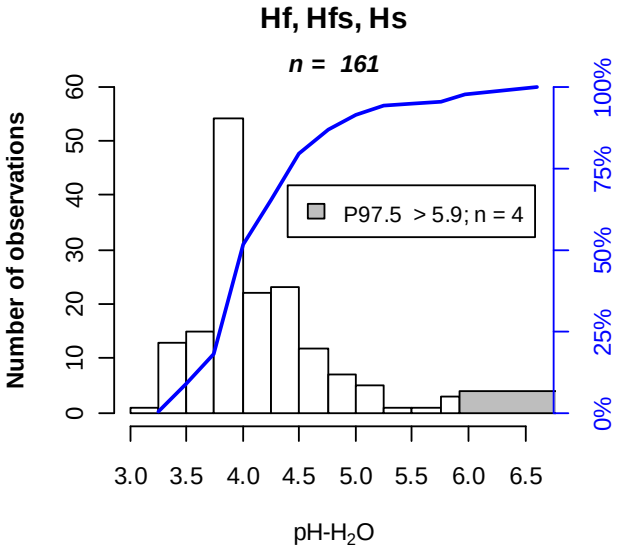


Figure 3.4.22. Absolute and cumulative frequency distribution (in blue) of pH-H_2O in hydromorphic forest floor layers of all BioSoil$^+$ plots (Level I and Level II). The grey bars indicate observations above the 97.5 percentile.

The frequency pattern shows that class 3.75 - 4.0 holds most observations and that this number decreases gradually. The OFH median value of 4.2 is exactly 1.1 unit lower than for the OL layer. The mean pH-H_2O is 4.5 and the 95 % range is 3.5 – 6.8. It shows that the actual pH of OF and OH layers is generally lower than for OL layers.

In the hydromorphic forest floor layers (Hf, Hfs, Hs) the observed pH-H_2O range is more narrow: 3.3 – 6.6 and indicates also much more acidified conditions than in terrestrial layers. Most frequent values are within the pH-H_2O 3.75 - 4.0 range (Figure 3.4.22) and very few observations are found exceeding pH 6. The calculated median pH-H_2O value is 4.0 and the mean is 4.2.

Mineral layers

The frequency distributions for mineral layers at four depth intervals are given in Figure 3.4.23. In the 0 - 10 cm layer, pH-H_2O ranges from 3.2 to 8.6 but the 95 % range is 3.7 - 7.8. The median value is 4.5 and mean 4.8, and most observations are situated within the 4.25 – 4.5 class. Bimodal distributions are mainly noticeable for the layers below 10 cm, although the distribution of higher pH values in calcareous soils is weak. Similarly as for pH-$CaCl_2$, the distribution clearly shifts to the right with increasing depth. The increase from M01 to M48 is indicated by the median values (i.e. 4.5 < 4.8 < 5.0 < 5.2) and mean values (i.e. 4.8 < 5.1 < 5.3 < 5.5). The $P_{97.5}$ level also increases with depth as shown in Figure 3.4.23.

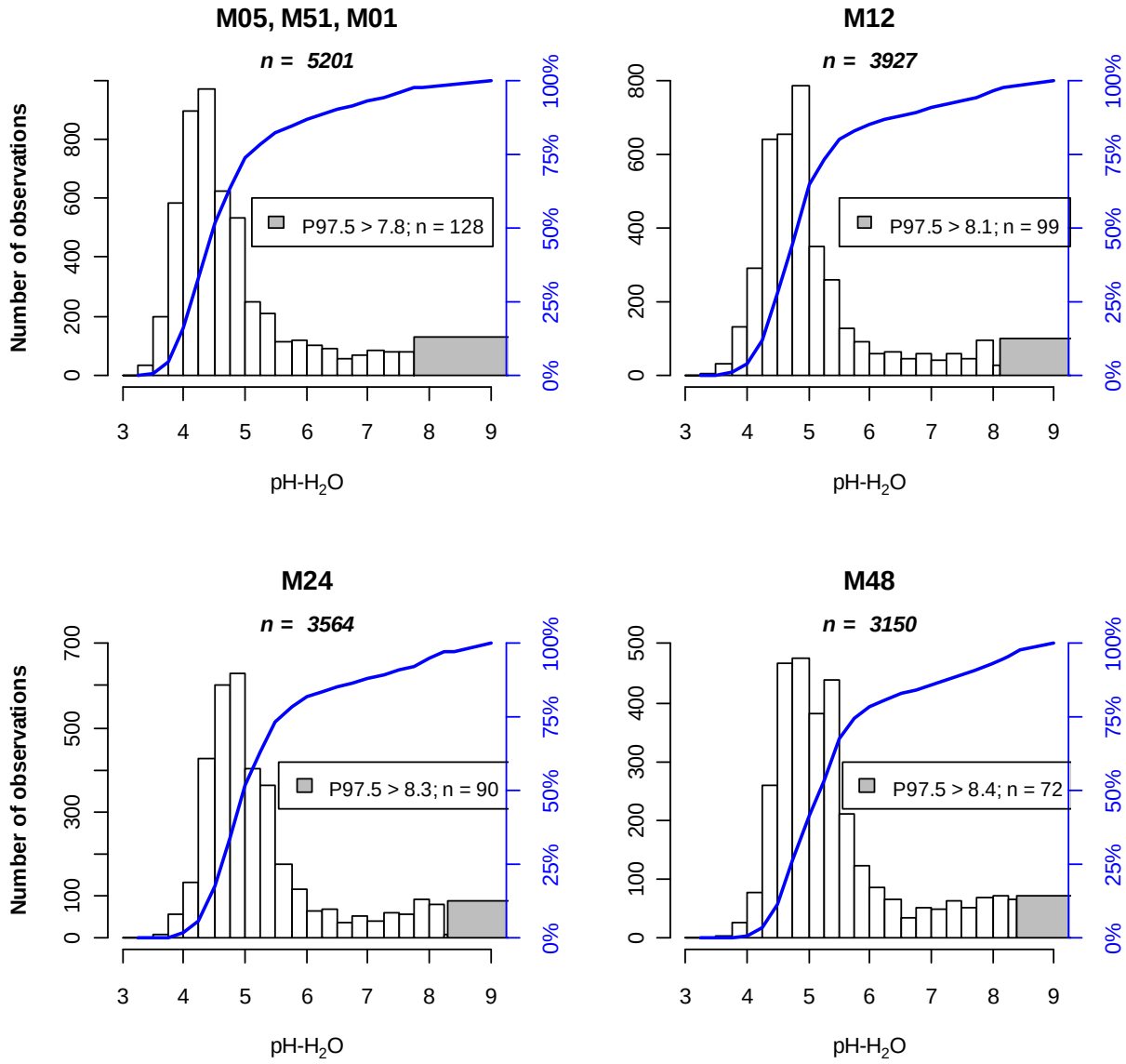


Figure 3.4.23. Absolute and cumulative frequency distribution (in blue) of pH-H_2O in mineral soil layers of all BioSoil$^+$ plots (Level I and Level II). The grey bars indicate observations above the 97.5 percentile.

Peat soils

The pH-H_2O distribution in peats is displayed in Figure 3.4.24. Most observations remain in the range 3.25 – 4.25, indicating very acidified conditions. Apparently, relatively more observations are found in the pH 5 - 7 range for M48 than for the other layers. The kurtosis of the M48 distribution (kurtosis = 1.82) is much lower than for the other distributions (kurtosis > 3.7). Median values slightly raise with increasing depth: 4.0, 4.0, 4.1, 4.5 just like the mean values (i.e. 4.2, 4.4, 4.4, 4.7) for M01, M12, M24 and M48 respectively. Thus, the greatest increase is found in the M48 layer.

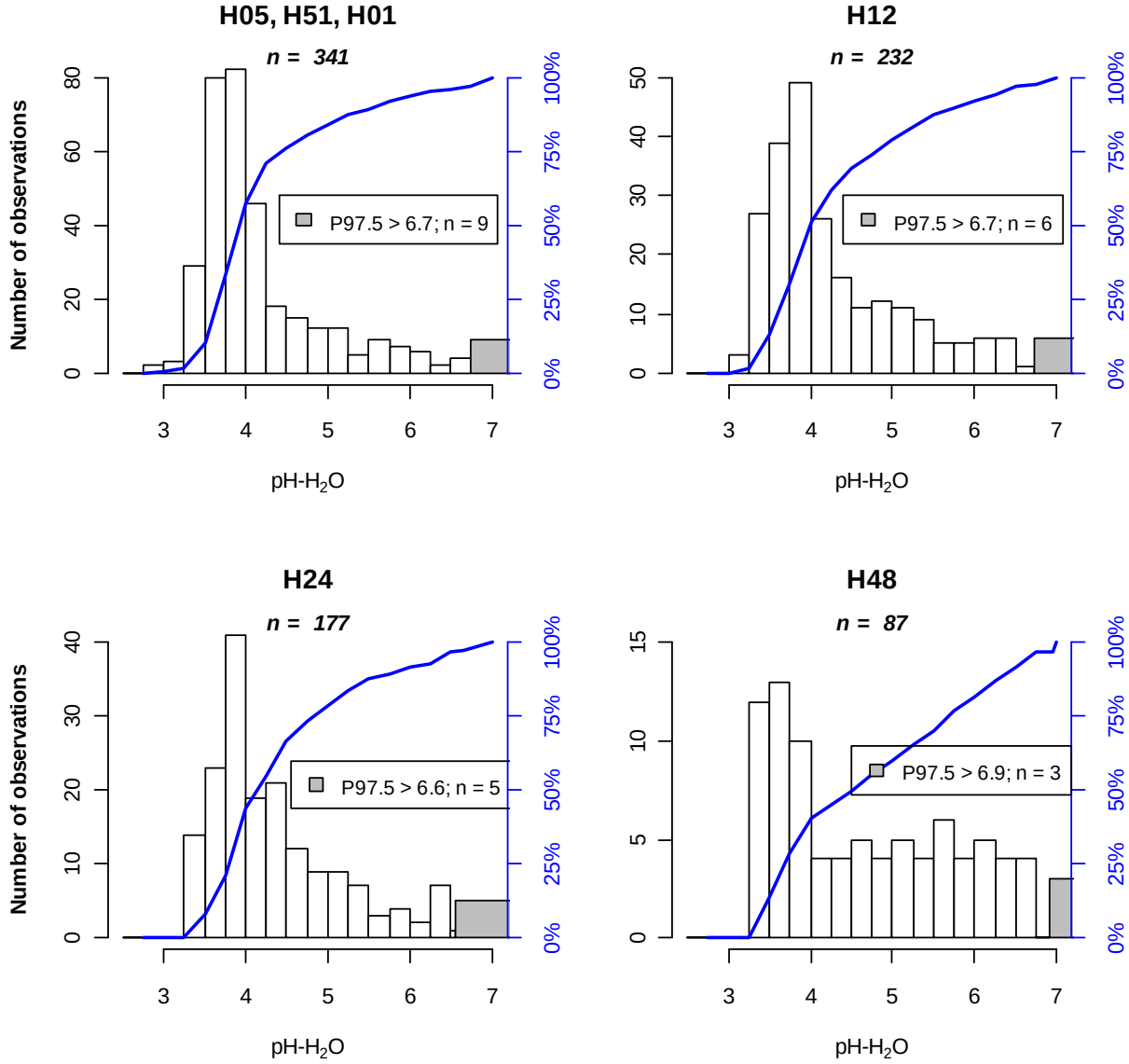


Figure 3.4.24. Absolute and cumulative frequency distribution (in blue) of pH-H_2O in peat layers of all BioSoil$^+$ plots (Level I and Level II). The grey bars indicate observations above the 97.5 percentile.

3.4.6 Carbonates

Carbonates were mainly reported for mineral layers (Table 2.6.14). A limited number of observations for organic layers are present in the BioSoil^{+} database, though mostly too few (n < 25) for the development of useful histograms. Furthermore, the manual requested only carbonate analysis when pH-$CaCl_2$ exceeded 5.5 for organic layers and 6 for mineral layers. Even with that restriction many reported values are below or near the LOQ (Figure 3.4.25). Hence, any statistic based on data below the horizontal line (LOQ threshold) is unreliable or invalid and must be estimated using methods for censored data. The graph shows that carbonates in peat soils (H01 till H48) and OL layers are mainly below the LOQ.

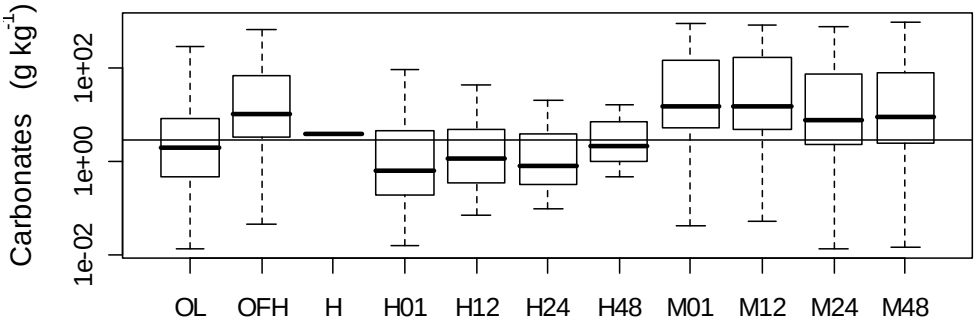


Figure 3.4.25. Box plot of carbonate contents in organic and mineral layers, including values below LOQ (horizontal line at 3 g kg^{-1}). The whiskers extend to the minimum and maximum data values.

Mineral layers

About half (46 to 58 %) of the reported carbonate analyses in mineral soils are below the limit of quantification (Figure 3.4.26). They comprise zero-values, '-1' values and values < 3 g kg^{-1}. The other half is mainly situated below 661 g kg^{-1} (2.5 % of the observations is greater). The number of observations is slowly declining with increasing carbonate content. Contrary to expectation, no clear distribution pattern was found for higher carbonate contents. Median values are similar for M01 and M12 (~15 g carbonate kg^{-1}) and are lower in M24 (8 g kg^{-1}) and M48 (9 g kg^{-1}). General statistics are tabularised in Annex II.

Peat soils

A limited number of observations (max 28 per layer) were reported for H01, H12, H24 and H48 layers. Over 58 % of the carbonate values are below LOQ in peats. Median values range from 0.66 to 2.09 g kg^{-1}. No carbonate content greater than 100 g kg^{-1} was reported. More statistics are given in Annex II.

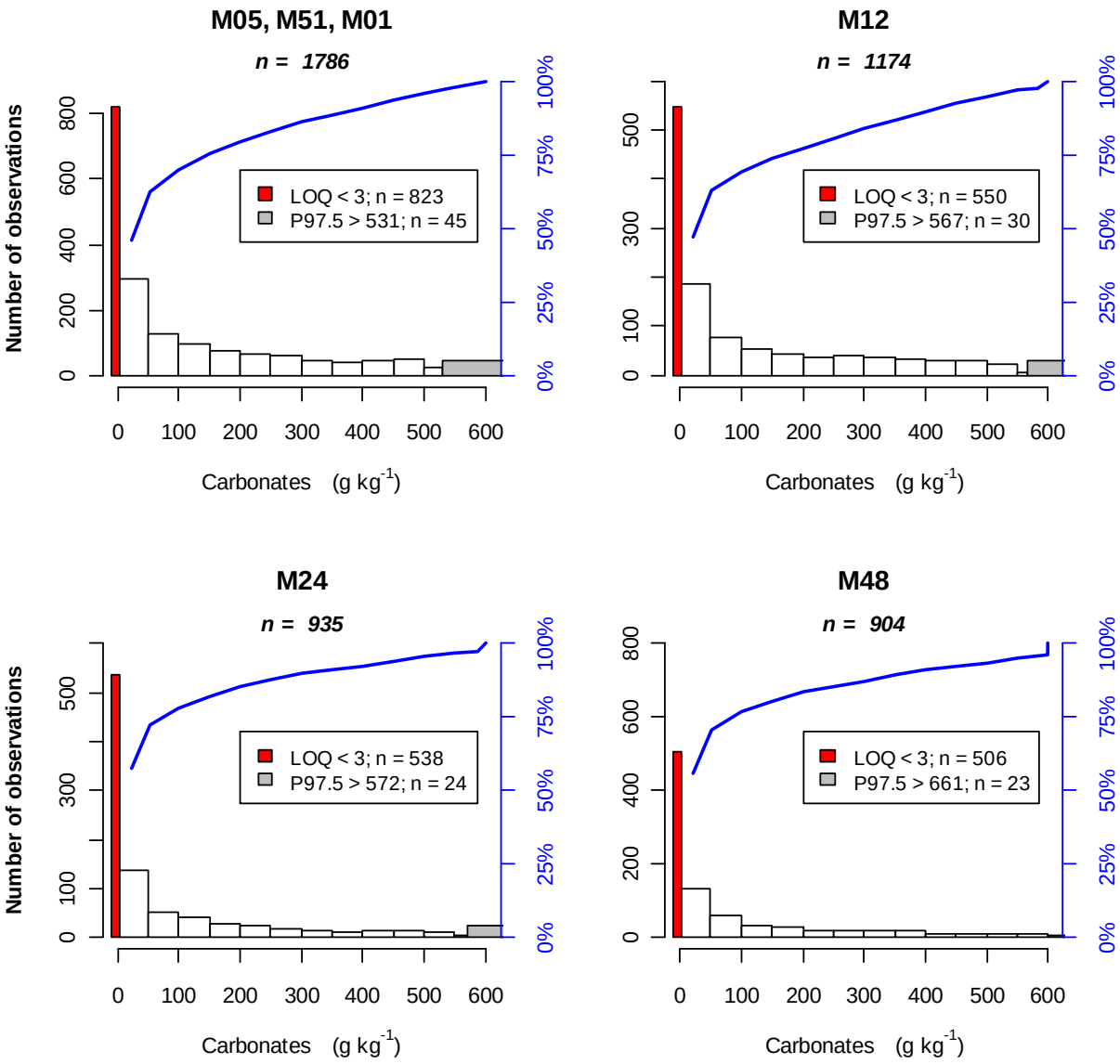


Figure 3.4.26. Absolute and cumulative frequency distribution (in blue) of carbonates in mineral soil layers of all BioSoil+ plots (Level I and Level II). The red bars indicate observations below LOQ, the grey bars observations above the 97.5 percentile.

Map 10 in Annex III shows the geographical distribution of the carbonate concentrations in the upper 10 cm of the mineral soil. Blank areas mean that no carbonates have been reported for the plots located there. As expected based on Map 9 of the pH, most calcareous soils are located in the Mediterranean countries although some small slightly calcareous regions are found in the Baltic states and England as well. When classifying soils according to WRB, the reference soil groups Chernozems, Kastanozems, Calcisols; the qualifiers calcareous, calcaric, calcic and, rendzic and calcareous diagnostic materials all indicate the presence of carbonates (though possibly only at greater depths). Plots where one of these indications are present are shown on Map 10 as separate orange dots.

3.4.7 Organic Carbon

The organic carbon concentration is measured in all forest floor, mineral and peat layers. Figure 3.4.27 compares the distribution of each layer, showing the high concentrations (~500 g OC kg^{-1}) in the organic layers and the much lower concentrations (0 - 150 g OC kg^{-1}) in mineral soil. Note the negatively skewed narrow distribution of OC in the organic layers compared to the wider ranges in mineral layers, even on a logarithmic scale. It is obvious that only data of mineral layers are observed below LOQ, especially from the subsoil.

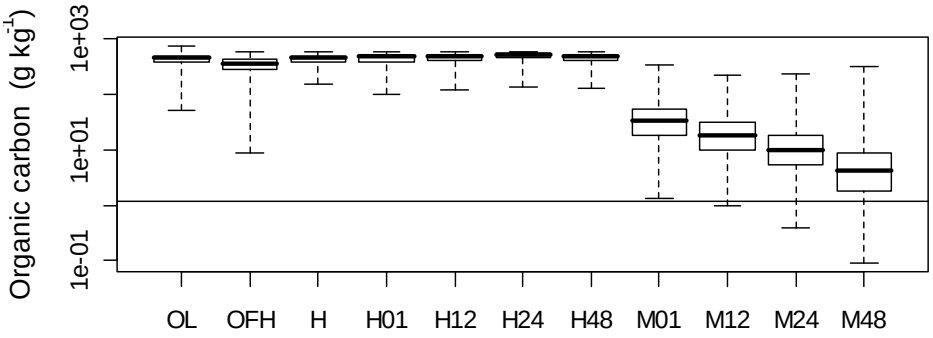


Figure 3.4.27. Box plot of organic carbon concentration (logarithmic scale) of all organic and mineral layers. The whiskers extend to the minimum and maximum data values. The horizontal line is the LOQ at 1.2 g kg^{-1}.

Forest Floor

The OC distribution in litter (OL), fragmentation and humus layers (OF,OH and OFH) of all Level I and II plots is shown in Figure 3.4.28. Ninety-five percent of all forest floor OC observations are comprised within 93 – 547 g kg^{-1}. Theoretically, in aerated conditions a lower limit of 200 g OC kg^{-1} is defined as the threshold of organic material in WRB (IUSS Working Group WRB 2006) whereas an upper limit of 580 g kg^{-1} is the highest OC content present in pure organic matter. For OL, only 2.8 % of the observations are lower than 200 g kg^{-1} while 10.7 % for OFH layers. It is clear that mixing of mineral soil occurs more in OH and OFH layers than in OL layers. Just 2 OL observations exceed 580 g OC kg^{-1} and only one OFH layer, strongly confirming this upper limit.

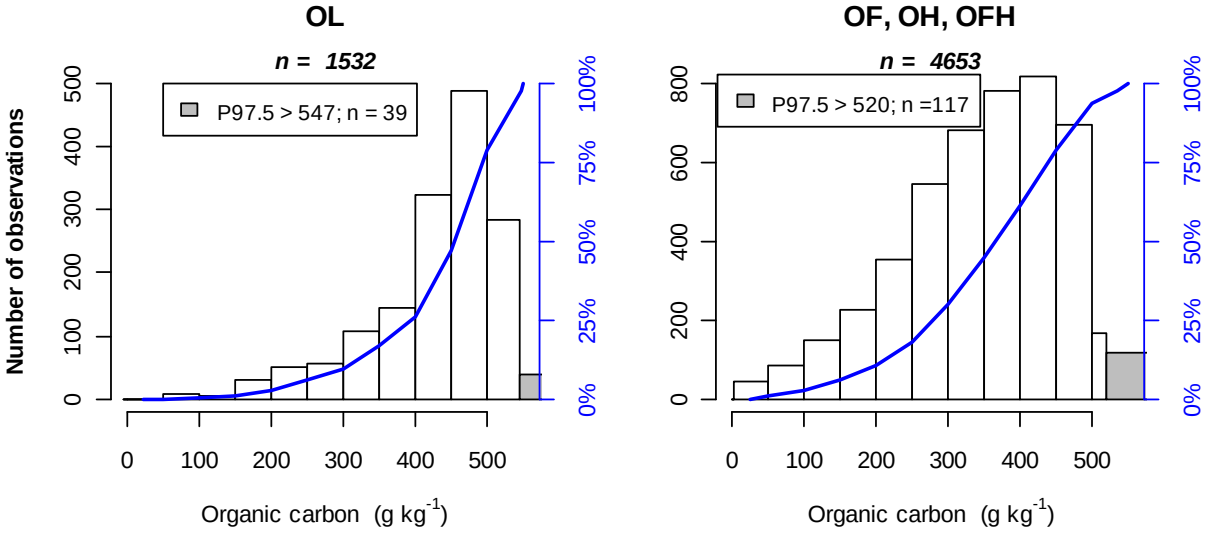


Figure 3.4.28. Absolute and cumulative frequency distribution (in blue) of organic carbon in OL (left) and OF, OH and OFH layers (right) of all BioSoil+ plots (Level I and Level II). The grey bars indicate all observations above the 97.5 percentile.

Since both distributions are skewed to the left, median values are less than the average: for OL the average concentration is 432 g kg^{-1} (median: 454 g kg^{-1}) and for OF, OH and OFH the average is 352 g kg^{-1} (median : 366 g kg^{-1}).

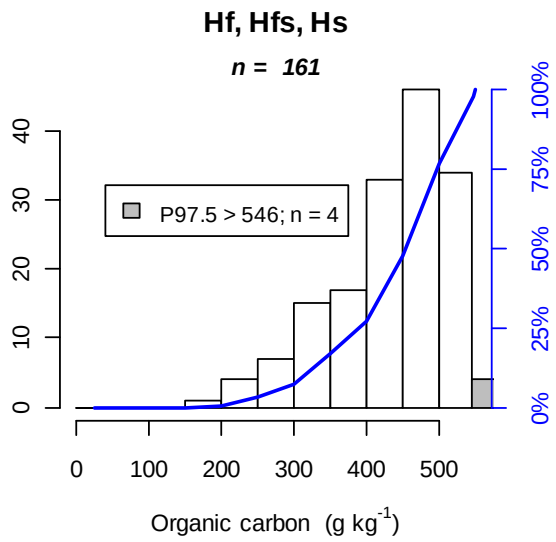


Figure 3.4.29. Absolute and cumulative frequency distribution (in blue) of organic carbon in hydromorphic forest floor layers of all BioSoil+ plots (Level I and Level II). The grey bars indicate all observations above the 97.5 percentile.

In water-saturated forest floors (H layers), 95 % of all observations are comprised within the 246 – 546 g OC kg^{-1} interval. Only four observations exceed this interval and highest reported value is 581 g OC kg^{-1}. As illustrated in Figure 3.4.29, most values are situated in the 450 to 500 g OC kg^{-1} class holding also the median 456 g OC kg^{-1} (mean: 435 g kg^{-1}). Compared to well aerated forest floors, relatively more layers show contents above 500 g OC kg^{-1}, indicating organic matrices containing few mineral particles.

Since many H layers are overlying Histosols, mixing with peat material following bioturbation keeps the organic fraction in the Hf, Hfs and Hs layers high.

Mineral layers

The 95 % range for mineral soil layers is between the quantification limit (1.2 g kg^{-1}) and 152 g OC kg^{-1}. Although most TC analysers may have an LOQ of 0.1 g kg^{-1} or lower (De Vos et al. 2005), ringtests show that matrix LOQ for forest soils are on average 1.2 g kg^{-1} OC (De Vos 2008). In contrast to organic layers, the OC concentration in mineral soil samples below the LOQ may be substantial, especially in the subsoil (Figure 3.4.30). For instance, in the M48 layer, 18 % (n = 607) of all samples were reported to have less than 1.2 g kg^{-1} of organic carbon. At the higher end, the maximum OC concentration is 344 g kg^{-1} (in M01 layer) and very few mineral samples exceed 200 g kg^{-1}, as evidenced by the cumulative frequency distribution given in Figure 3.4.30.

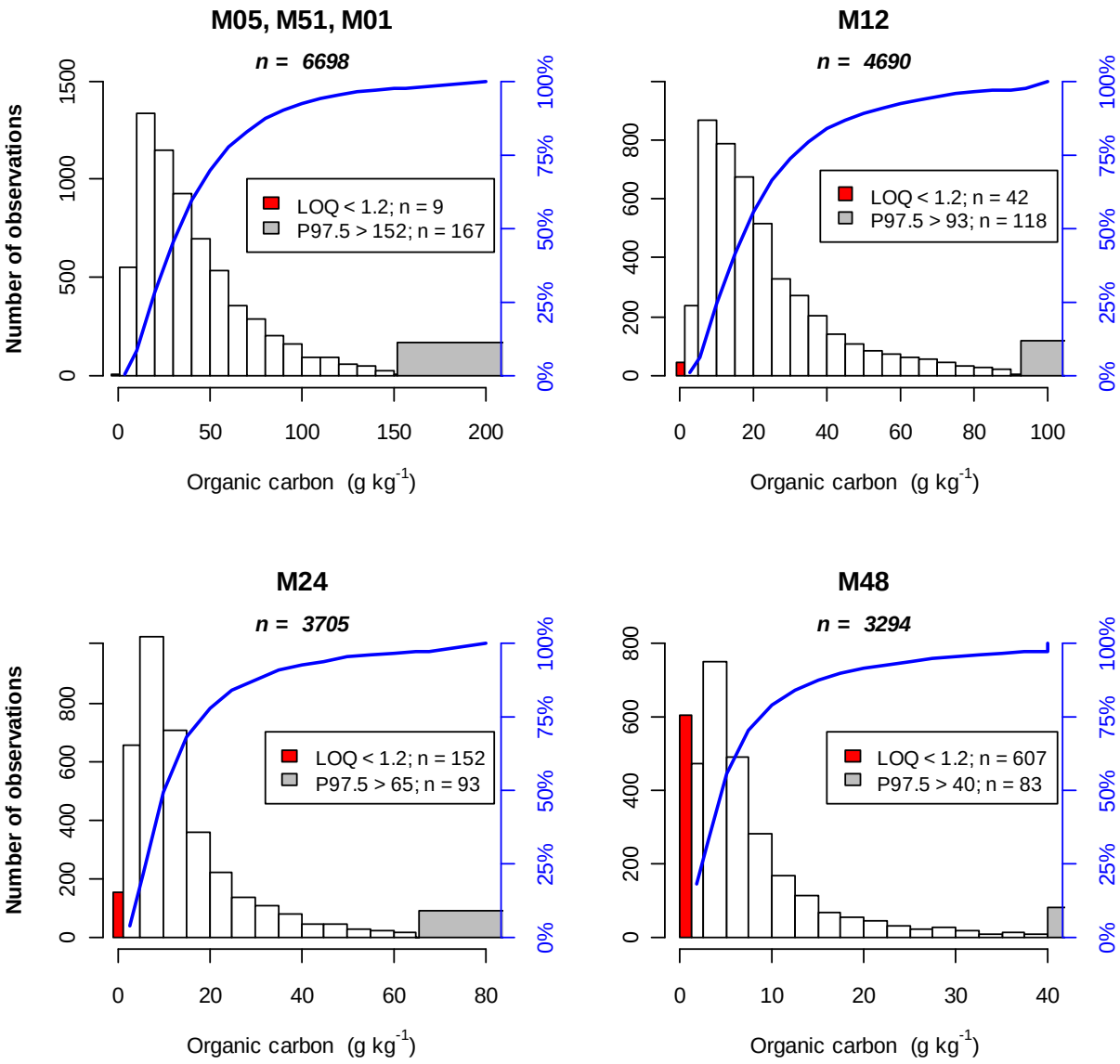


Figure 3.4.30. Absolute and cumulative frequency distribution (in blue) of organic carbon in mineral soil layers of all BioSoil+ plots (Level I and Level II). The red bars indicate observations below LOQ, the grey bars observations above the 97.5 percentile.

The OC concentrations follow lognormal distributions for all layers. Since the carbon concentration decreases exponentially with depth, the median (and mean) OC values for M01, M12, M24 and M48 decrease in the order: 33.1 (43.8) > 18.0 (25.1) > 10.2 (15.6) > 4.3 (8.1) g OC kg^{-1}. The calculations for mean and median take the left censored values (less than LOQ) statistically into account. The highest frequency of observations for M01 is within the 10 - 20 g OC kg^{-1} class, for M12 and M24: 5 - 10 g OC kg^{-1} class and for M24 within the 2.5 - 5 g OC kg^{-1} class (Figure 3.4.30). Higher classes for each layer represent mainly mineral layers enriched with humic substances, whereas the observations contained in the upper grey class comprise mainly peaty layers in the soil profile.

Peat soils

The distribution of OC concentrations in the H layers of Histosols is shown in Figure 3.4.31. As for the forest floors, the distribution is negatively skewed but here most observations are comprised in the class 500 - 550 g OC kg^{-1} for all depths. No samples are observed with OC concentrations below 100 g OC kg^{-1} and very few below 200 g OC kg^{-1}. As indicated by the percentiles, the limit of 580 g kg^{-1} is rarely exceeded. For all layers, median values are similar and all within the interval: 485 – 520 g OC kg^{-1} (means: 441 - 487 g OC kg^{-1}).

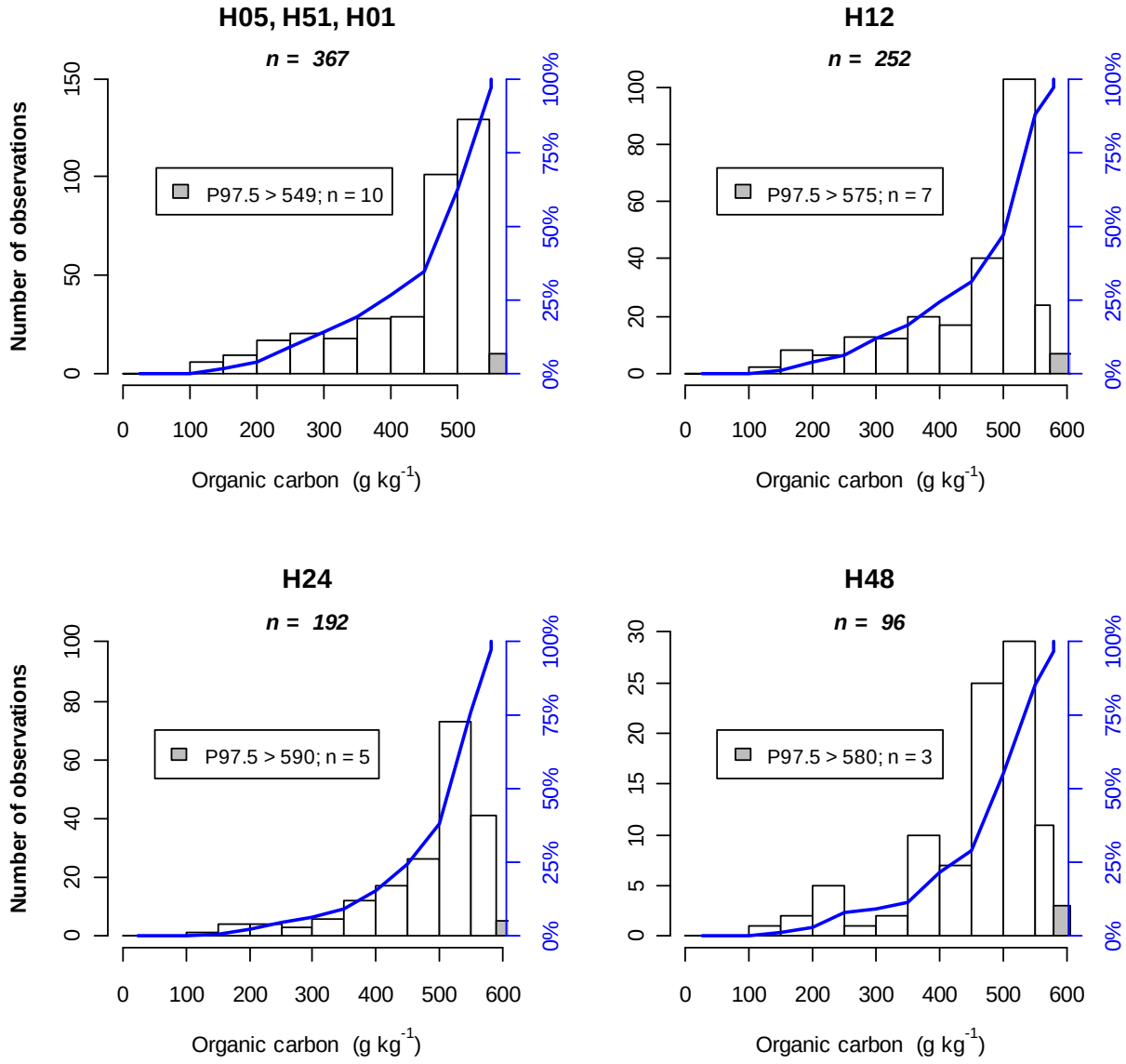


Figure 3.4.31. Absolute and cumulative frequency distribution (in blue) of organic carbon in peat layers of all BioSoil+ plots (Level I and Level II). The red bars indicate observations below LOQ, the grey bars observations above the 97.5 percentile.

Map 11 in Annex III shows the geographical distribution of the total organic carbon concentration in the upper 10 cm of mineral and peat soils across European forests. Concentrations above 80 g kg^{-1} are found in Northern Europe, Ireland, Wales and Scotland though also high concentrations are found in the Alps and central Italy. Note that these high concentrations do not automatically translate into high organic carbon stocks. For more information related to the assessment of organic carbon stocks in European forest soils, see Volume II of this report.

3.4.8 Total Nitrogen

Just as for carbon, total organic nitrogen (TON) is measured in all forest floor, mineral and peat layers. Figure 3.4.32 shows the distribution of each layer with similar high concentrations (10 - 40 g N kg^{-1}) for the organic layers and distinct lower concentrations (0 - 10 g N kg^{-1}) in mineral soil. Note the negatively skewed narrow distribution of TON in the organic layers compared to the wider ranges in mineral layers, even on a logarithmic scale. Only data of mineral layers are observed below LOQ, especially those from the subsoil.

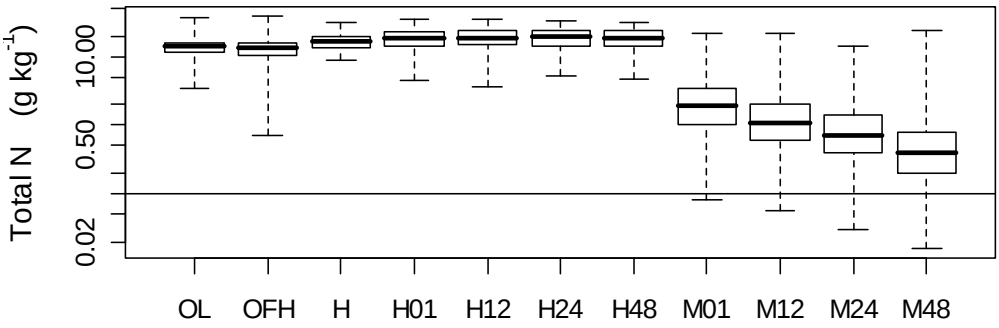


Figure 3.4.32. Box plot of total nitrogen concentration (logarithmic scale) of all organic and mineral layers. The whiskers extend to the minimum and maximum data values. The horizontal line is the LOQ at 0.1 g kg^{-1}.

Forest Floor

Nitrogen concentration in the forest floor layers range from ~0.7 g kg^{-1} to 40 g kg^{-1} at most. The limit of reliable quantification (LOQ) of total organic nitrogen (TON) in organic layers is estimated at 0.5 g kg^{-1}, whereas it is lower (i.e. 0.1 g N kg^{-1}) for mineral layers. The 95 % range for TON in OL layers is 6.8 – 21.2 g kg^{-1} and 4.3 – 21.9 g kg^{-1} for OFH layers, as may be inferred from the distribution functions in Figure 3.4.33.

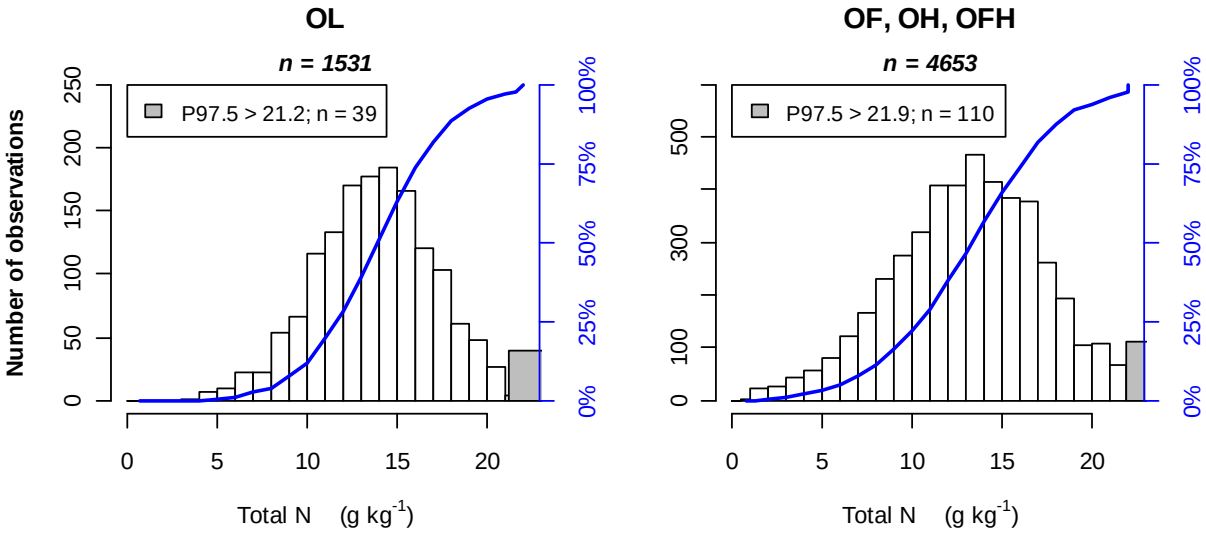


Figure 3.4.33. Absolute and cumulative frequency distribution (in blue) of total nitrogen in OL (left) and OF, OH and OFH layers (right) of all BioSoil^{+} plots (Level I and Level II). The grey bars indicate observations above the 97.5 percentile.

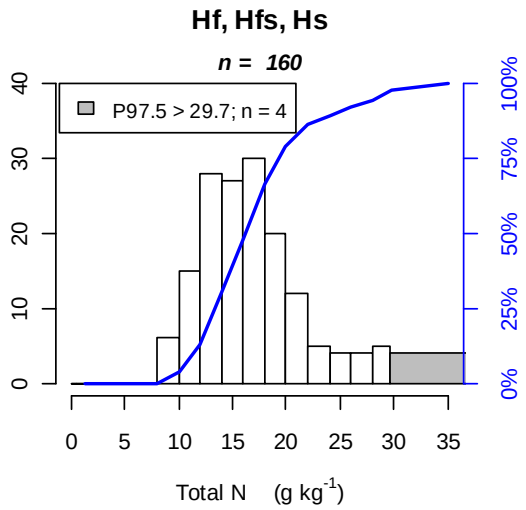


Figure 3.4.34. Absolute and cumulative frequency distribution (in blue) of total nitrogen in Hf, Hfs and Hs layers of all BioSoil+ plots (Level I and Level II). The grey bars indicate observations above 97.5 percentile.

Both distributions are slightly skewed (skewness < 0.5) with median values of 13.9 and 13.4 g N kg^{-1} for OL and OFH layers respectively. Respective means are 14.0 and 13.3 g N kg^{-1}. The most frequently observed class is 14 – 15 g N kg^{-1} in OL and 13 - 14 g N kg^{-1} for OFH layers.

Figure 3.4.34 learns that the nitrogen concentration is generally greater in semi-terrestrial humus layers with 95 % of all observations between 9.6 and 29.7 g N kg^{-1}, a median value of 16.3 g N kg^{-1} and a mean of 17.0 N g kg^{-1}. This distribution seems more positively skewed (skewness = 0.95), but is based on a relatively low number of observations.

Mineral layers

The total nitrogen concentration in mineral layers is approximately a factor 10 lower than in organic layers. All distributions are strongly skewed to the right (skewness ranging from 2.1 to 11.0). Samples with concentrations below LOQ, increase with depth from 0.4 % in M01 to 13 % of all M48 observations. The narrowing scales and decreasing $P_{97.5}$ values in Figure 3.4.35 indicate a strong decline of N concentration with depth, similar to organic carbon.

Median N levels decrease (significantly) in the order: 1.91 > 1.10 > 0.70 > 0.40 g N kg^{-1} and mean values: 2.63 > 1.60 > 1.11 > 0.65 g N kg^{-1}. For these calculations the left censored values are taken into account. All these statistics are tabularised in Annex II.

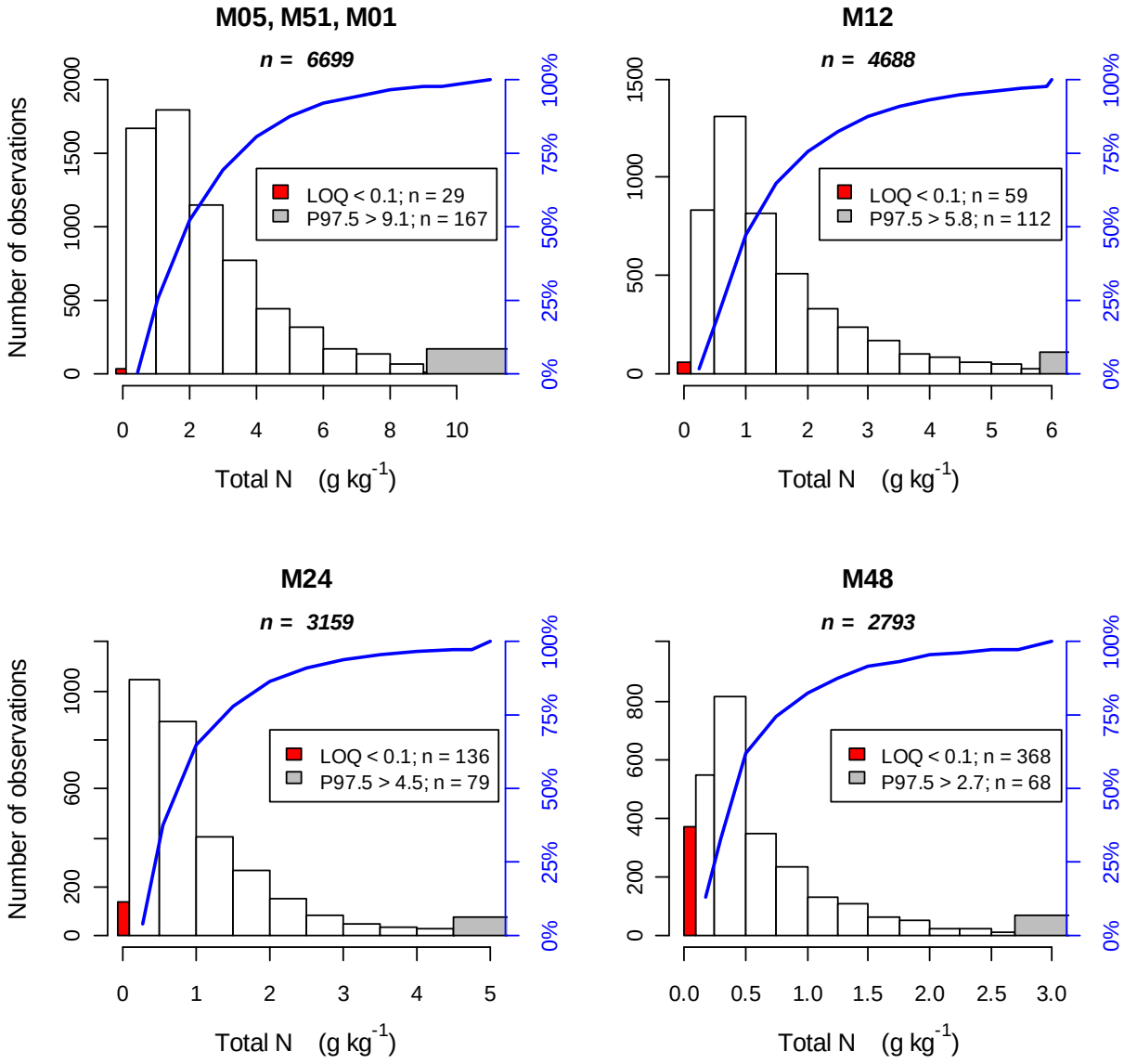


Figure 3.4.35. Absolute and cumulative frequency distribution (in blue) of total nitrogen in mineral soil layers of all BioSoil+ plots (Level I and Level II). The red bars indicate observations below LOQ, the grey bars observations exceeding the 97.5 percentile.

Peat soils

The distribution of TON concentrations in the Histosols layers is shown in Figure 3.4.36. In contrast to mineral soils, nitrogen concentrations do not decrease strongly with depth. Medians of all depths are close to each other within the range 18.3 - 19.2 g N kg^{-1} and so are the means (within the range 18.8 – 19.5 g N kg^{-1}). Despite the limited number of observations, distributions seem to follow a unimodal pattern centred around a mean of ~19 g N kg^{-1}. None of the observations are below the LOQ (0.5 g N kg^{-1}). Peat soil layers tend to have the greatest nitrogen concentrations of all organic layers.

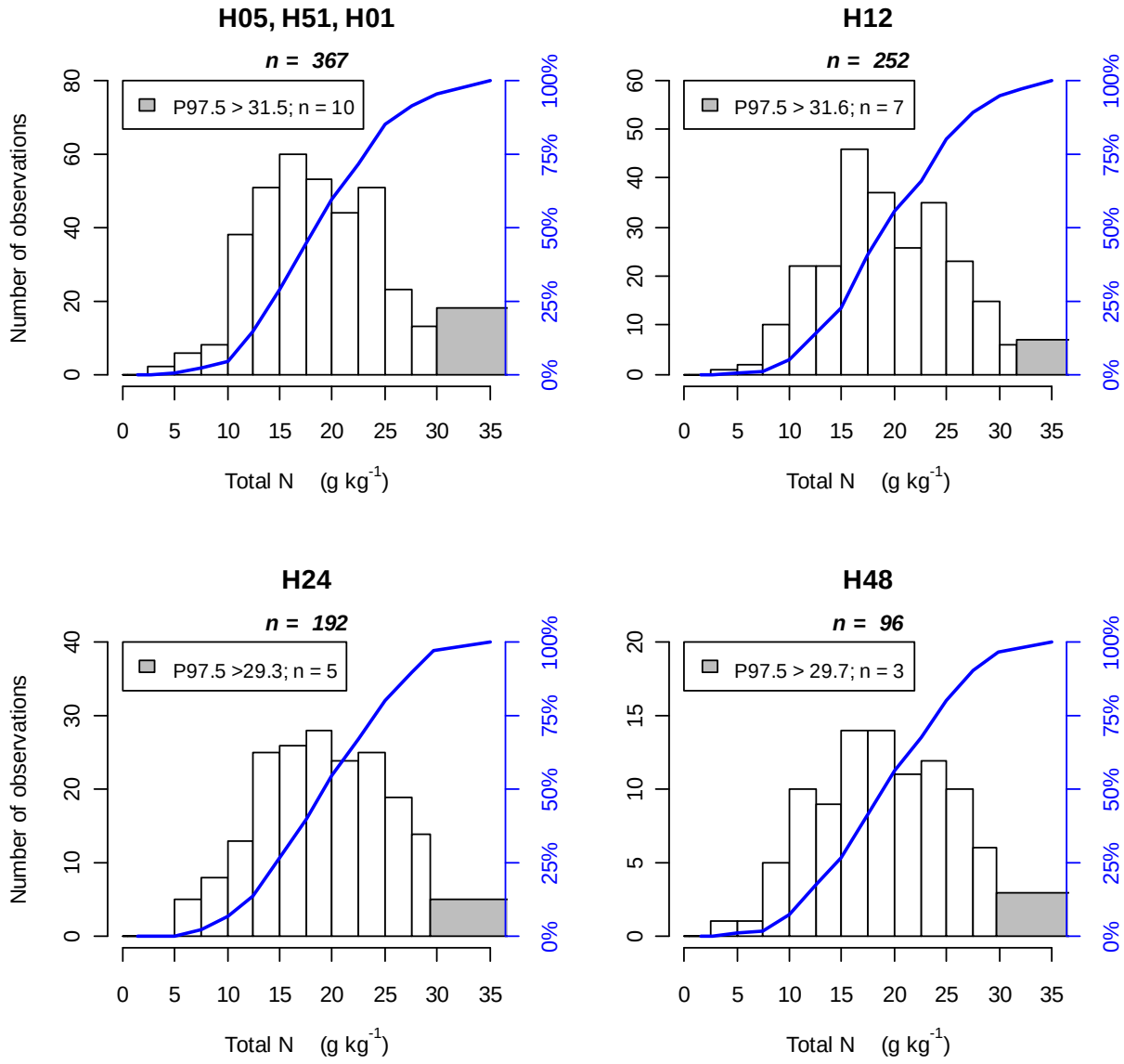


Figure 3.4.36. Absolute and cumulative frequency distribution (in blue) of total nitrogen in peat layers of all BioSoil+ plots (Level I and Level II). The grey bars indicate observations exceeding the 97.5 percentile.

Map 12 in Annex III shows the geographical distribution of the total nitrogen concentration in the upper 10 cm of mineral and peat soils across European forests. Concentrations of more than 10 g kg^{-1} are found in a zone stretching from Ireland over Wales and Scotland towards southern Sweden, Southern Finland and the Baltic states plus eastern Poland. A second zone with high N concentration is located around the Adriatic Sea.

3.4.9 Exchangeable elements

3.4.9.1 Free H^+

The concentration of free hydrogen was determined in the organic and mineral layers. The concentration ranges, median and quartiles for each layer are displayed along a logarithmic scale (base 10) in Figure 3.4.37. Note the difference in magnitude between the organic (forest floor and peat layers) and mineral layers. The latter are situated near the quantification limit (LOQ = 0.1 $cmol_+ kg^{-1}$). Mineral layers below 10 cm of depth have more than 50% of their values below the average LOQ which indicates that most labs had difficulties in analysing these low levels of free H^+ accurately. Conversely, in organic layers free H^+ seems to be reliably quantifiable, but the biogeochemical interpretation of these concentrations in organic matrices remains unclear.

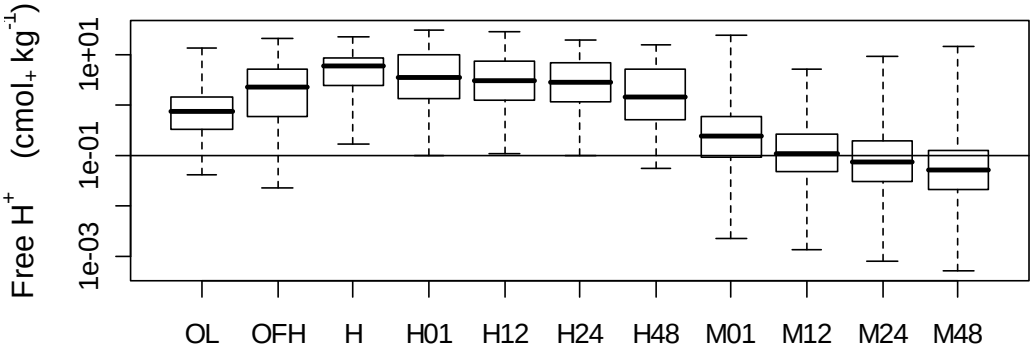


Figure 3.4.37. Box plot of exchangeable free hydrogen (H^+) for all layers. The Y-axis is logarithmic. The overall horizontal line indicates the LOQ.

Forest Floor

Free H^+ in the terrestrial forest floor layers ranges from less than 0.1 $cmol_+ kg^{-1}$ (LOQ) to maximally ~20 $cmol_+ kg^{-1}$. Figure 3.4.38.

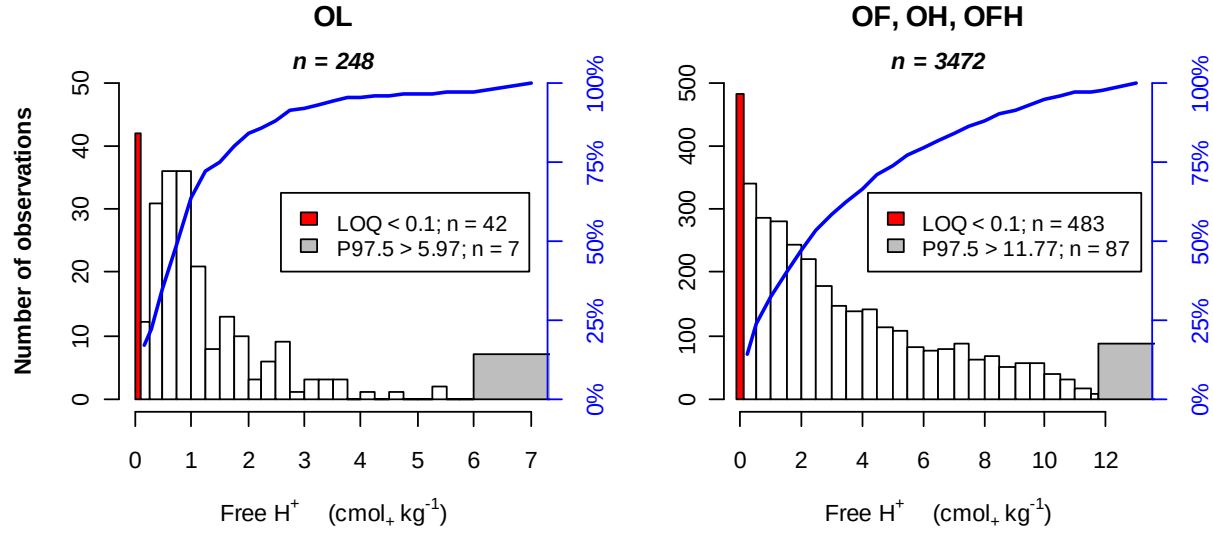


Figure 3.4.38. Absolute and cumulative frequency distribution (in blue) of free H^+ in OL (left) and OF, OH and OFH layers (right) of all BioSoil$^+$ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

About 17 % of the OL and 14 % of the OFH layers show observations below the LOQ and less than 2.5 % of all observations exceed 5.97 in OL and 11.8 $cmol_+ kg^{-1}$ in OFH layers. In OL, the free H^+

concentration is predominantly less than 2 $cmol_+$ kg^{-1} whereas in OFH, levels between 2 and 10 $cmol_+$ kg^{-1} are well represented in the dataset. The median values are 0.76 and 2.20 $cmol_+$ protons kg^{-1} whereas means are 1.23 and 3.35 $cmol_+$ kg^{-1} for OL and OFH layers respectively. The OL distribution is clearly more positively skewed (skewness = 3.9) than the OFH distribution (skewness = 1.2).

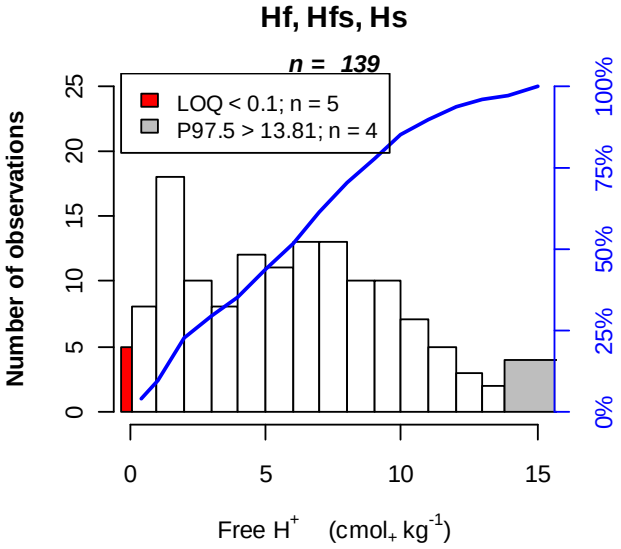


Figure 3.4.39. Absolute and cumulative frequency distribution (in blue) of free H^+ in hydromorphic forest floor layers of BioSoil$^+$ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

The free H^+ distribution for hydromorphic humus layers seems bimodal, with a modus at 1-2 $cmol_+$ kg^{-1} and one at 6-8 $cmol_+$ kg^{-1} (Figure 3.4.39). Skewness (0.7) is slightly positive. Compared to the terrestrial humus layers the number of values below LOQ is low (i.e. 3.6 %). The range is comparable with the one for OFH layers, but the median (i.e. 5.74 $cmol_+$ kg^{-1}) is more than double.

Mineral layers

The free H^+ concentration range in mineral layers ranges from less than 0.1 $cmol_+ kg^{-1}$ (LOQ) up to 2.8 $cmol_+ kg^{-1}$ based on over 17000 analyses. Figure 3.4.40 clearly shows that most observations of mineral soil H^+ are below the average labs-LOQ (red bars). The proportion increases from 35.1% of the M01 layers up to 70% of the M48 layers. Estimated median values using statistics for censored data reveal decreasing median values with depth: 0.25 > 0.11 > 0.07 > 0.05 $cmol_+ kg^{-1}$ for M01, M12, M24 and M48 layers respectively. Consistently, the 97.5 percentile values also decrease with depth indicating much less free hydrogen in the subsoil, which is also more difficult to quantify accurately. All statistical values are summarised in Annex II.

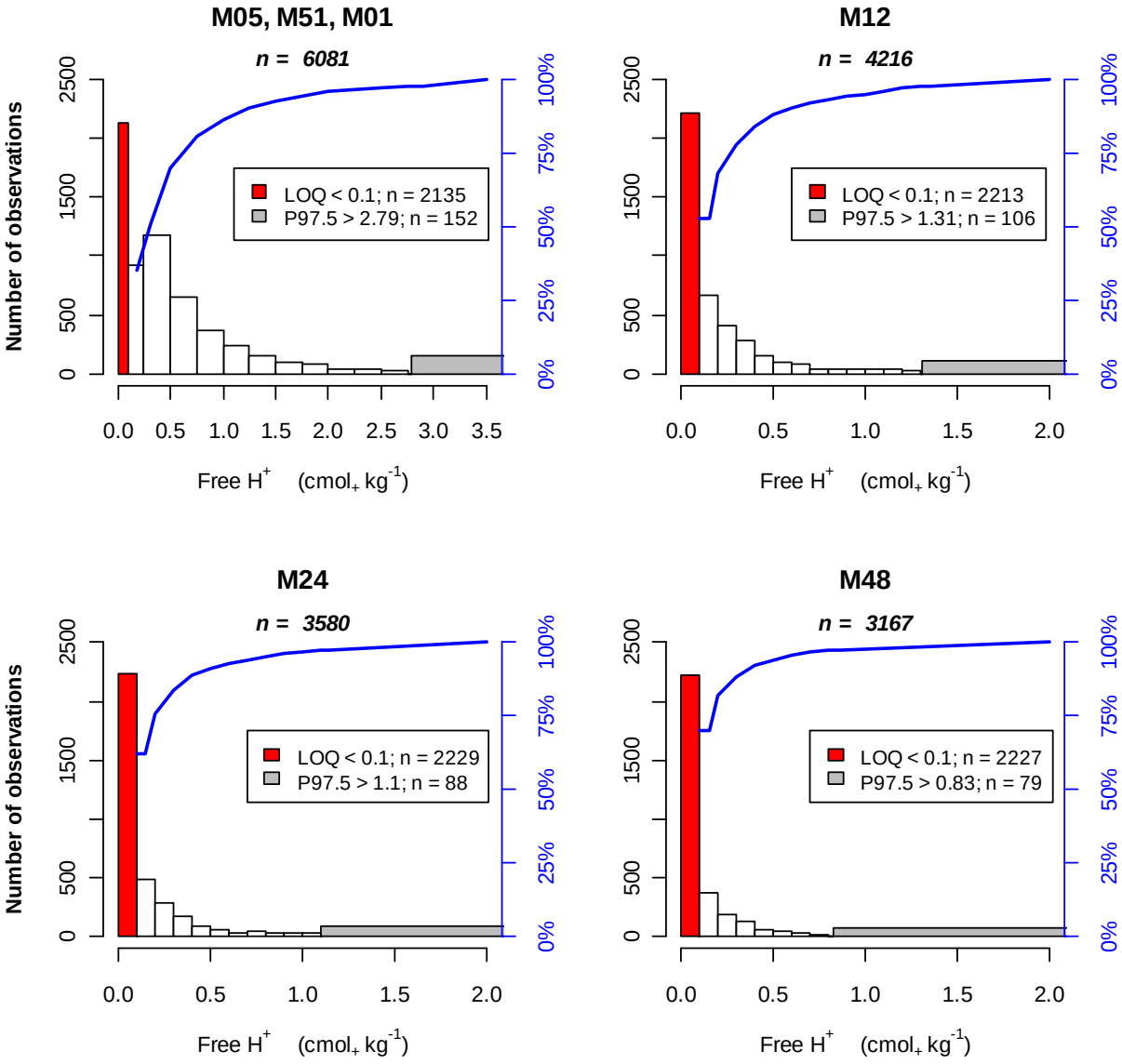


Figure 3.4.40. Absolute and cumulative frequency distribution (in blue) of free H^+ in mineral soil layers of all BioSoil$^+$ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

Peat soils

The median concentration of free H^+ in peat layers is a factor 10 to 20 greater than in mineral layers. The distribution is shown in Figure 3.4.41. A limited number of observations are below LOQ (~ 5% for H01, H12 and H24 layers and 14.1% for H48 layers) and less than 2.5% of the observations exceed 17.5 $cmol_+$ kg^{-1}. Regardless of the layer depth, a similar distribution pattern is found: most observations are situated between 0 and 3 $cmol_+$ kg^{-1} followed by a noisy, slightly decreasing pattern of higher values within roughly the same range for each layer. Just as for mineral soil, the median value decreases with depth in the order: 3.62 > 3.08 > 2.77 and 1.5 $cmol_+$ protons kg^{-1}. The statistical values are listed per layer in Annex II.

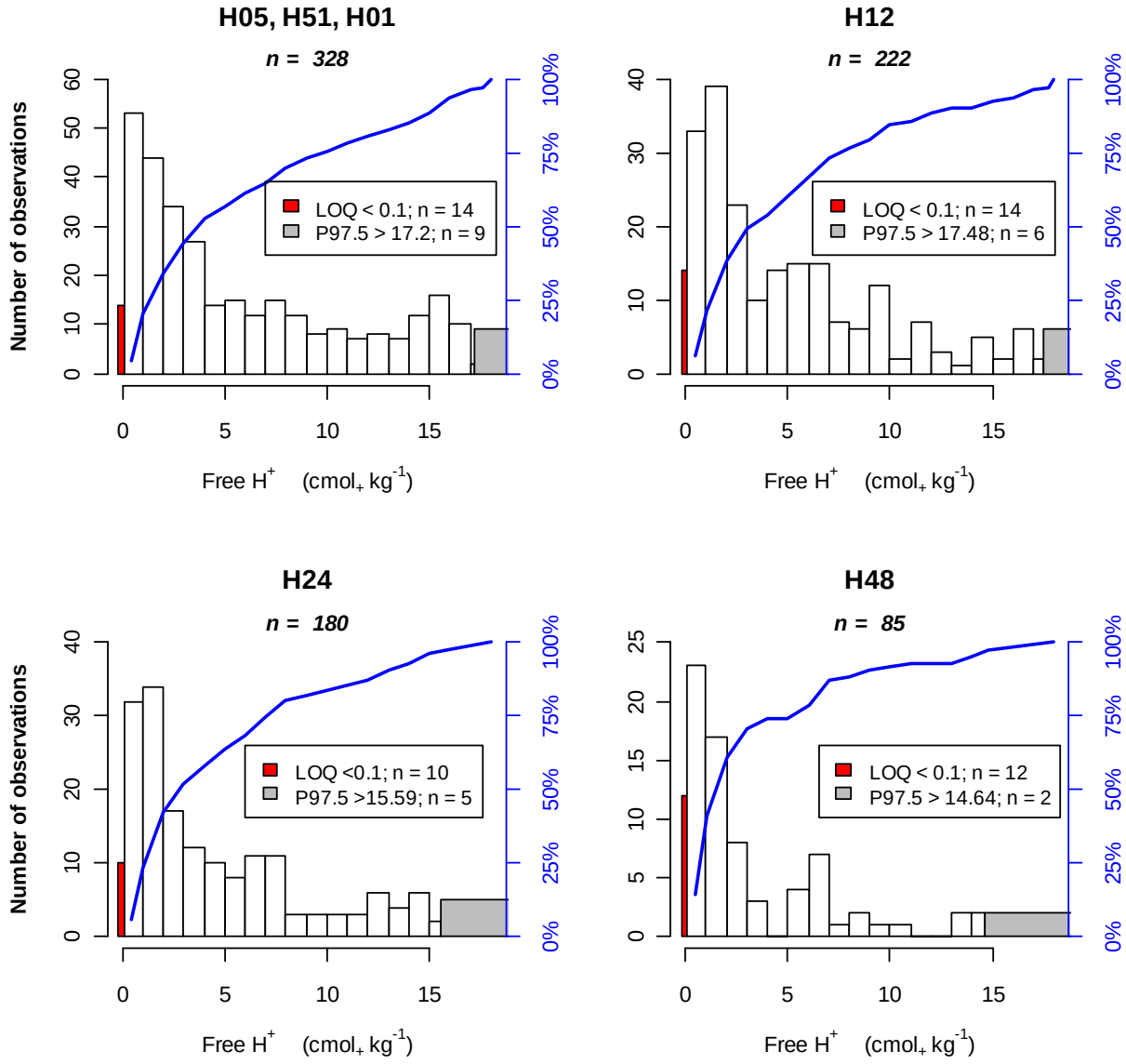


Figure 3.4.41. Absolute and cumulative frequency distribution (in blue) of free H^+ in peat layers of all BioSoil$^+$ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

3.4.9.2 Exchangeable Acidity

The concentration range of exchangeable acidity, the median and quartiles for each layer are presented in Figure 3.4.42. Just as for free H^+, levels are generally higher in organic matrices than in mineral soil, but the difference in magnitude between the groups is not as large. In contrast to free H^+, most exchangeable acidity observations are well above the quantification limit, also for mineral soils. Exchangeable acidity increases from OL to OFH layer and is highest in semi-terrestrial humus forms (H layers). The acidity levels generally decrease with depth in peat and mineral soils, though this is most clear in the latter.

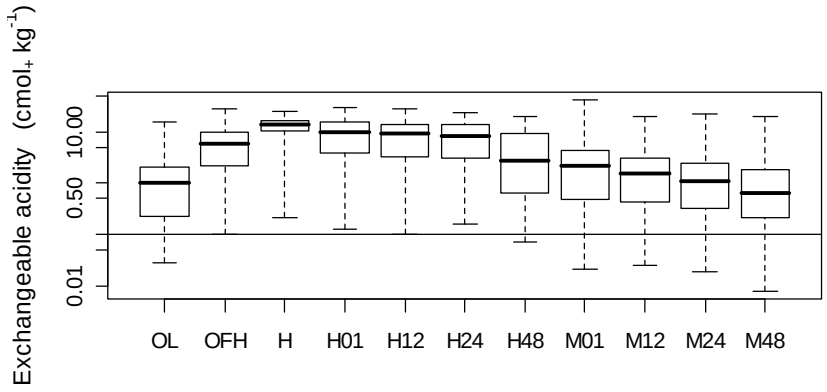


Figure 3.4.42. Box plot of exchangeable acidity for all layers. The Y-axis is logarithmic. The horizontal line indicates the LOQ at 0.1 $cmol_+ kg^{-1}$.

Forest Floor

Exchangeable acidity of terrestrial forest floor layers ranges from less than 0.1 $cmol_+ kg^{-1}$ (LOQ) to maximally ~28.5 $cmol_+ kg^{-1}$. About 13% of the OL and 4% of the OFH layers show observations below the LOQ and less than 2.5 % of all observations exceed 6.87 $cmol_+ kg^{-1}$ in OL and 17.2 $cmol_+ kg^{-1}$ in OFH layers (Figure 3.4.43). In OL, the exchangeable acidity is usually less than 2 $cmol_+ kg^{-1}$ whereas in OFH the levels between 2 and 15 $cmol_+ kg^{-1}$ are well represented in the dataset.

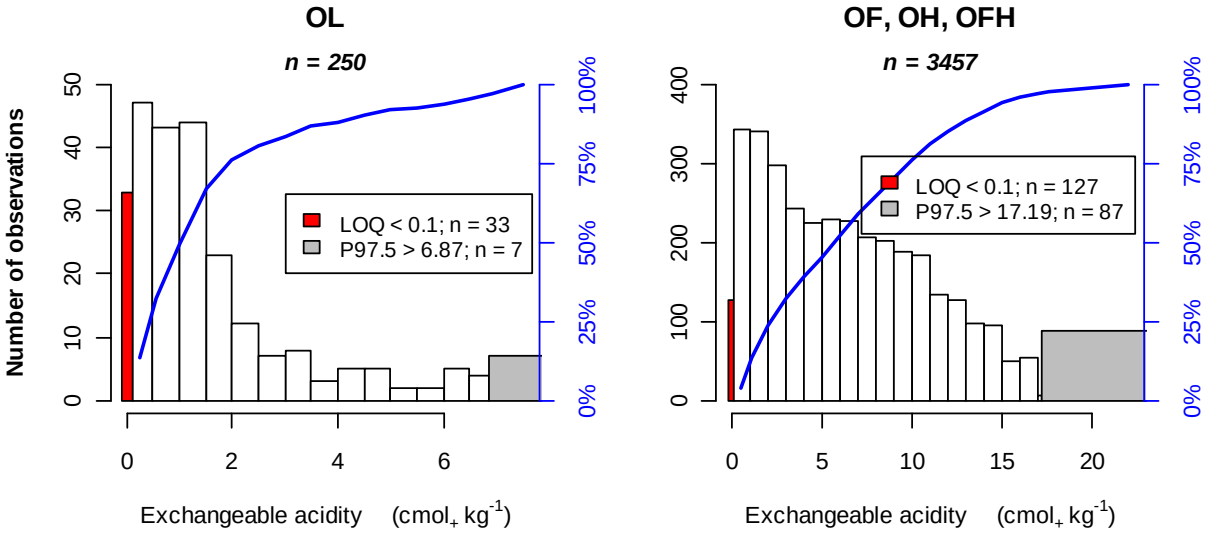


Figure 3.4.43. Absolute and cumulative frequency distribution (in blue) of exchangeable acidity in OL (left) and OF, OH and OFH layers (right) of all BioSoil$^+$ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

The median values for exchangeable acidity are 1.04 and 5.71 $cmol_+ kg^{-1}$ whereas means are 1.68 and 6.46 $cmol_+ kg^{-1}$ for OL and OFH layers respectively. The kurtosis of the OL distribution (i.e. 14.8) is 4 times higher than for the OFH distribution.

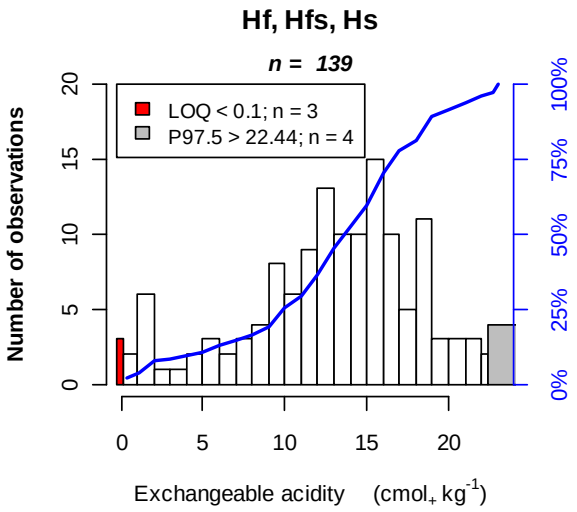


Figure 3.4.44. Absolute and cumulative frequency distribution (in blue) of exchangeable acidity in hydromorphic forest floor layers of BioSoil+ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

Figure 3.4.44 shows the distribution of the exchangeable acidity of hydromorphic humus layers which is skewed to the left (skewness = -0.5) with a low number of values below LOQ (i.e. 2.2 %). An acidity of 15 - 16 $cmol_+ kg^{-1}$ is often observed while this is rarely found in terrestrial humus forms. The median value of 13.6 $cmol_+ kg^{-1}$ is highest of all observed layers, including peat and mineral layers.

Mineral layers

Exchangeable acidity in mineral layers ranges from less than 0.1 $cmol_+ kg^{-1}$ (LOQ) up to 42 $cmol_+ kg^{-1}$ at most. Figure 3.4.45 clearly shows that a substantial number of observations of mineral soil acidity belong to the class below LOQ (red bars). The proportion increases from 16.8 % of the M01 layers up to 24 % of the M48 layers. Median values estimated using statistics for censored data reveal decreasing values with depth: 2.24 > 1.53 > 1.10 > 0.66 $cmol_+ kg^{-1}$ for M01, M12, M24 and M48 layers respectively. Consistently, the 97.5 percentile values also decrease with depth indicating less exchangeable acidity in the subsoil. All distributions are right skewed. The statistical values are summarised in Annex II.

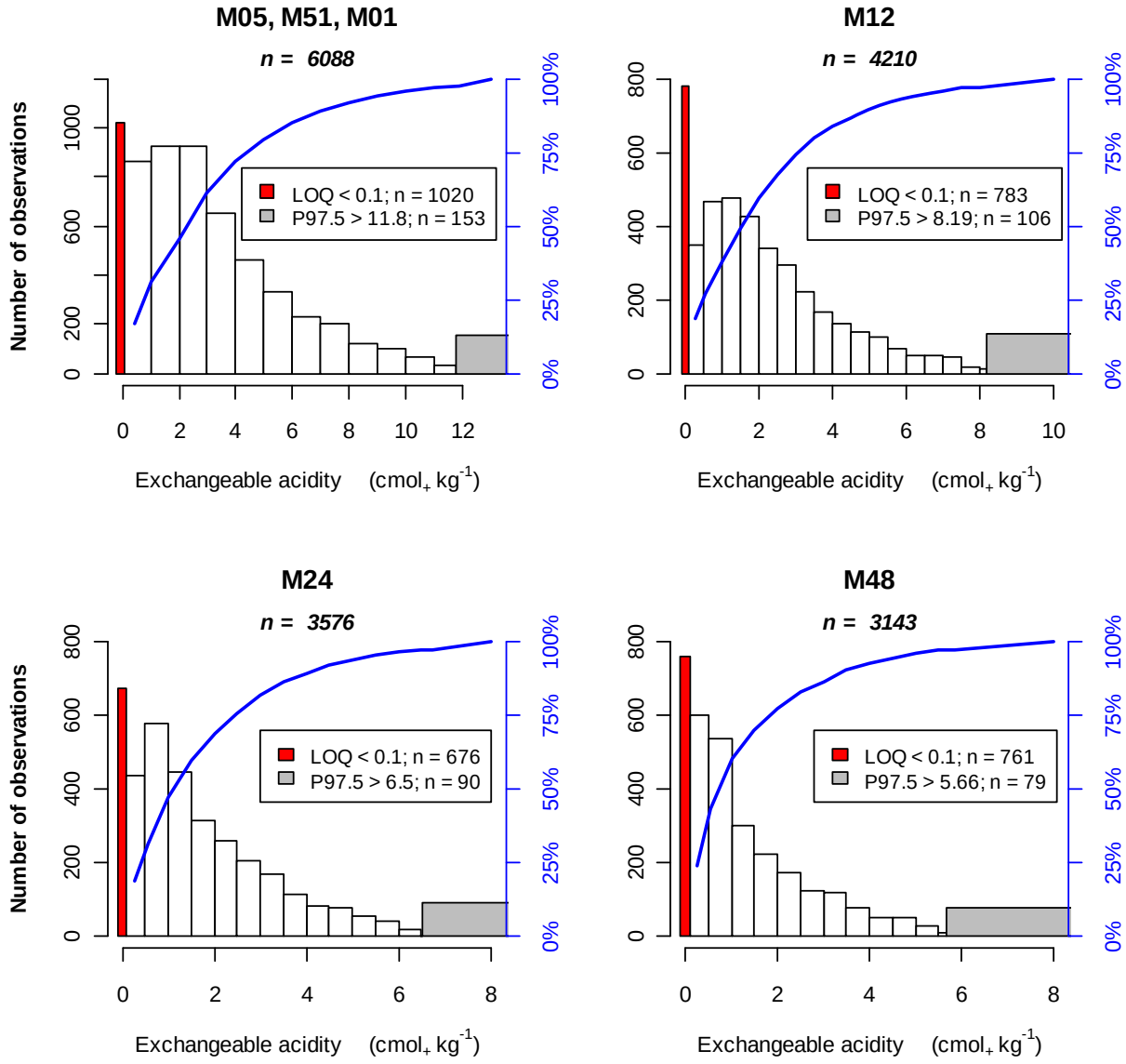


Figure 3.4.45. Absolute and cumulative frequency distribution (in blue) of exchangeable acidity in mineral soil layers of all BioSoil$^+$ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

Peat soils

The median concentration of exchangeable acidity in peat layers is about a factor 5 greater than in mineral layers. The distributions are shown in Figure 3.4.46. A limited number of observations are below LOQ (< 4% for H01, H12 and H24 layers and 14.1% for H48 layers) and less than 2.5% of the observations exceed 21.3 $cmol_+$ kg^{-1}. Contrasting to the distributions for mineral layers, here the distribution is much more flat with classes evenly distributed over the whole range, except for the lowest ones. Kurtosis values are typically smaller than 3 whereas they are > 8 for mineral layers. The median values decrease with depth in the order: 9.83 > 9.11 > 8.14 > 2.73 $cmol_+$ kg^{-1}. The statistical values are listed per layer in Annex II.

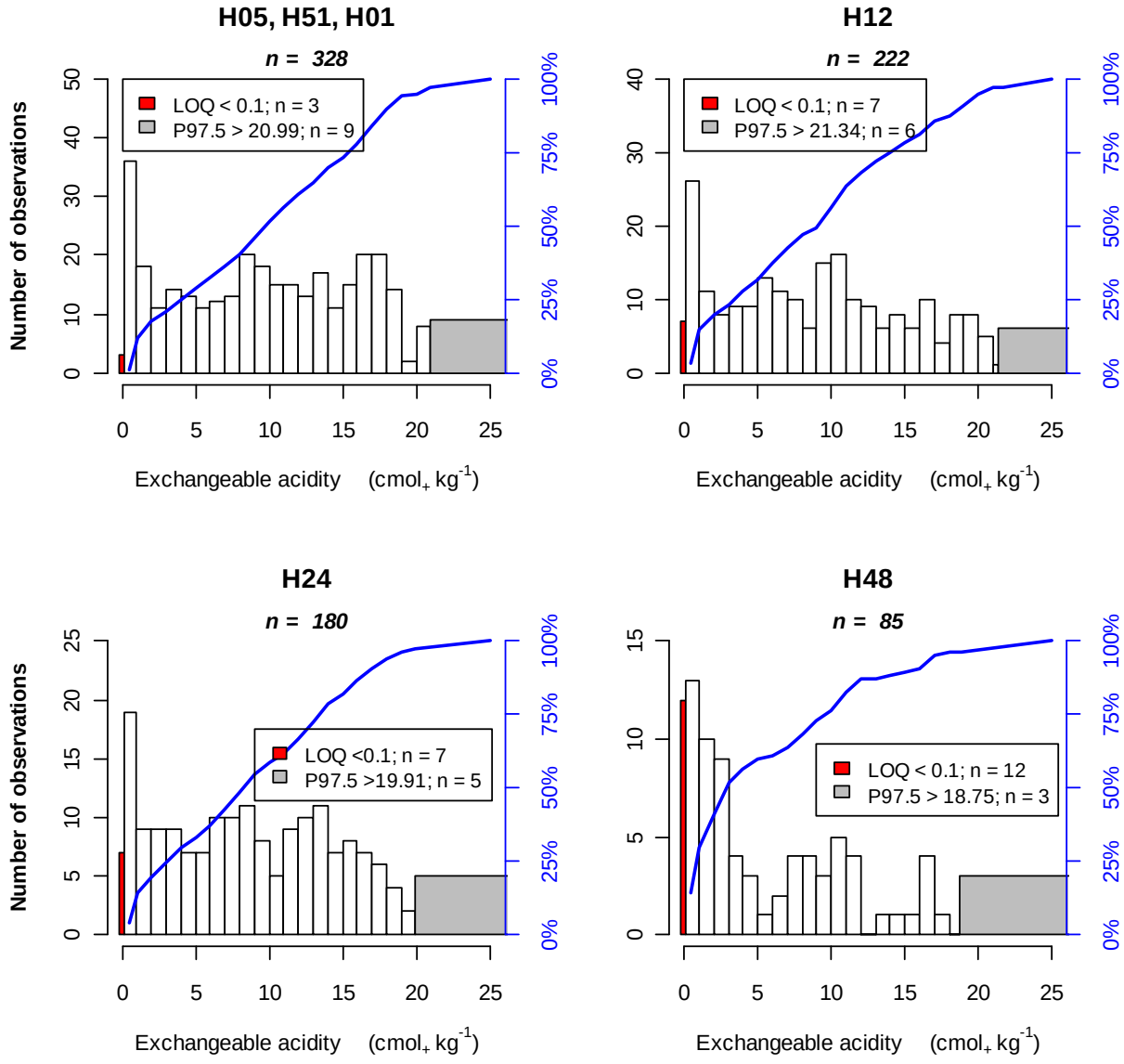


Figure 3.4.46. Absolute and cumulative frequency distribution (in blue) of exchangeable acidity in peat layers of all BioSoil$^+$ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

3.4.9.3 Exchangeable Potassium

The concentration range of exchangeable potassium, the median and quartiles for each layer are presented in Figure 3.4.47. In general, median values are greater in organic matrices than in mineral soil, mostly well above the quantification limit. Concentration levels generally decrease with depth both in peat and mineral soils, but the decrease is more distinct for peat.

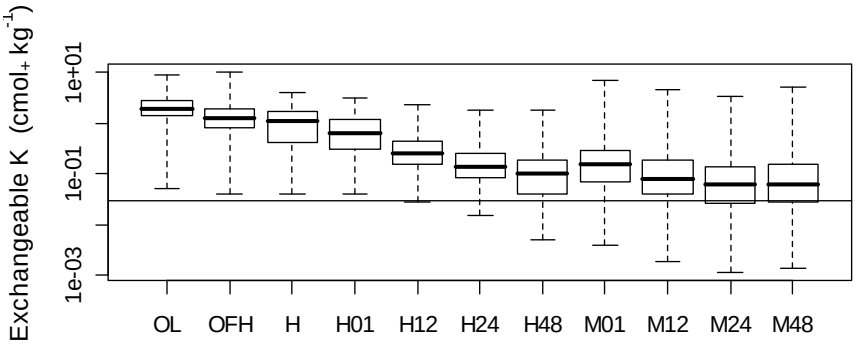


Figure 3.4.47. Box plot of exchangeable potassium for all layers. The Y-axis is logarithmic. The horizontal line indicates the LOQ at 0.03 cmol$_+$ kg^{-1}.

Forest Floor

Exchangeable potassium of terrestrial forest floor layers ranges from less than 0.03 cmol$_+$ kg^{-1} (LOQ) to maximally 10 cmol$_+$ kg^{-1}. Less than 1% of the observations are below the LOQ and less than 2.5 % of all observations exceed 5.26 cmol$_+$ kg^{-1} in OL and 3.80 cmol$_+$ kg^{-1} in OFH layers (Figure 3.4.48). Both distributions are unimodal, with a modus between 1 and 2 cmol$_+$ kg^{-1} for OL, and between 0.5 and 1 cmol$_+$ kg^{-1} for OFH.

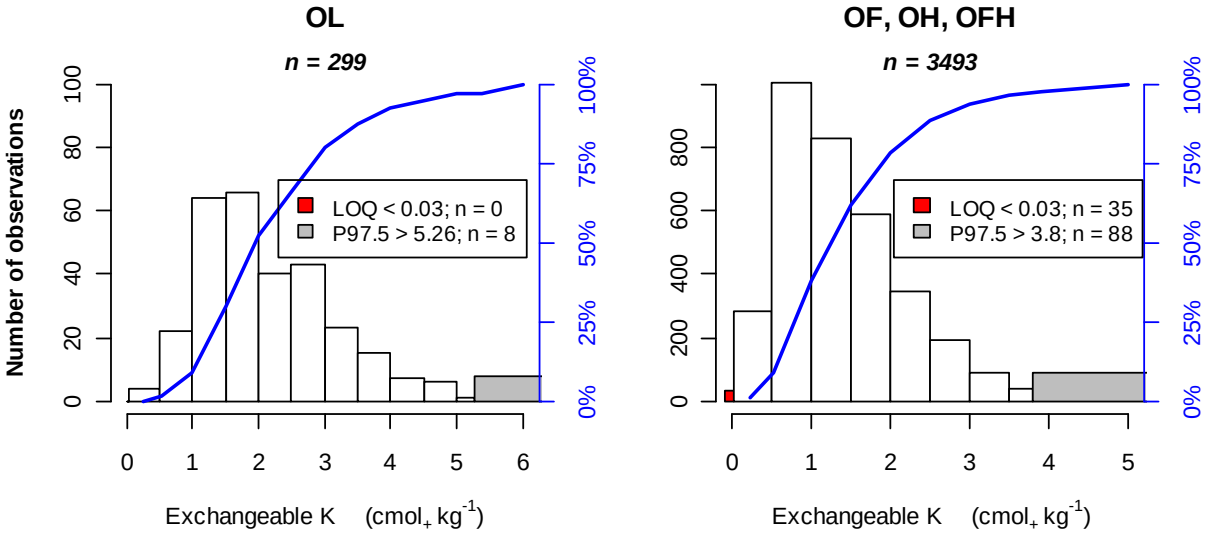


Figure 3.4.48. Absolute and cumulative frequency distribution (in blue) of exchangeable potassium in OL (left) and OF, OH and OFH layers (right) of all BioSoil$^+$ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

The median values are 1.94 and 1.25 cmol$_+$ K kg^{-1} whereas means are 2.22 and 1.45 cmol$_+$ kg^{-1} for OL and OFH layers respectively.

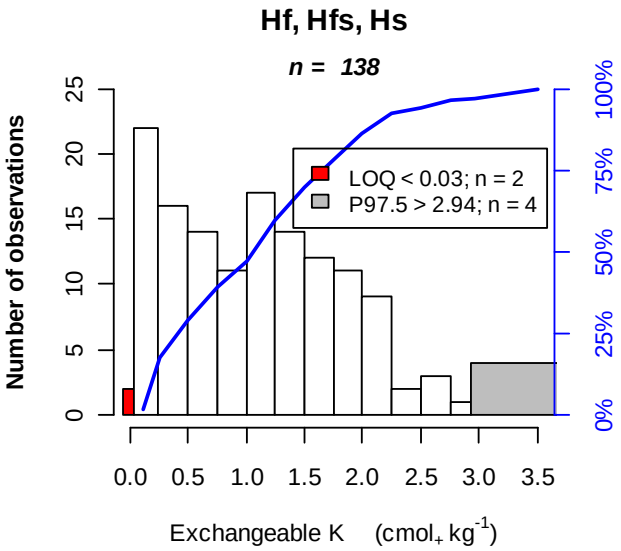


Figure 3.4.49. Absolute and cumulative frequency distribution (in blue) of exchangeable potassium in hydromorphic forest floor layers of all BioSoil+ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

In hydromorphic humus layers, the exchangeable K range is smaller than in terrestrial forms, with maximum values up to 4 $cmol_+$ kg^{-1} and a $P_{97.5}$ of 2.94 $cmol_+$ kg^{-1}. The median value is 1.09 $cmol_+$ K kg^{-1}, and the histogram in Figure 3.4.49 shows a rather even distribution of observations between 0.03 and 2 $cmol_+$ K kg^{-1}. About 1.4 % of observations are below LOQ.

Mineral layers

Exchangeable potassium in mineral layers ranges from less than 0.03 $cmol_+ kg^{-1}$ (LOQ) up to 7.09 $cmol_+ kg^{-1}$ at most. The red bars of Figure 3.4.50, indicating number of observations below LOQ, increase with depth. In the M01 topsoil, 8.3% of the observations are below LOQ, whereas 23% in M12 and ~33% in M24 and M48. So, below 20 cm of depth, one third of the samples may not be accurately analysed for exchangeable K by some labs. Median values estimated using statistics for censored data reveal decreasing values with depth: 0.15 > 0.08 > 0.06 = 0.06 $cmol_+ kg^{-1}$ for M01, M12, M24 and M48 layers respectively. Consistently, the 97.5 percentile values also decrease with depth indicating about half of exchangeable potassium in the subsoil compared to the 0-10 cm topsoil. Apart from the class below LOQ, most observations fall within the 0.03 - 0.1 $cmol_+ kg^{-1}$ class and rarely exceed 1 $cmol_+ kg^{-1}$. The statistical values are summarised in Annex II.

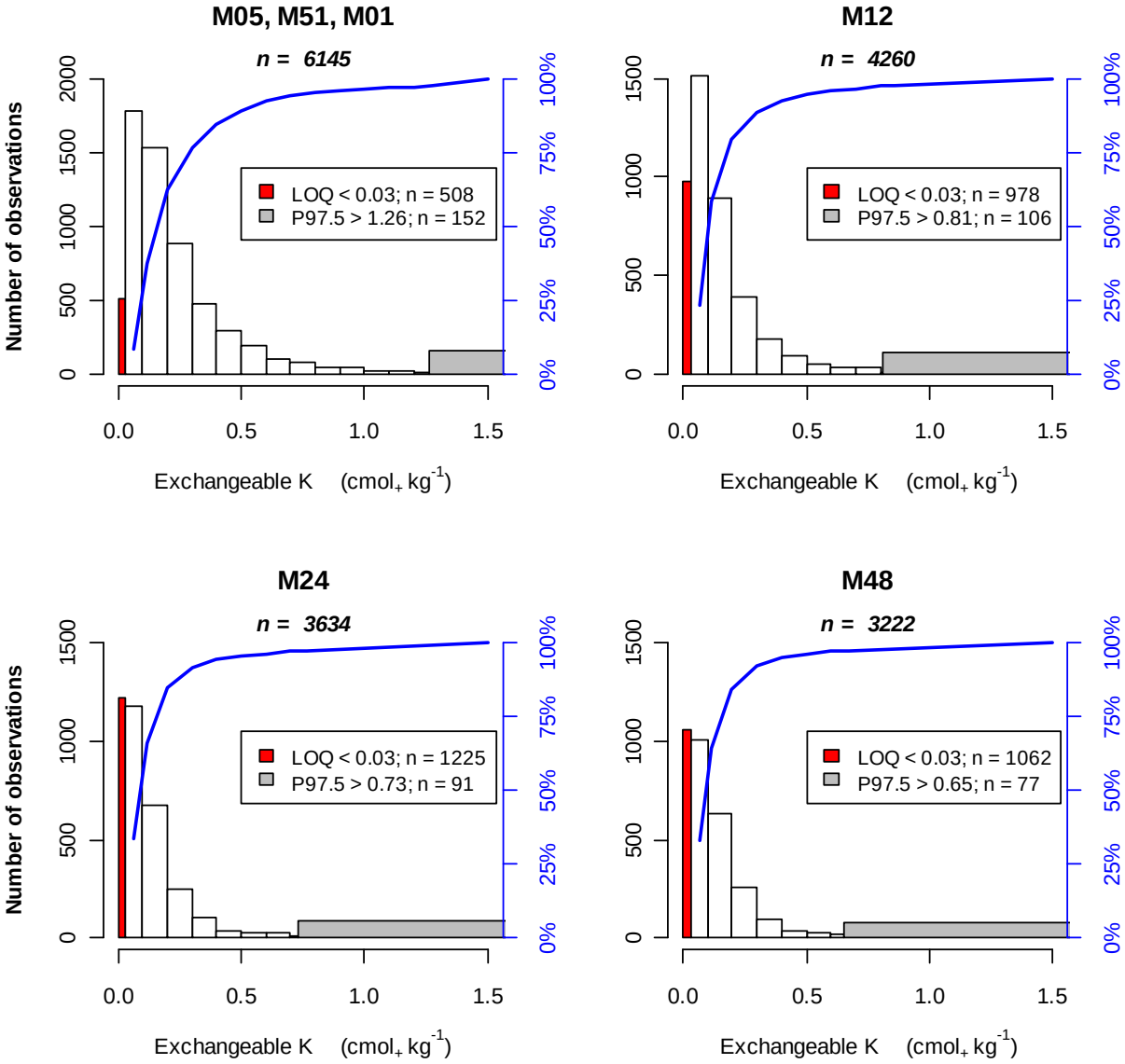


Figure 3.4.50. Absolute and cumulative frequency distribution (in blue) of exchangeable potassium in mineral soil layers of all BioSoil+ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

Peat soils

The median concentration of exchangeable potassium in peat layers is 2 to 4 times higher than in mineral layers. The distributions are shown in Figure 3.4.51. Since median values strongly decrease with depth, from 0.62 $cmol_+$ kg^{-1} in H01, to 0.26, 0.14 and 0.10 $cmol_+$ kg^{-1} in M12, M24 and M48 respectively, proportionally more values are getting below LOQ, which is 0.9, 4.5, 9.4 and 20.9 % of the observations. Roughly, most samples have a concentration below 0.4 $cmol_+$ kg^{-1} and only in the topsoil, few of them a concentration above 2 $cmol_+$ kg^{-1}, and 1.5 $cmol_+$ kg^{-1} for deeper layers.

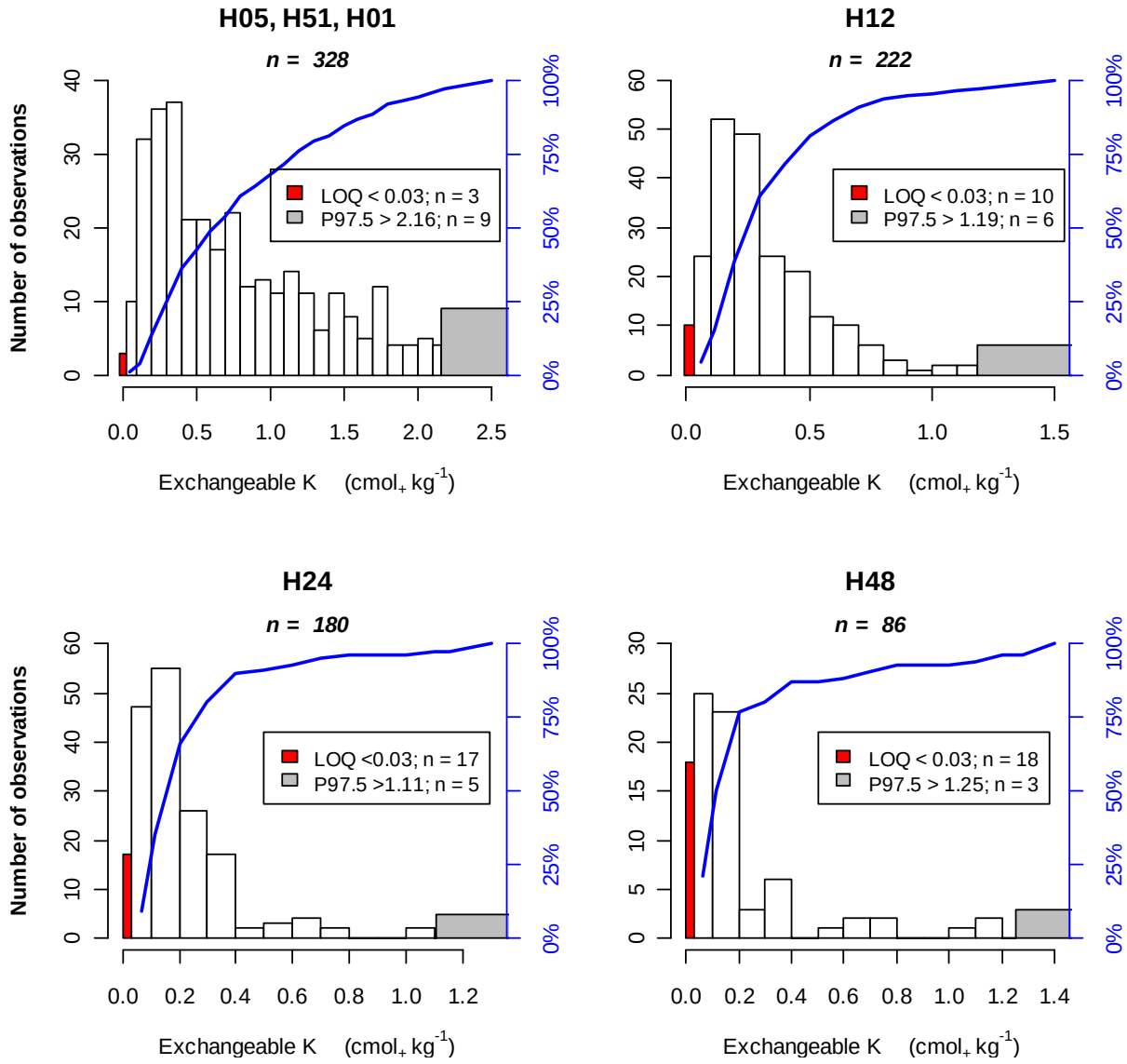


Figure 3.4.51. Absolute and cumulative frequency distribution (in blue) of exchangeable potassium in peat layers of all BioSoil⁺ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

3.4.9.4 Exchangeable Calcium

The concentration range of exchangeable calcium, the median and quartiles for each layer are presented in Figure 3.4.52. Exchangeable Ca is markedly higher in organic matrices (median values around 10 $cmol_+ kg^{-1}$) than in the mineral soil (median values in the order 0.1 to 1 $cmol_+$ Ca kg^{-1}). Part of the analyses of mineral soil are below the LOQ of 0.03 $cmol_+ kg^{-1}$. While the median values slightly decrease with depth in the mineral layers, the opposite is observed for the peat layers.

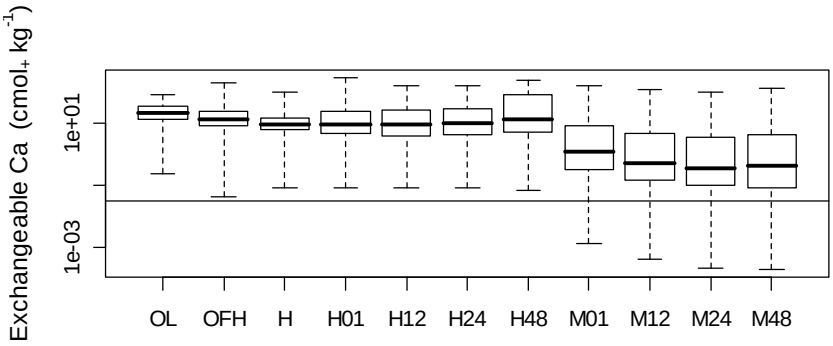


Figure 3.4.52. Box plot of exchangeable calcium for all layers. The Y-axis is logarithmic. The horizontal line indicates the LOQ at 0.03 $cmol_+ kg^{-1}$.

Forest Floor

Exchangeable calcium of terrestrial forest floor layers ranges from less than 0.03 $cmol_+ kg^{-1}$ (LOQ) to maximally 197 $cmol_+ kg^{-1}$. Less than 0.7% of the layers show concentrations below the LOQ and less than 2.5 % of all observations exceed 64.4 $cmol_+ kg^{-1}$ in OL and 82.3 $cmol_+ kg^{-1}$ in OFH layers (Figure 3.4.53). Both distributions are unimodal and skewed to the right, with modus in the 20-25 $cmol_+$ Ca kg^{-1} class for OL and in the 5-10 $cmol_+ kg^{-1}$ class for OFH.

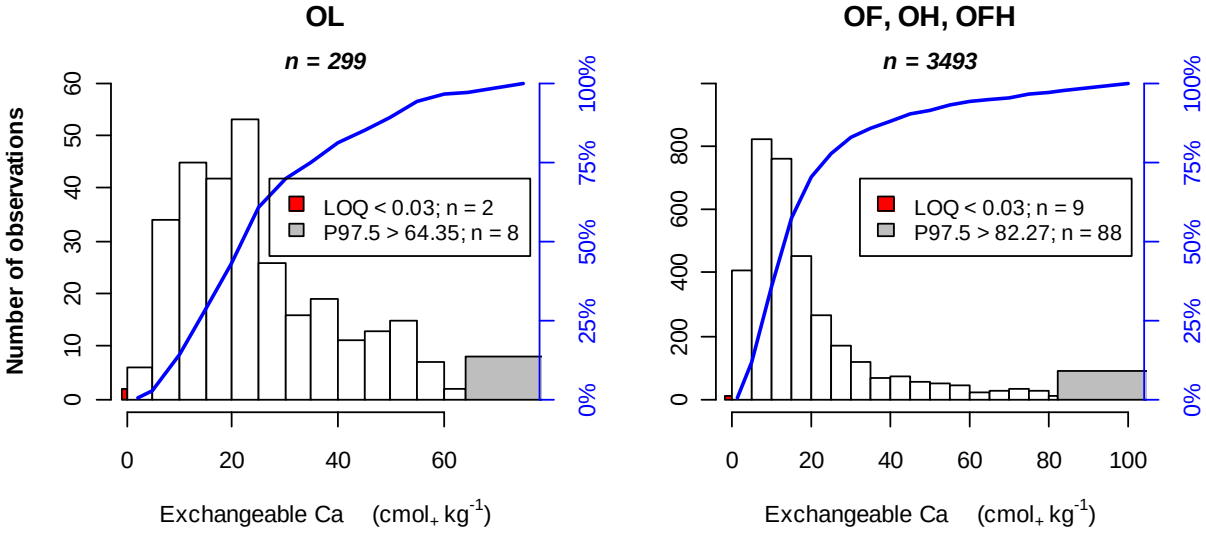


Figure 3.4.53. Absolute and cumulative frequency distribution (in blue) of exchangeable calcium in OL (left) and OF, OH and OFH layers (right) of all BioSoil+ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

The median values are 21.4 and 13.0 $cmol_+$ Ca kg^{-1} whereas means are 25.6 and 19.9 $cmol_+ kg^{-1}$ for OL and OFH layers, respectively.

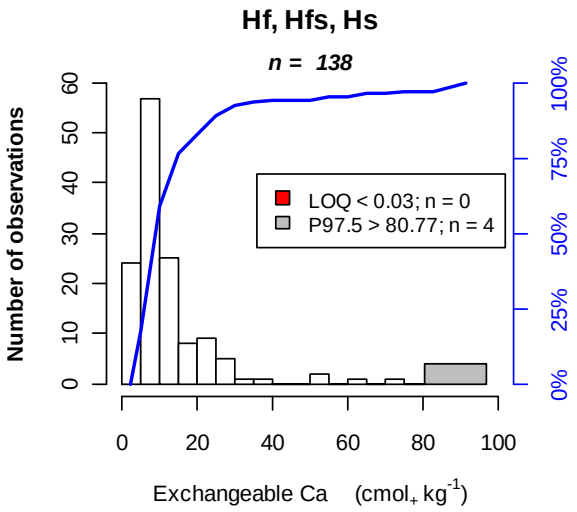


Figure 3.4.54. Absolute and cumulative frequency distribution (in blue) of exchangeable calcium in hydromorphic forest floor layers of BioSoil+ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

The distribution of exchangeable calcium concentrations of hydromorphic humus layers is shown in Figure 3.4.54. No observations were found below LOQ and most of them are below 80 $cmol_+$ kg^{-1}. The best represented class is 5 to 10 $cmol_+$ Ca kg^{-1} in which also the median of 9.08 $cmol_+$ kg^{-1} is situated.

Mineral layers

Exchangeable calcium in mineral layers ranges from less than 0.03 $cmol_+ kg^{-1}$ (LOQ) up to 169 $cmol_+ kg^{-1}$ at most. Figure 3.4.55 clearly shows that most observations belong to the 0.03 - 2.5 $cmol_+ kg^{-1}$ class, which is associated to non-calcareous soils (see section 3.4.11.2). The proportion of observations below LOQ increases from 1.5 % for M01 to 10.7 % for M48 layers. Median values estimated using statistics for censored data reveal a decreasing trend with depth: 1.23 > 0.51 > 0.35 < 0.43 $cmol_+ kg^{-1}$ for M01, M12, M24 and M48 layers respectively. Also the 97.5 percentile values decrease with depth. The statistical values are summarised in Annex II.

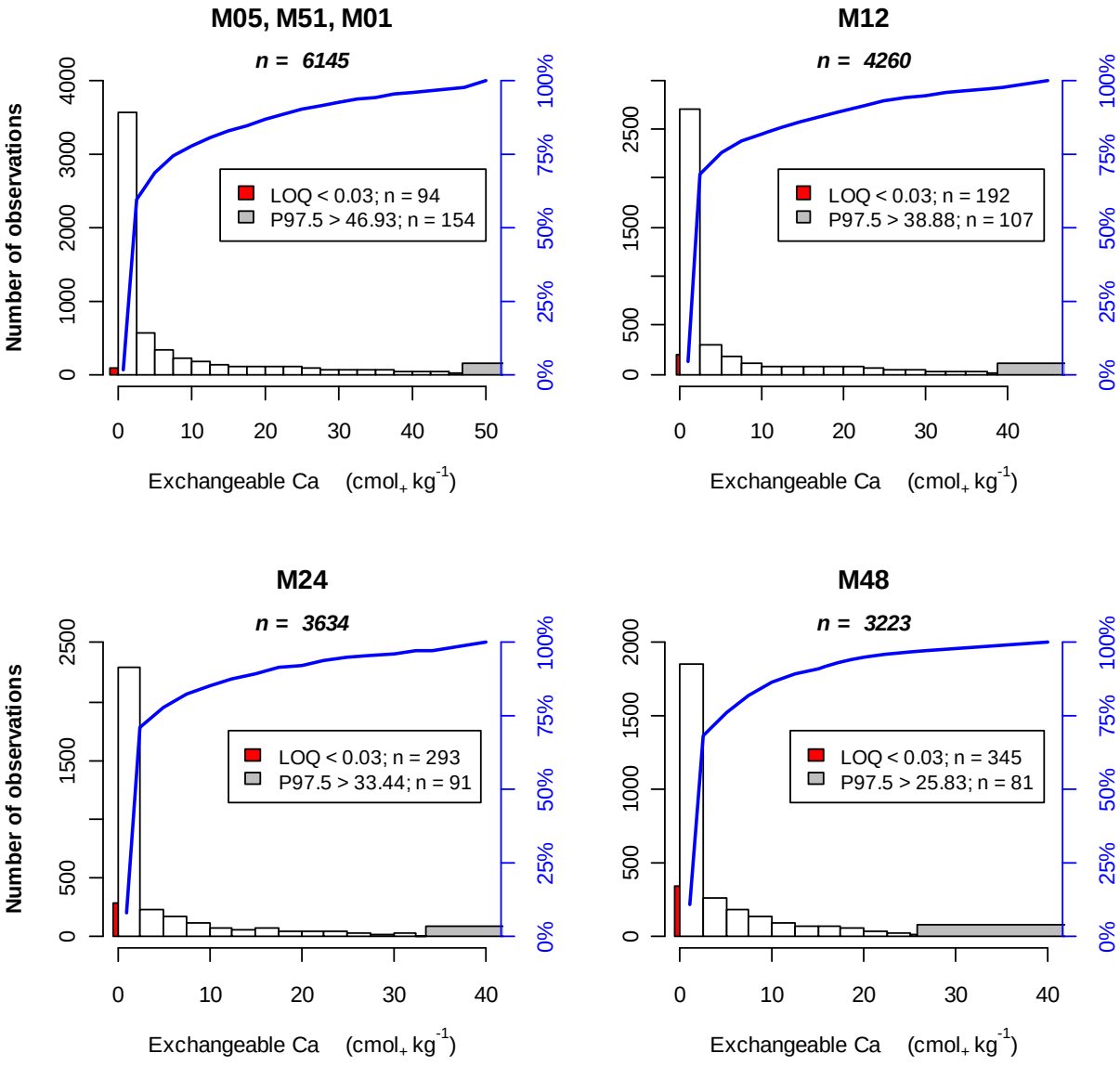


Figure 3.4.55. Absolute and cumulative frequency distribution (in blue) of exchangeable calcium in mineral soil layers of all BioSoil+ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

Peat soils

The median concentration of exchangeable calcium in peat layers is about 10 $cmol_+$ kg^{-1} and the upper range limit extends to about 3 times the one for mineral layers (Figure 3.4.56). The distribution patterns for all depths are quite similar, with most observations in the 0 - 10 $cmol_+$ kg^{-1} class. Except for layer H12, no values below LOQ are reported. The $P_{97.5}$ values slightly increase with depth just as the median values as listed in Annex II.

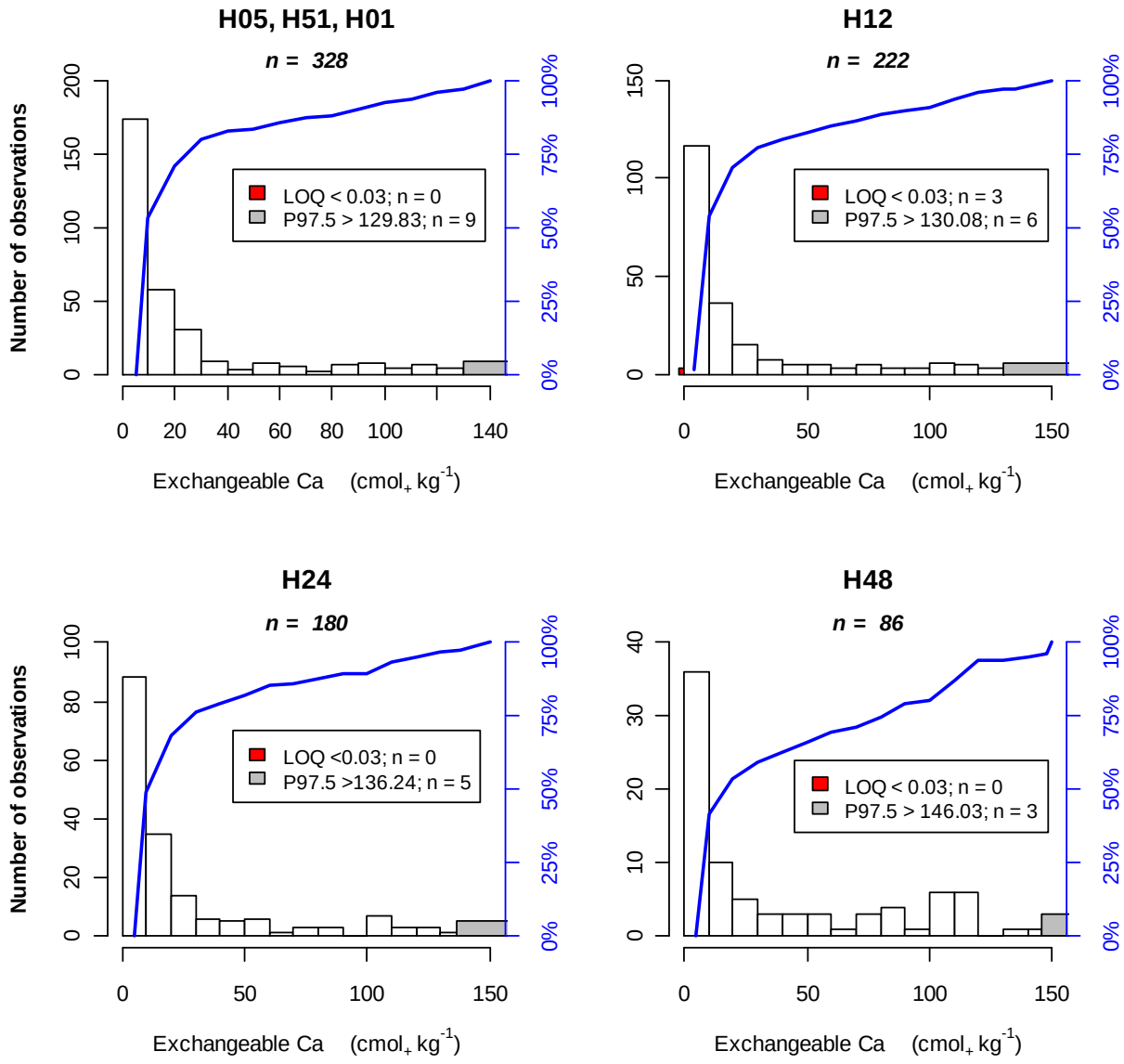


Figure 3.4.56. Absolute and cumulative frequency distribution (in blue) of exchangeable calcium in peat layers of BioSoil+ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

3.4.9.5 Exchangeable Magnesium

The concentration range of exchangeable magnesium, the median and quartiles for each layer are presented in Figure 3.4.57. Just as for exchangeable calcium, levels are generally higher in organic matrices than in mineral soil. The inter-quartile range is also more narrow for organic samples than for the mineral ones. The 1st quartile of layers M24 and M48 are close to the LOQ, indicating that one quarter of observations are difficult to quantify reliably by many labs.

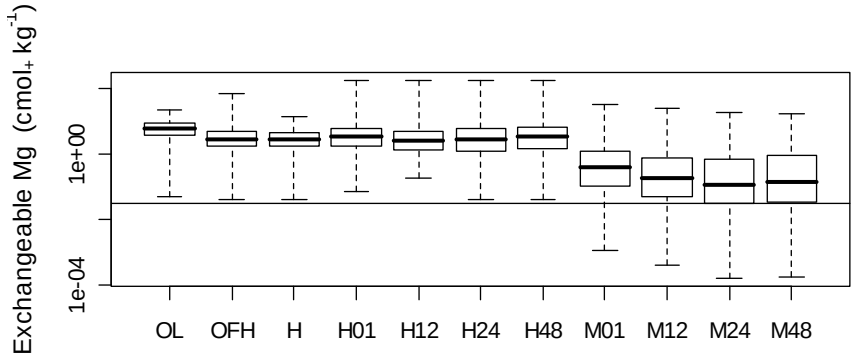


Figure 3.4.57. Box plot of exchangeable magnesium for all layers. The Y-axis is logarithmic. The horizontal line indicates the LOQ at 0.03 $cmol_+ kg^{-1}$.

Forest Floor

Exchangeable magnesium of terrestrial forest floor layers ranges from less than 0.03 $cmol_+ kg^{-1}$ (LOQ) to maximally ~69 $cmol_+ kg^{-1}$. Less than 0.7% of OL and OFH layers have concentrations below LOQ and less than 2.5 % of all observations exceed 14.4 $cmol_+ kg^{-1}$ in these layers (Figure 3.4.58). Both distributions are unimodal, but the OFH distribution is much more skewed to the right (skewness = 4) compared to the OL distribution (skewness = 1). The class 5 – 6 $cmol_+ kg^{-1}$ holds most observations for OL layers whereas for OFH layers this is class 1 – 2 $cmol_+ kg^{-1}$.

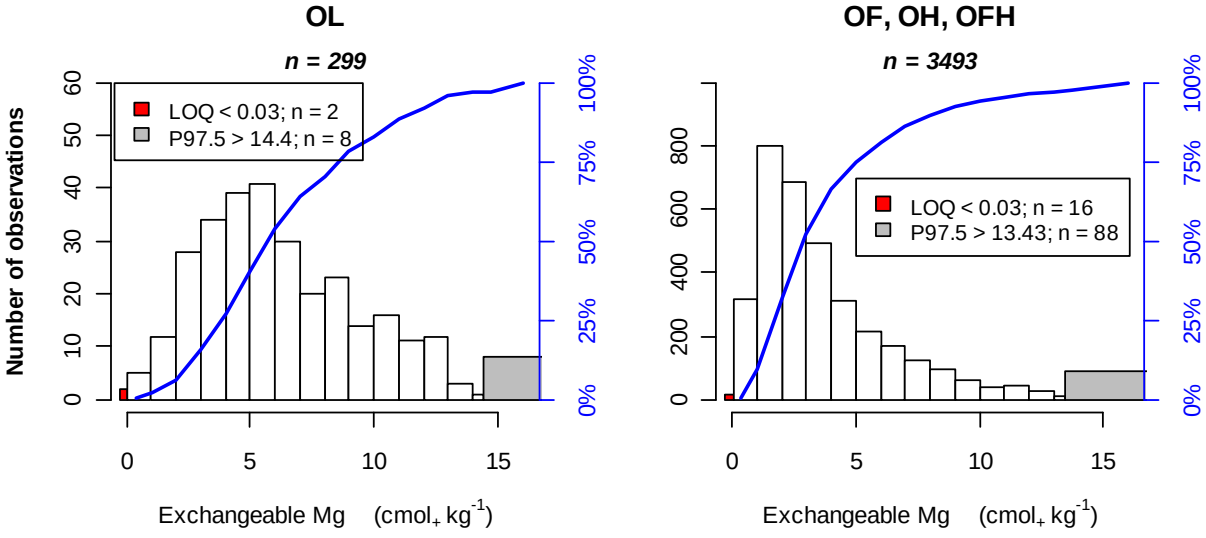


Figure 3.4.58. Absolute and cumulative frequency distribution (in blue) of exchangeable magnesium in OL (left) and OF, OH and OFH layers (right) of all BioSoil+ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

The median values are 5.77 and 2.89 $cmol_+$ Mg kg^{-1} whereas means are 6.43 and 3.97 $cmol_+$ kg^{-1} for OL and OFH layers respectively.

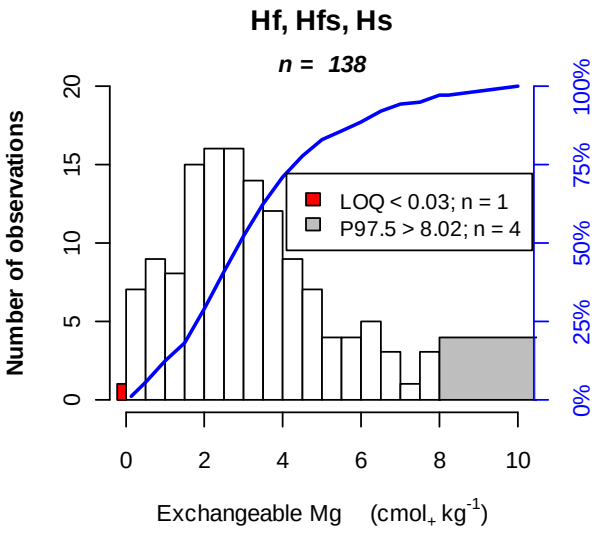


Figure 3.4.59. Absolute and cumulative frequency distribution (in blue) of exchangeable magnesium in hydromorphic forest floor layers of all BioSoil+ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

The exchangeable magnesium distribution of hydromorphic humus layers, shown in Figure 3.4.59, is slightly skewed to the right (skewness = 1.7) with a maximum number of values between 2 and 3 $cmol_+$ Mg kg^{-1}. Just 1 observation is below LOQ. The median value of 2.85 $cmol_+$ kg^{-1} is close to that of OFH layers (2.89), but the $P_{97.5}$ is quite lower which might be due to the limited number of observations.

Mineral layers

Exchangeable magnesium in mineral layers ranges from less than 0.03 $cmol_+ kg^{-1}$ (LOQ) up to 32 $cmol_+ kg^{-1}$ at most. Figure 3.4.60 clearly shows that most observations are situated in the 0.03 - 0.5 $cmol_+ kg^{-1}$ class. The proportion of left censored observations increases from 8.4 % of the M01 layers up to 30 % of the M48 layers. Median values estimated using statistics for censored data reveal a decreasing trend with depth: 0.38 > 0.18 > 0.11 < 0.14 $cmol_+ kg^{-1}$ for M01, M12, M24 and M48 layers respectively. The 97.5 percentile values are also highest in the topsoil and are less than 6 $cmol_+ kg^{-1}$ in the 20 – 40 cm layer. The statistical values are summarised in Annex II.

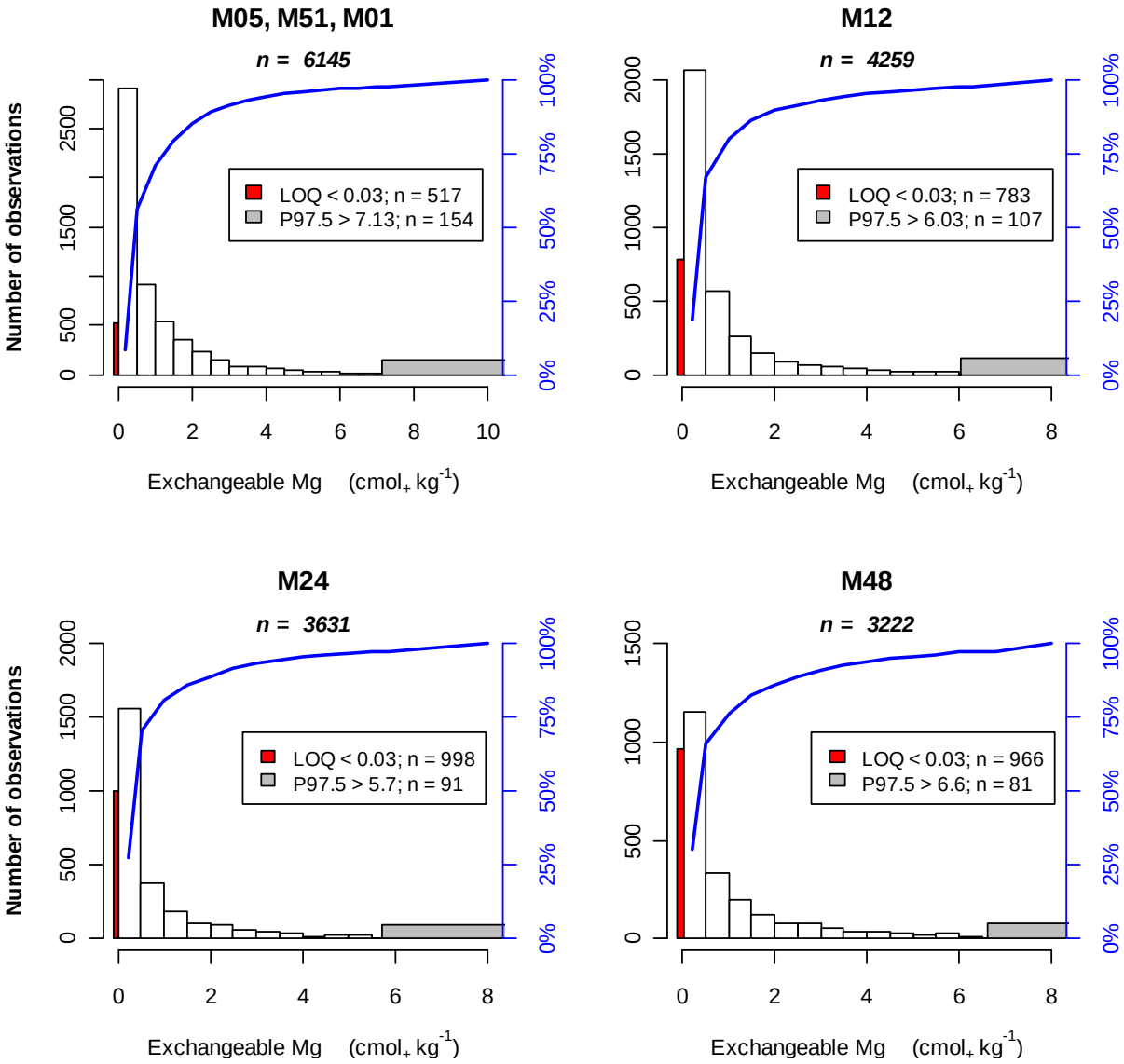


Figure 3.4.60. Absolute and cumulative frequency distribution (in blue) of exchangeable magnesium in mineral soil layers of all BioSoil⁺ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

Peat soils

The median concentration of exchangeable magnesium in peat layers is about a factor 6 to 20 greater than in mineral layers. The distributions are shown in Figure 3.4.61. A limited number of observations are below LOQ (< 2.3 %) and less than 2.5 % of the observations exceed 21.5 $cmol_+$ kg^{-1}. The distributions contrast with those for mineral layers, with much more observations in the 0 to 5 $cmol_+$ kg^{-1} range and a substantial amount between 5 and 10 $cmol_+$ kg^{-1}. Median values range from 2.41 to 3.48 $cmol_+$ kg^{-1} and mean values between 4.26 and 6.63 $cmol_+$ kg^{-1}. The statistical values are listed per layer in Annex II.

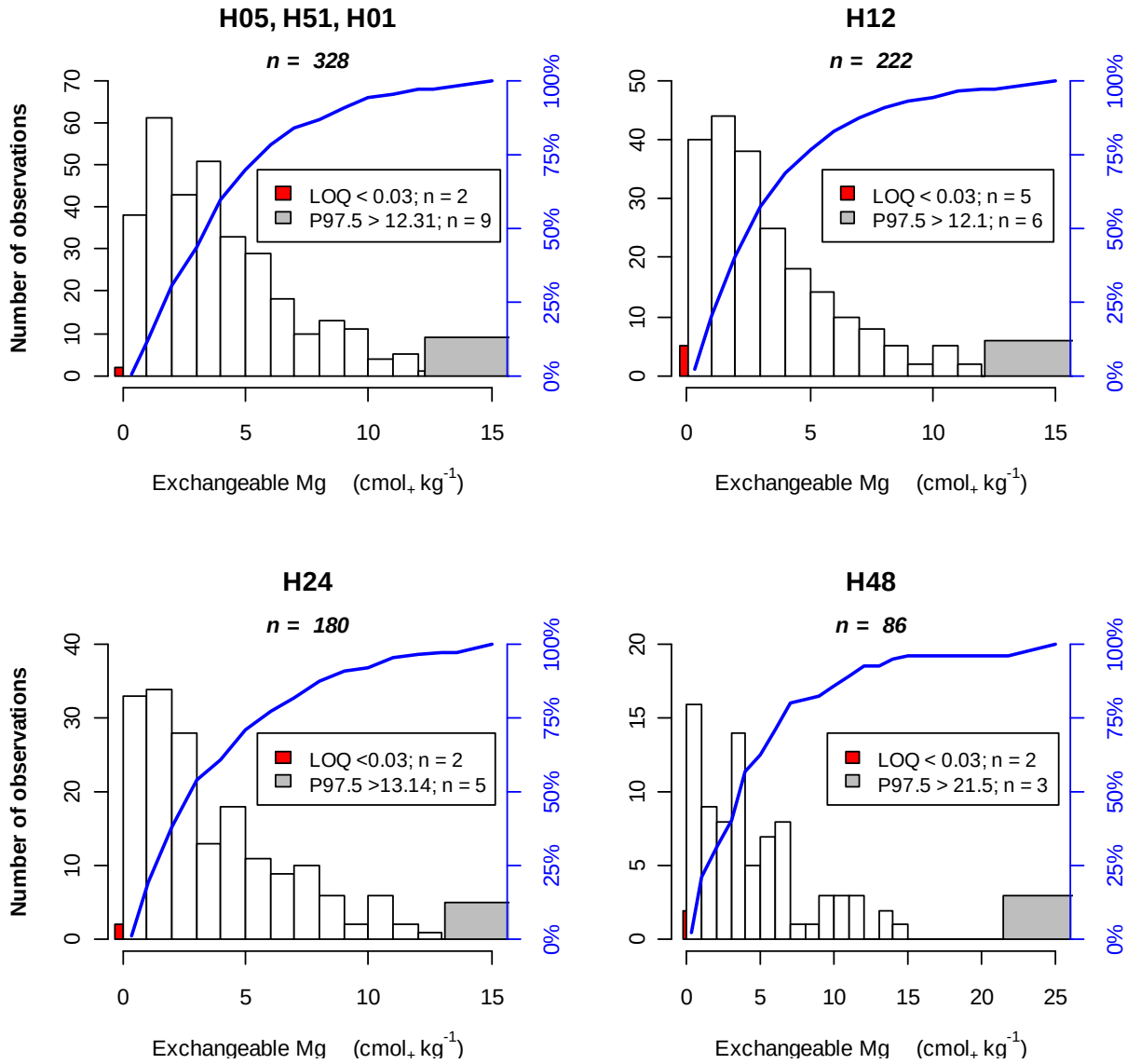


Figure 3.4.61. Absolute and cumulative frequency distribution (in blue) of exchangeable magnesium in peat layers of all BioSoil⁺ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

3.4.9.6 Exchangeable Sodium

The concentration range of exchangeable sodium, the median and quartiles for each layer are presented in Figure 3.4.62. Apart from the OL layer, all other organic layers contain about ten times more exchangeable sodium than the mineral layers and their range is generally more narrow. Mineral layers have low exchangeable sodium contents and show median values near the LOQ, indicating difficulties for accurate determinations of these levels by most labs, similar to the detection of aqua regia extractable Na. Within mineral and peat layers, little variation in exchangeable Na distribution is found with depth.

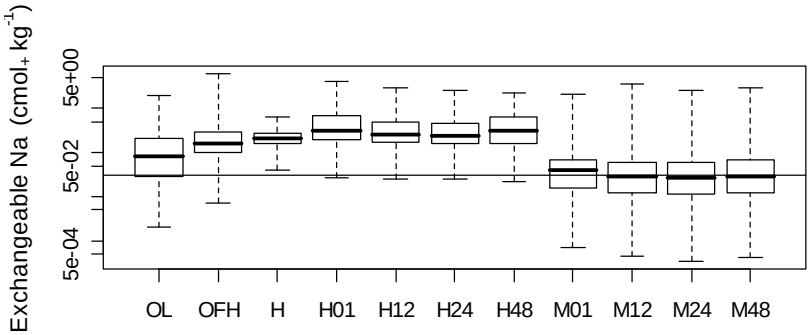


Figure 3.4.62. Box plot of exchangeable sodium for all layers. The Y-axis is logarithmic. The horizontal line indicates the LOQ at 0.03 $cmol_+ kg^{-1}$.

Forest Floor

Exchangeable sodium of terrestrial forest floor layers ranges from less than 0.03 $cmol_+ kg^{-1}$ (LOQ) to maximally 6 $cmol_+ kg^{-1}$. About 31 % of the OL and 8 % of the OFH layers show observations below the LOQ and less than 2.5 % of all observations exceed 1.40 $cmol_+ kg^{-1}$ in OL and 1.15 $cmol_+ kg^{-1}$ in OFH layers (Figure 3.4.63). In OL and OFH layers, exchangeable Na is usually less than 0.5 $cmol_+ kg^{-1}$.

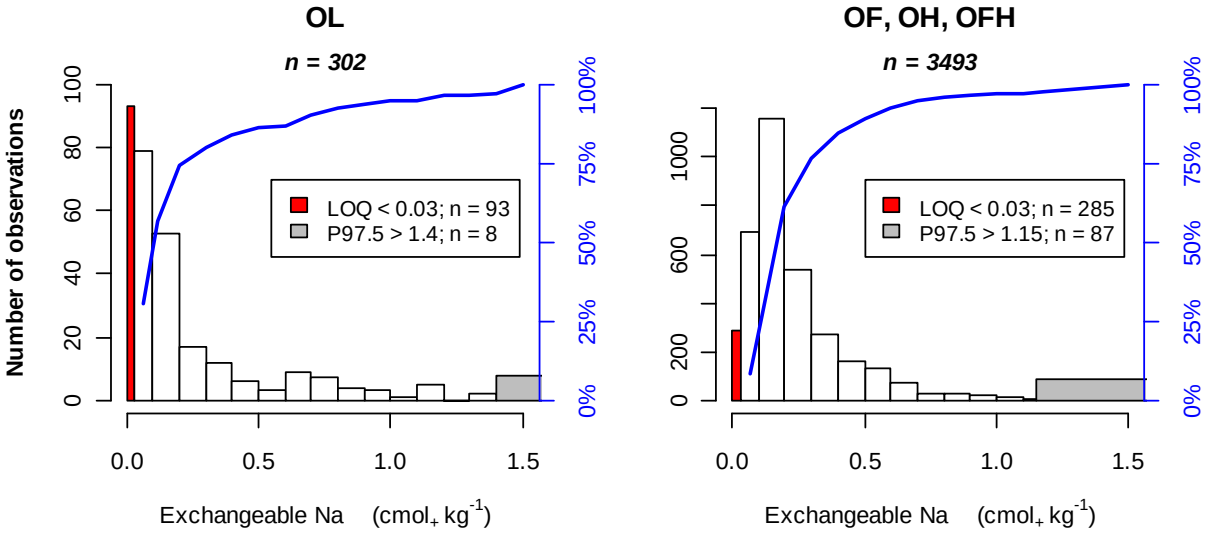


Figure 3.4.63. Absolute and cumulative frequency distribution (in blue) of exchangeable sodium in OL (left) and OF, OH and OFH layers (right) of all BioSoil+ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

The median values are 0.08 and 0.16 $cmol_+ kg^{-1}$ whereas means are 0.23 and 0.26 $cmol_+ kg^{-1}$ for OL and OFH layers respectively.

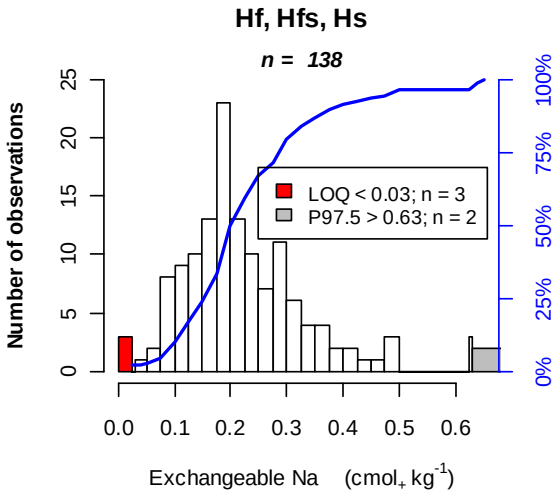


Figure 3.4.64. Absolute and cumulative frequency distribution (in blue) of exchangeable sodium in hydromorphic forest floor layers of all BioSoil+ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

The exchangeable sodium distribution of hydromorphic humus layers is unimodal (modus and median around 0.20 $cmol_+ kg^{-1}$) and slightly skewed to the right. Only 2.2 % of the observations is below LOQ as indicated by the red bar in Figure 3.4.64. Rarely values above 0.5 $cmol_+ kg^{-1}$ were observed.

Mineral layers

Exchangeable sodium in mineral layers ranges from less than 0.03 $cmol_+ kg^{-1}$ (LOQ) up to 3.54 $cmol_+ kg^{-1}$ at most. Figure 3.4.65 clearly shows that about half of all observations are situated below LOQ (red bars) and the other part is mainly situated below 0.1 $cmol_+ kg^{-1}$.

Statistics for left censored data predict similar median values (~0.03) and means (~0.08) for all depth layers. Consistently, the 97.5 percentile values are similar with depth: ~0.43 $cmol_+ kg^{-1}$. The statistical values are summarised in Annex II.

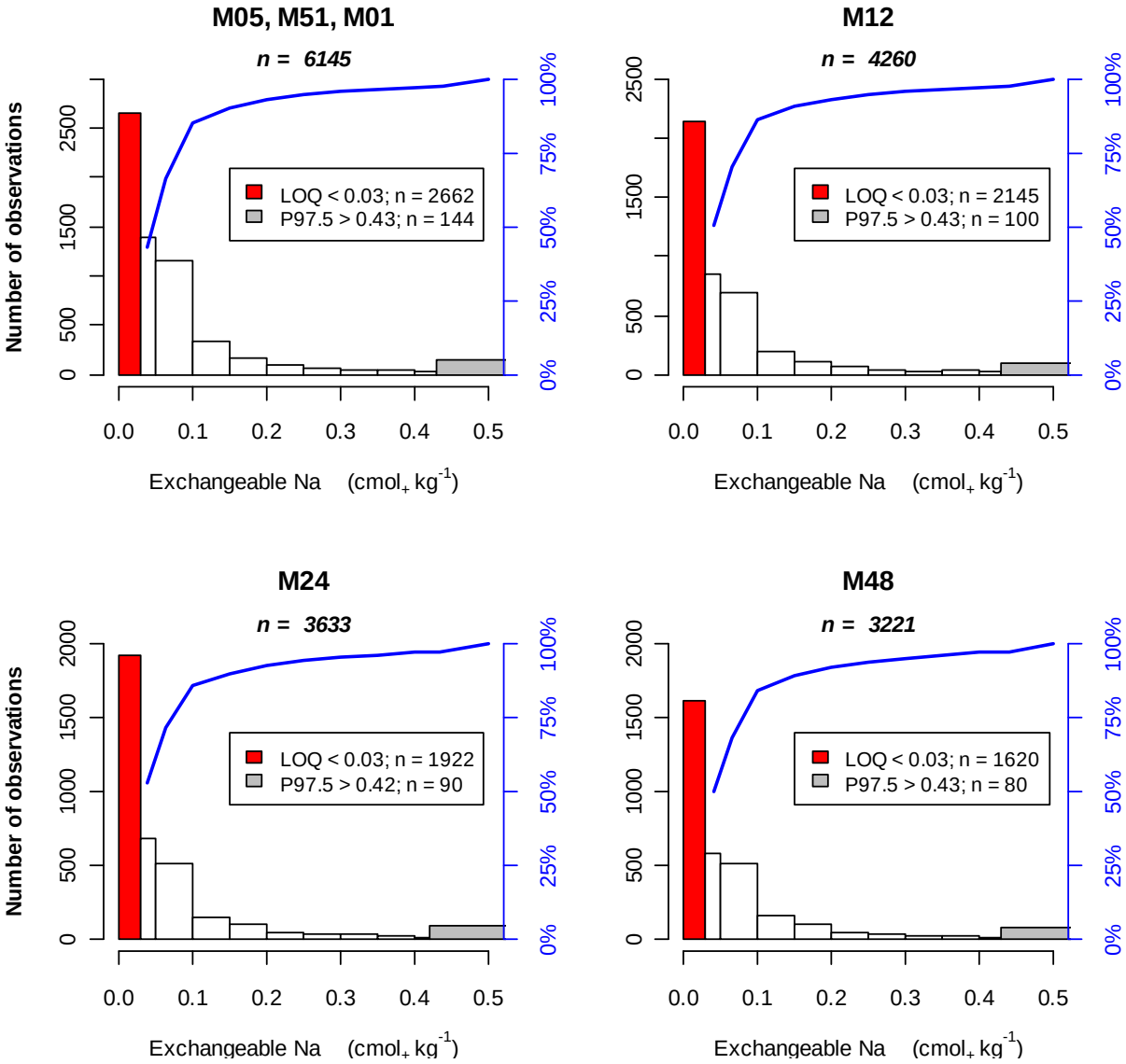


Figure 3.4.65. Absolute and cumulative frequency distribution (in blue) of exchangeable sodium in mineral soil layers of all BioSoil⁺ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

Peat soils

The median concentration of exchangeable sodium in peat layers is about a factor 10 greater than in mineral layers, and therefore much more easy to quantify as evidenced by the lower proportion of left censored values (max 5.8 %). See the distributions in Figure 3.4.66 with less than 2.5 % of the observations exceeding 2.33 $cmol_+ kg^{-1}$. The median values are situated between 0.24 and 0.30 $cmol_+ kg^{-1}$ and the means between 0.45 and 0.54 $cmol_+ kg^{-1}$. More statistical values are listed per layer in Annex II.

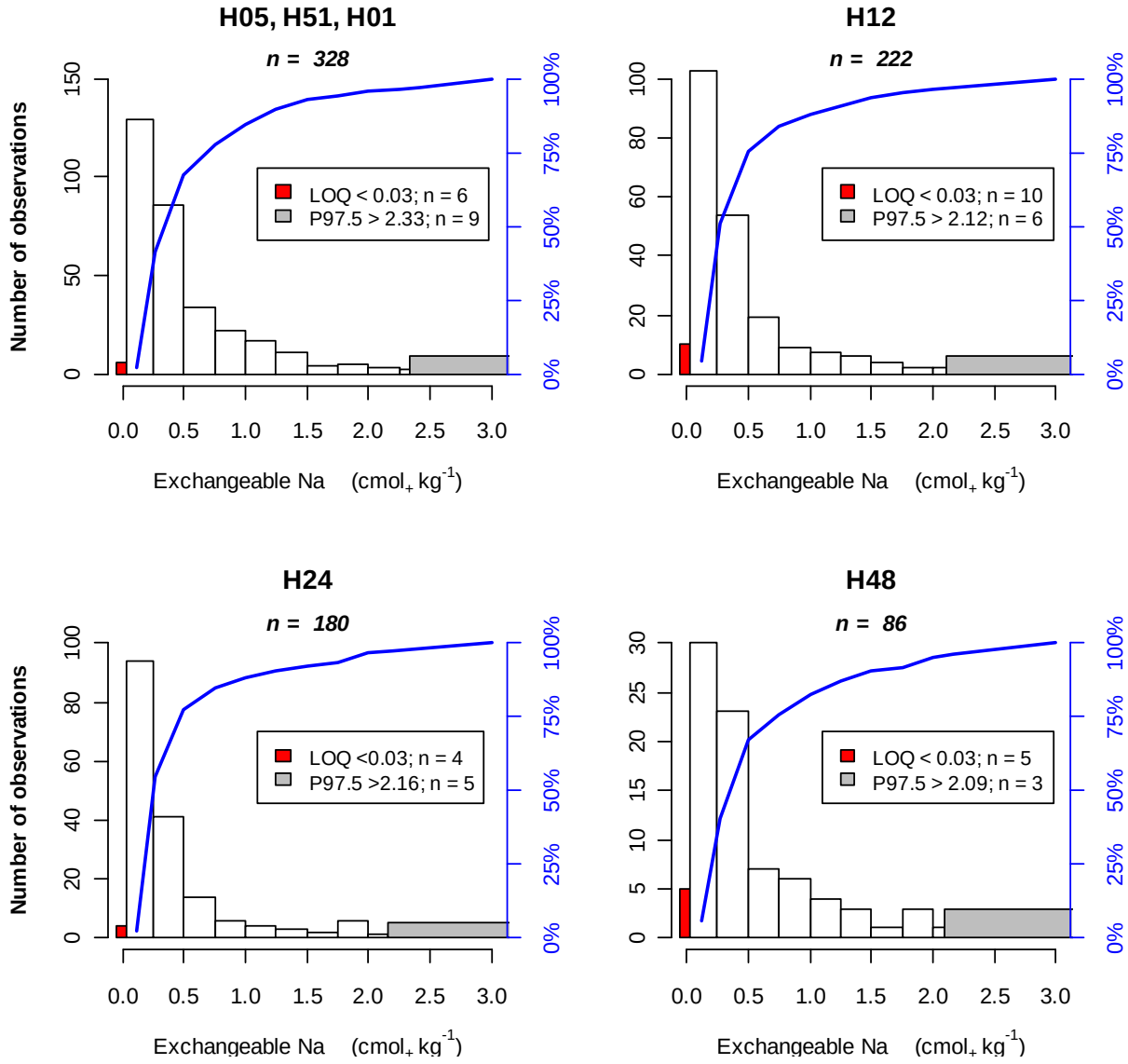


Figure 3.4.66. Absolute and cumulative frequency distribution (in blue) of exchangeable sodium in peat layers of all BioSoil$^+$ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

3.4.9.7 Exchangeable Aluminium

The concentration range of exchangeable aluminium, the median and quartiles for each layer are presented in Figure 3.4.67. Lowest values are found for OL layers and highest for hydromorphic forest floor H-layers. The median values for the other layers vary from 0.51 $cmol_+ kg^{-1}$ to 2.33 $cmol_+ kg^{-1}$. For each depth range, exchangeable Al in peat layers is generally higher than for mineral soils. Most exchangeable aluminium observations are well above the quantification limit, except for the OL layer.

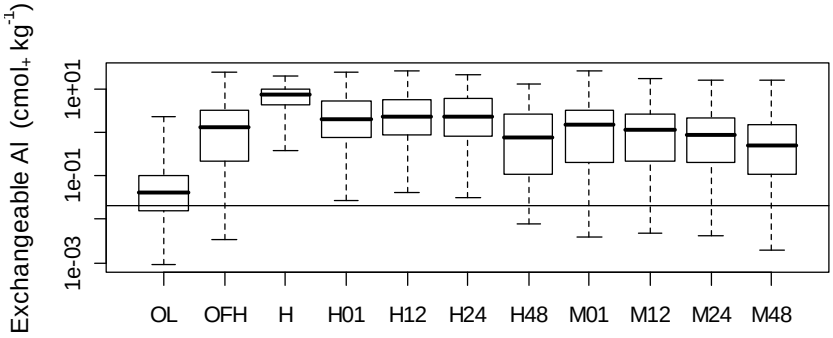


Figure 3.4.67. Box plot of exchangeable aluminium for all layers. The Y-axis is logarithmic. The horizontal line indicates the LOQ at 0.02 $cmol_+ kg^{-1}$.

Forest Floor

Exchangeable aluminium of terrestrial forest floor layers ranges from less than 0.02 $cmol_+ kg^{-1}$ (LOQ) to maximally ~23 $cmol_+ kg^{-1}$. About 37 % of the OL and 11 % of the OFH layers show observations below the LOQ and less than 2.5 % of all observations exceed 0.77 $cmol_+ kg^{-1}$ in OL and 9.16 $cmol_+ kg^{-1}$ in OFH layers (Figure 3.4.68). In OL, the exchangeable Al concentration is generally less than 0.3 $cmol_+ kg^{-1}$ whereas in OFH the levels between 0 and 5 $cmol_+ kg^{-1}$ are well represented in the dataset.

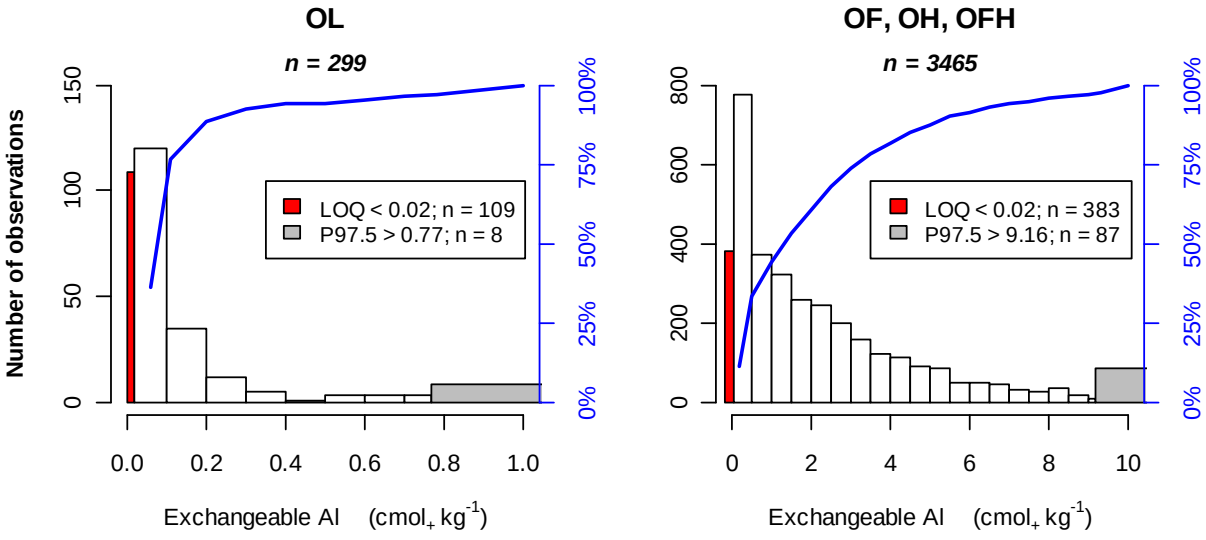


Figure 3.4.68. Absolute and cumulative frequency distribution (in blue) of exchangeable aluminium in OL (left) and OF, OH and OFH layers (right) of all BioSoil+ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

The median values are 0.04 and 1.32 $cmol_+$ Al kg^{-1} whereas means are 0.12 and 2.19 $cmol_+ kg^{-1}$ for OL and OFH layers respectively. The OL distribution is much more skewed to the right and has a higher kurtosis than the OFH distribution.

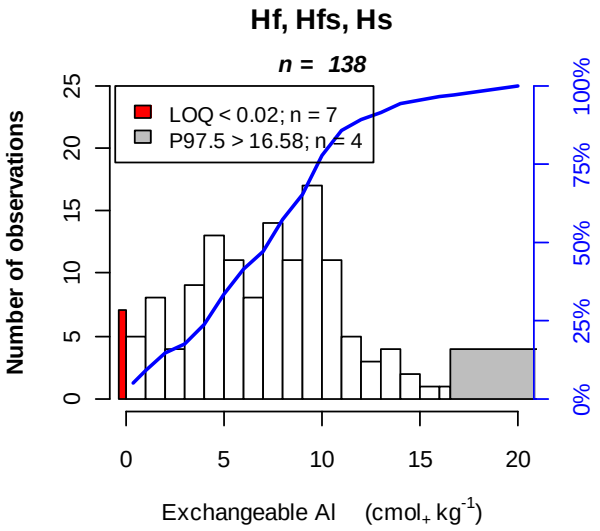


Figure 3.4.69. Absolute and cumulative frequency distribution (in blue) of exchangeable aluminium in hydromorphic forest floor layers of all BioSoil^{+} plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

The exchangeable aluminium distribution (Figure 3.4.69*)* of hydromorphic humus layers has a modus near 10 $cmol_+$ kg^{-1} and about 5 % of its observations below LOQ. Less than 2.5 % of the observations were greater than 16.6 $cmol_+$ kg^{-1}.

With a median of 7.25 $cmol_+$ kg^{-1} the exchangeable Al in H layers is highest of all investigated layers.

Mineral layers

Exchangeable aluminium in mineral layers ranges from less than 0.02 $cmol_+ kg^{-1}$ (LOQ) up to 25.4 $cmol_+ kg^{-1}$ at most. Figure 3.4.70 clearly shows that most observations are observed in the range 0 to 10 $cmol_+ kg^{-1}$. Between 13 and 17 % of the observations are below LOQ (red bars). Median values estimated using statistics for censored data reveal decreasing values with depth: 1.45 > 1.17 > 0.85 > 0.51 $cmol_+ kg^{-1}$ for M01, M12, M24 and M48 layers respectively. Consistently, the 97.5 percentile values also decrease with depth indicating lower exchangeable aluminium levels in the subsoil compared to the topsoil. The statistical values are summarised in the tables of Annex II.

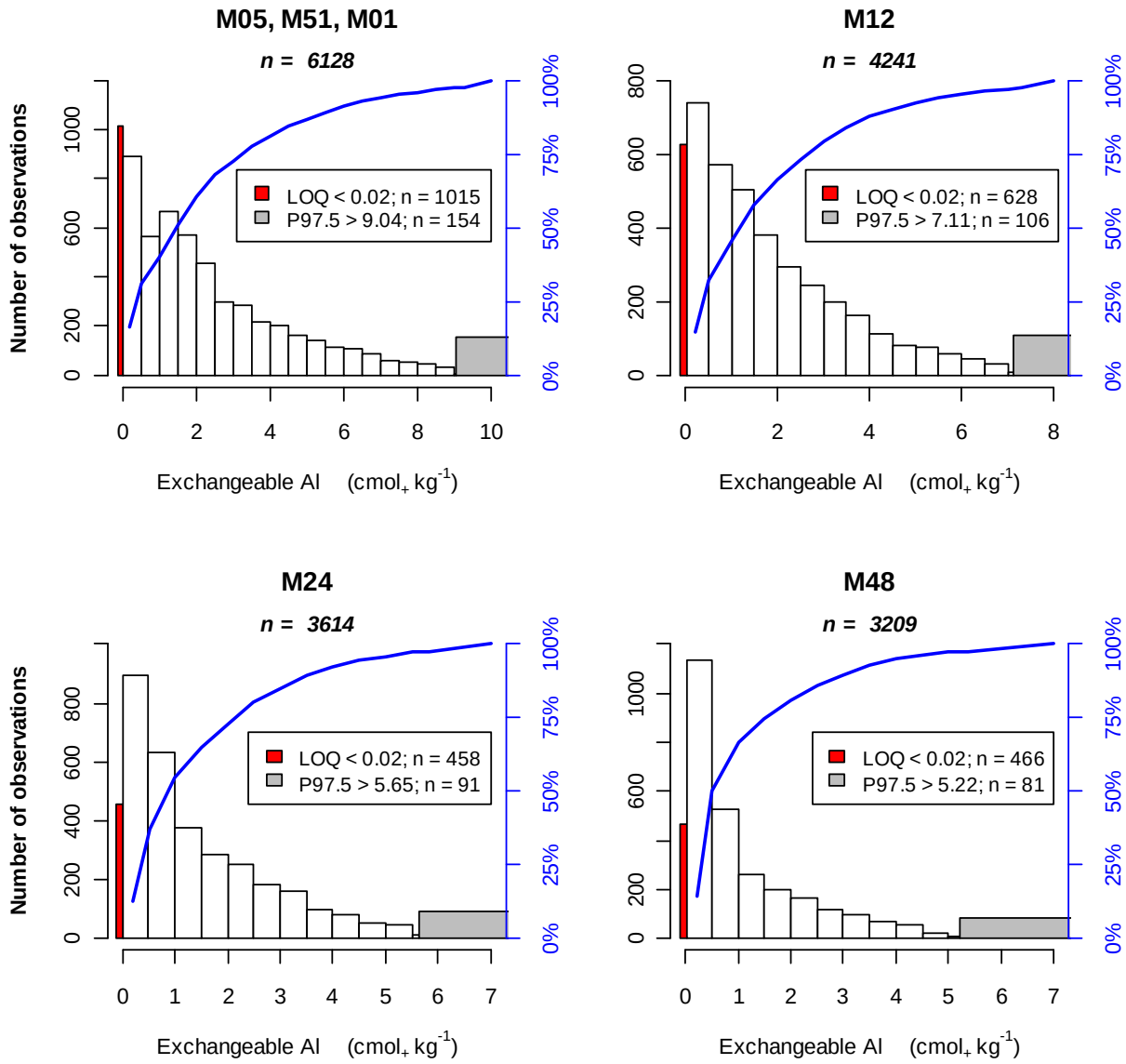


Figure 3.4.70. Absolute and cumulative frequency distribution (in blue) of exchangeable aluminium in mineral soil layers of all BioSoil+ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

Peat soils

The exchangeable aluminium concentration in peat layers is generally greater than in mineral soil layers as shown by the distributions in Figure 3.4.71. Between 8 and 26 % of the observations are below LOQ and less than 2.5 % of the observations exceed 15 $cmol_+ kg^{-1}$. The median values are lower for H01 (2.04 $cmol_+ kg^{-1}$) and H48 (0.77 $cmol_+ kg^{-1}$) layers compared to H12 and H24 layers (~2.30 $cmol_+ kg^{-1}$). Mean values are between 3.6 and 3.9 $cmol_+ kg^{-1}$ until 40 cm of depth and 2.1 $cmol_+ kg^{-1}$ for the H48 layer. The statistical values are listed per layer in Annex II.

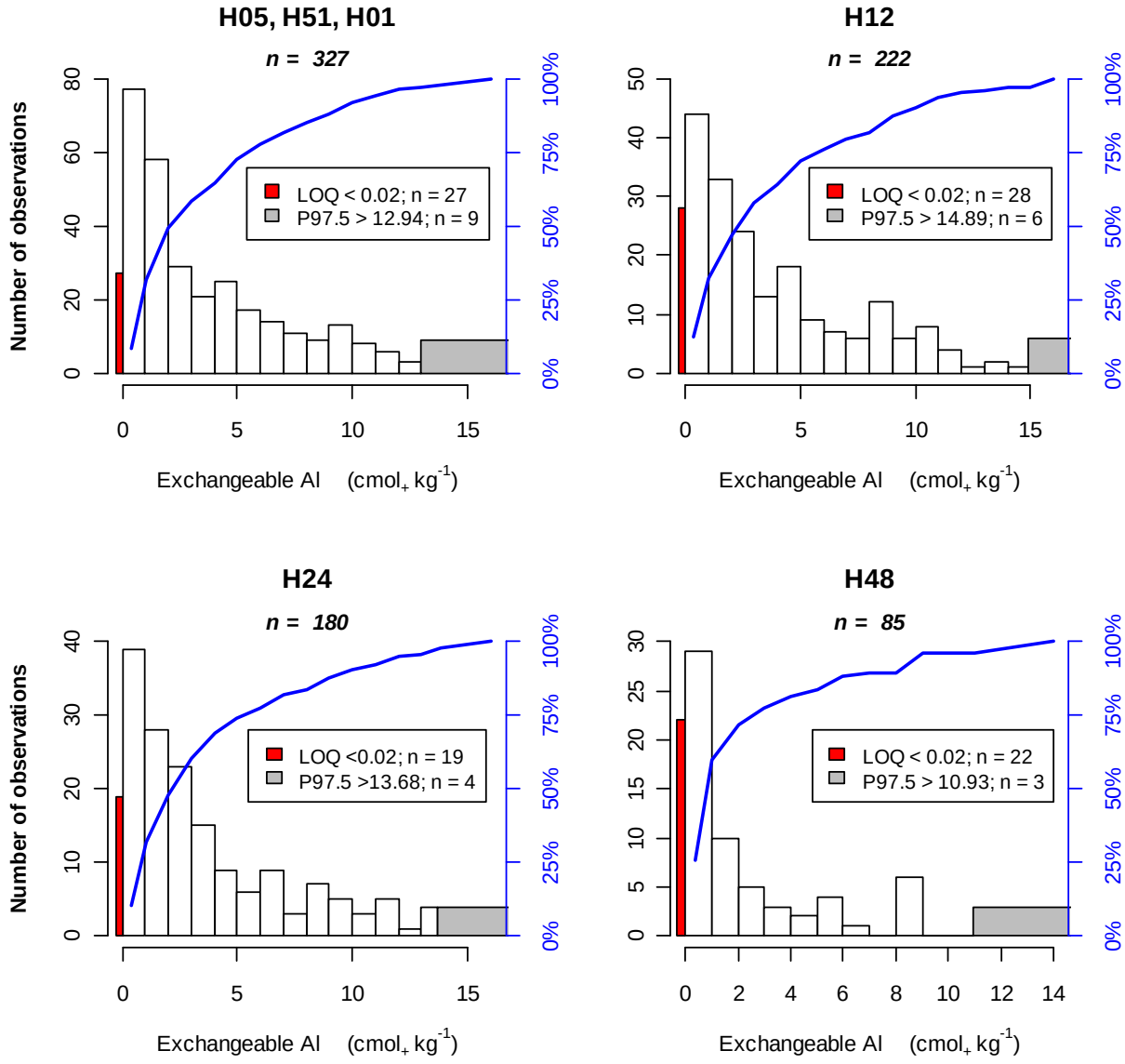


Figure 3.4.71. Absolute and cumulative frequency distribution (in blue) of exchangeable aluminium in peat layers of all BioSoil⁺ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

3.4.9.8 Exchangeable Iron

The concentration range of exchangeable iron, the median and quartiles for each layer are presented in Figure 3.4.72. Just as for exchangeable Al, levels are lowest for OL and highest for H layers and the concentrations in peat are generally greater than in mineral soil. Much more than for exchangeable Al, Fe concentrations below LOQ are found especially in the OL and the mineral layers. Hence, exchangeable Fe could not be quantified reliably for a considerable part of these samples provoking also calculation problems for the determination of CEC and base saturation. Note also the smaller concentration ranges of the peat samples compared to the mineral ones and the general decrease of exchangeable Fe with depth, both in mineral and peat layers.

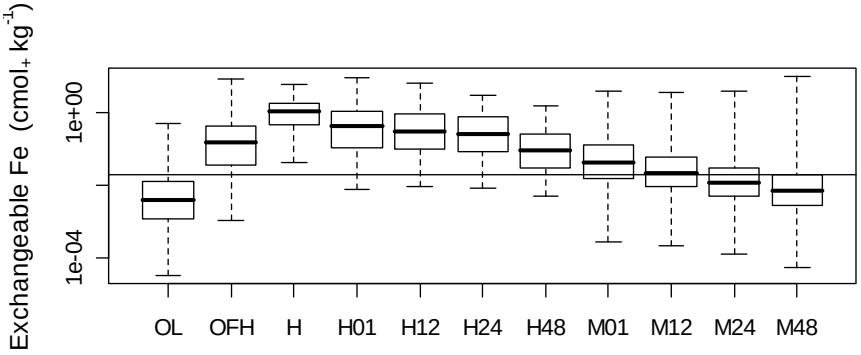


Figure 3.4.72. Box plot of exchangeable iron for all layers. The Y-axis is logarithmic. The horizontal line indicates the LOQ at 0.02 $cmol_+ kg^{-1}$.

Forest Floor

Exchangeable iron of terrestrial forest floor layers ranges from less than 0.02 $cmol_+ kg^{-1}$ (LOQ) to maximally 8.33 $cmol_+ kg^{-1}$. About 88 % of the OL and 26 % of the OFH layers show observations below the LOQ and less than 2.5 % of all observations exceed 0.16 $cmol_+ kg^{-1}$ in OL and 1.5 $cmol_+ kg^{-1}$ in OFH layers (Figure 3.4.73). Measuring exchangeable Fe in OL seems to have little sense, in contrast to OFH layers where the range extends about 10 times.

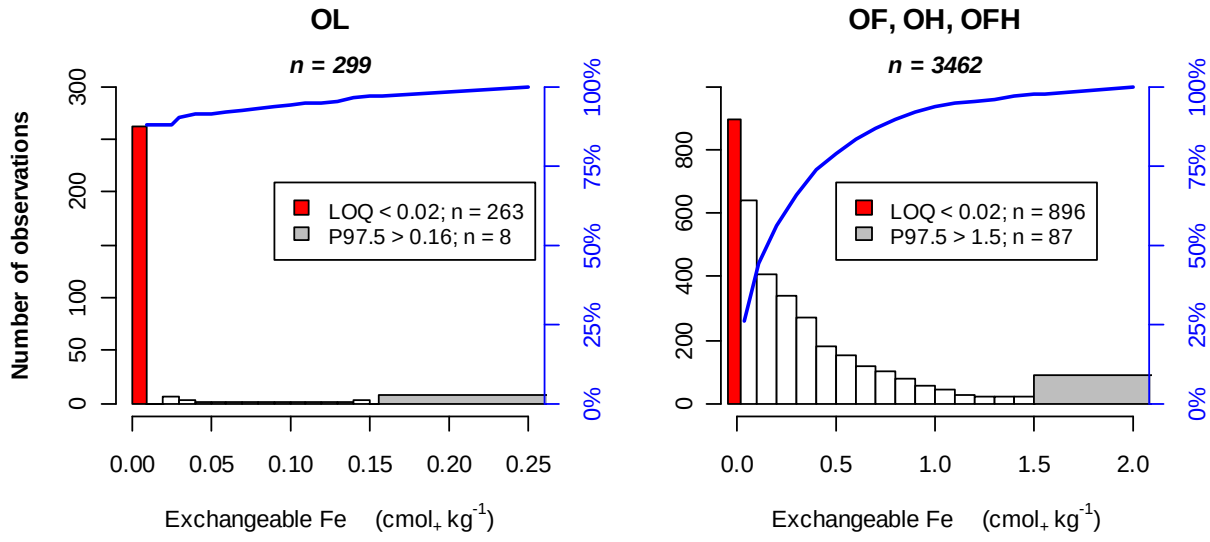


Figure 3.4.73. Absolute and cumulative frequency distribution (in blue) of exchangeable iron in OL (left) and OF, OH and OFH layers (right) of all BioSoil+ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

Using censored statistics the estimated median values are 0.00 and 0.15 $cmol_+$ Fe kg^{-1} whereas means are 0.04 and 0.32 $cmol_+$ kg^{-1} for OL and OFH layers respectively.

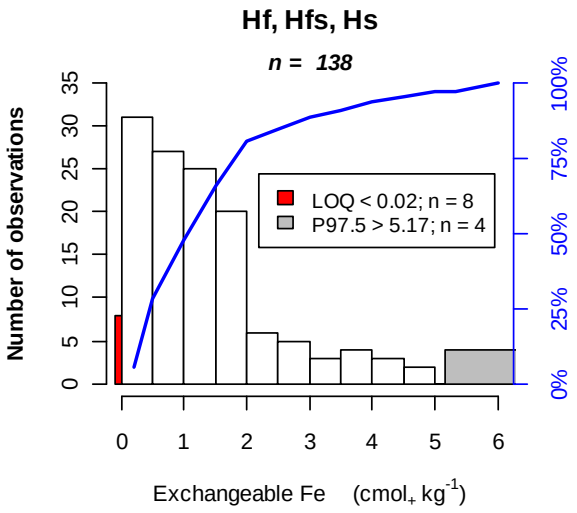


Figure 3.4.74. Absolute and cumulative frequency distribution (in blue) of exchangeable iron in hydromorphic forest floor layers of all BioSoil+ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

The exchangeable iron distribution of hydromorphic humus layers ranges roughly between 0 and 5 $cmol_+$ kg^{-1}, much more than for terrestrial humus forms.

Less than 6% of the observations is below LOQ and a substantial part of observations are situated between 0 and 2 $cmol_+$ kg^{-1} (Figure 3.4.74). The median value of 1.06 $cmol_+$ kg^{-1} (mean= 1.38 $cmol_+$ kg^{-1}) is highest of all observed layers, including peat and mineral layers.

Mineral layers

Exchangeable iron in mineral layers ranges from less than 0.02 $cmol_+ kg^{-1}$ (LOQ) up to 9.45 $cmol_+ kg^{-1}$ at most. Figure 3.4.75. clearly shows that a high number of observations belong to the class below LOQ (red bars). This proportion increases from 41 % of the M01 layers up to 78 % of the M48 layers. Median values estimated using statistics for censored data reveal decreasing values with depth: 0.04 > 0.02 > 0.01 = 0.01 $cmol_+ kg^{-1}$ for M01, M12, M24 and M48 layers respectively. Consistently, the 97.5 percentile values also decrease with depth indicating less exchangeable iron in the subsoil compared to the topsoil. The statistical values are summarised in Annex II.

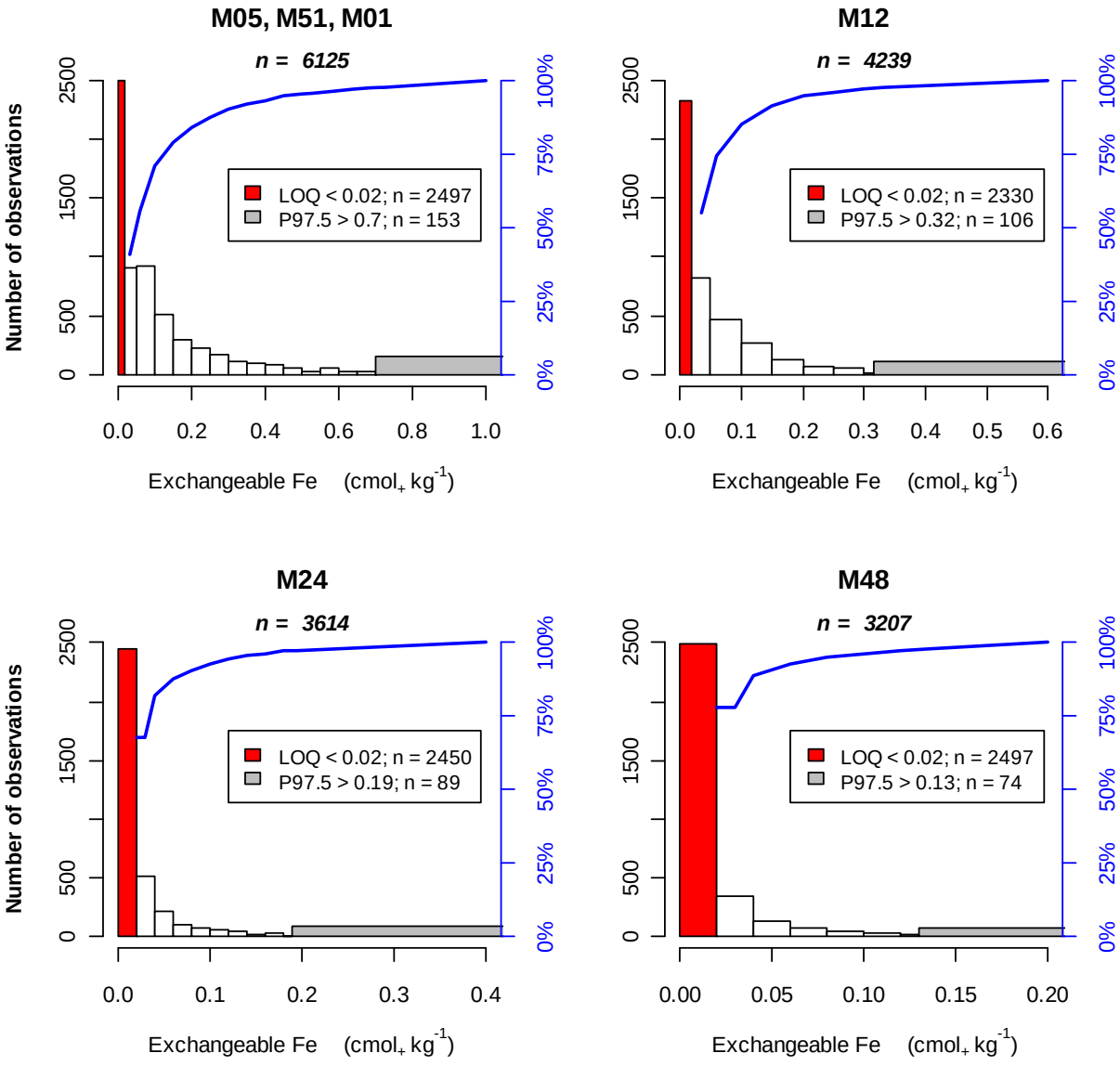


Figure 3.4.75. Absolute and cumulative frequency distribution (in blue) of exchangeable iron in mineral soil layers of all BioSoil⁺ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

Peat soils

The median concentration of exchangeable iron in peat layers is about a factor 5 to 10 greater than in mineral layers. The distributions are shown in Figure 3.4.76. Between 13 and 30 % of the observations are below LOQ and less than 2.5 % of them exceed 3.80 $cmol_+ kg^{-1}$. The median values decrease with depth in the order: 0.43 > 0.30 > 0.25 > 0.09 $cmol_+ kg^{-1}$ and the means 0.81 > 0.57 > 0.47 > 0.22 $cmol_+ kg^{-1}$. More statistical values are listed per layer in Annex II.

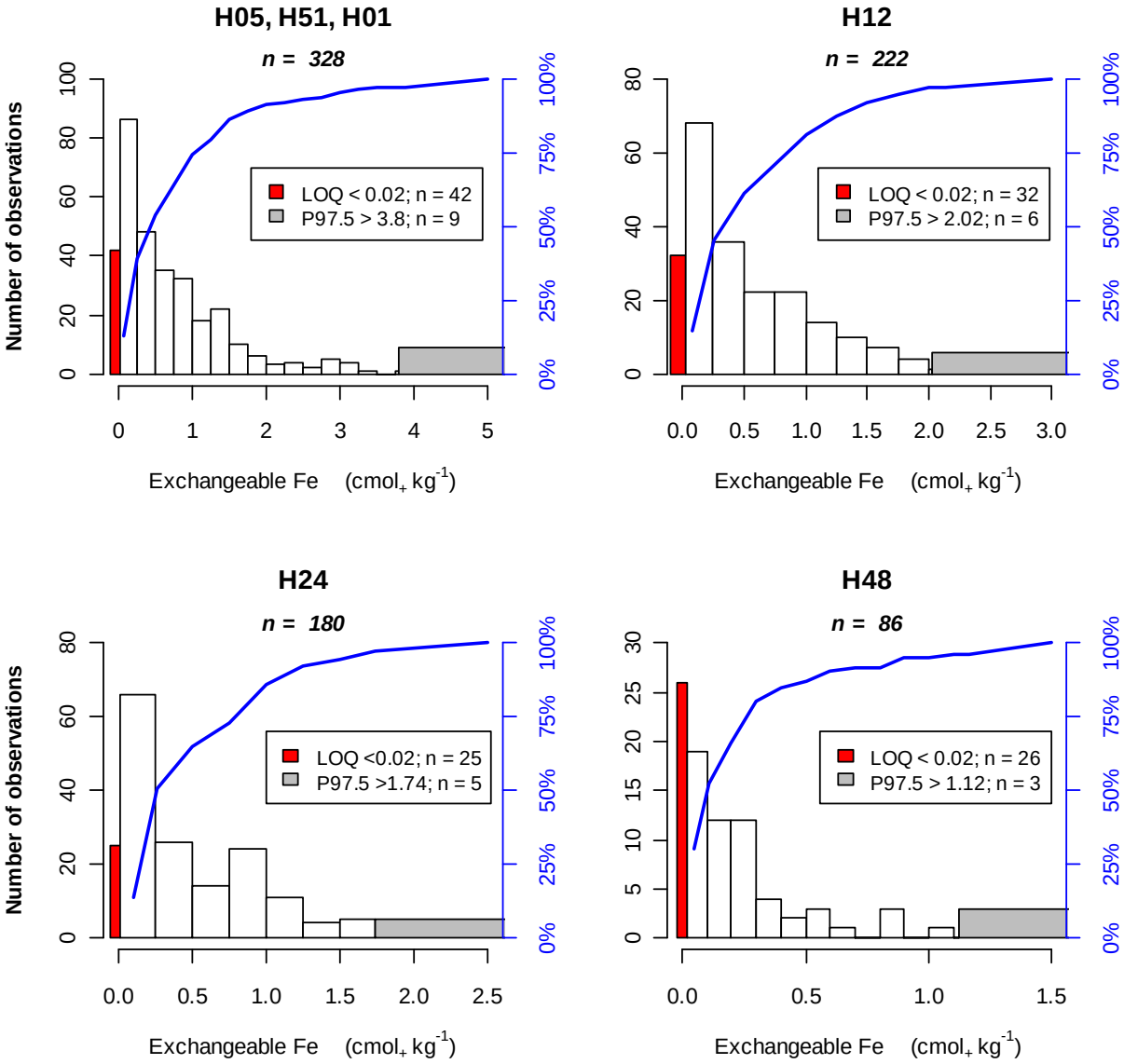


Figure 3.4.76. Absolute and cumulative frequency distribution (in blue) of exchangeable iron in peat layers of all BioSoil⁺ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

3.4.9.9 Exchangeable Manganese

The concentration range of exchangeable manganese, the median and quartiles for each layer are presented in Figure 3.4.77. Concentration levels are generally higher in forest floor layers than in mineral and peat soils. Note the large proportion of observations below LOQ for peat and mineral layers, indicating the overall low concentration levels that are hard to measure accurately.

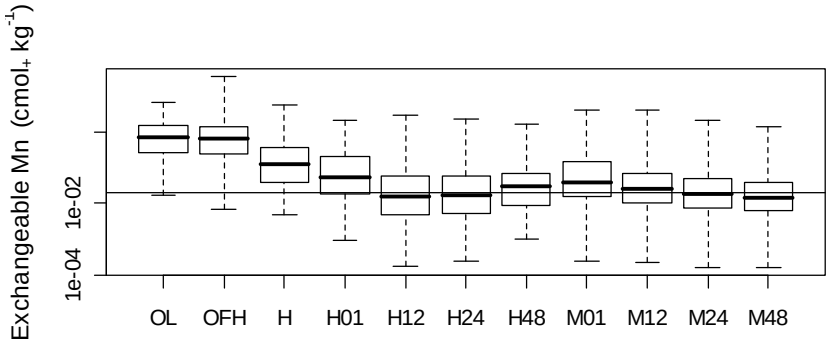


Figure 3.4.77. Box plot of exchangeable manganese for all layers. The Y-axis is logarithmic. The horizontal line indicates the LOQ at 0.02 $cmol_+ kg^{-1}$.

Forest Floor

Exchangeable manganese of terrestrial forest floor layers ranges from less than 0.02 $cmol_+ kg^{-1}$ (LOQ) to maximally 33.8 $cmol_+ kg^{-1}$. About 5 % of the OL and 4 % of the OFH layers show observations below the LOQ and less than 2.5 % of all observations exceed 5.66 $cmol_+ kg^{-1}$ in OL and 4.99 $cmol_+ kg^{-1}$ in OFH layers (Figure 3.4.78). For both OL and OFH, the distribution pattern and ranges are quite similar.

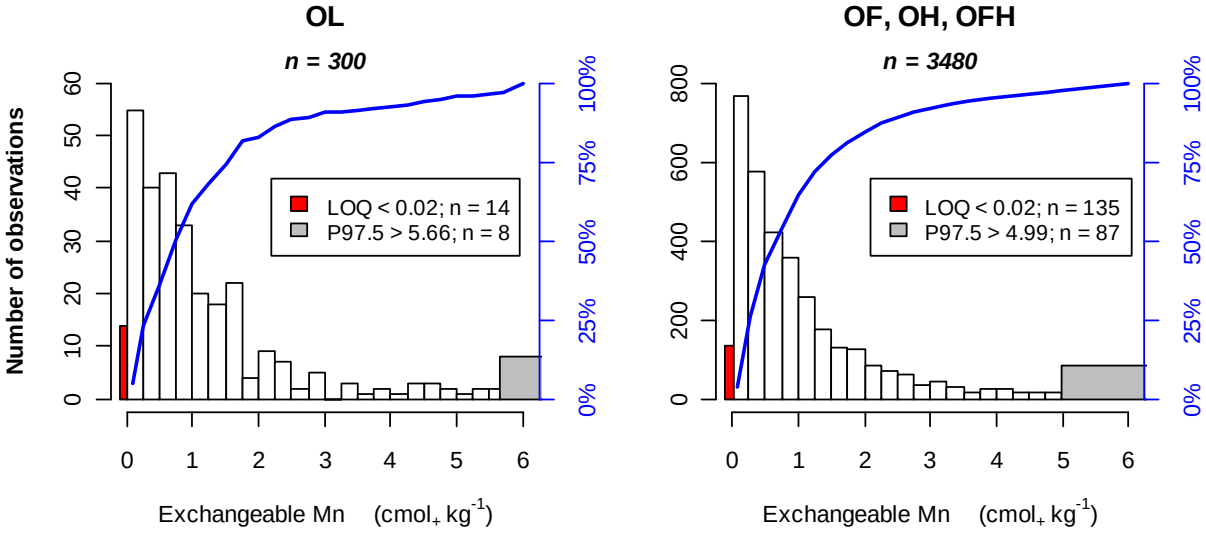


Figure 3.4.78. Absolute and cumulative frequency distribution (in blue) of exchangeable manganese in OL (left) and OF, OH and OFH layers (right) of all BioSoil+ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

The median values are 0.73 and 0.65 $cmol_+$ Mn kg^{-1} whereas means are 1.20 and 1.11 $cmol_+ kg^{-1}$ for OL and OFH layers respectively.

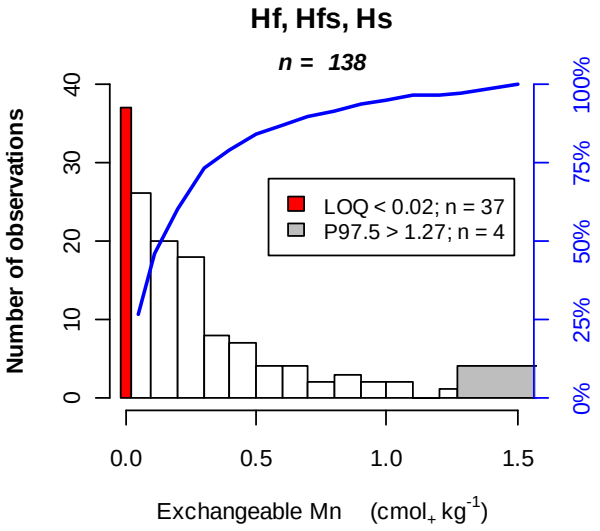


Figure 3.4.79. Absolute and cumulative frequency distribution (in blue) of exchangeable manganese in hydromorphic forest floor layers of all BioSoil+ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

Figure 3.4.79 shows that the exchangeable manganese distribution of hydromorphic humus layers has a far more narrow range than the terrestrial humus forms. Much more observations (27 % of them) are also below LOQ and concentrations rarely exceed 1.27 $cmol_+$ kg^{-1}.

Median concentration (0.12 $cmol_+$ kg^{-1}) is about 5 times lower than in aerated forest floors, but still more than double the median concentrations of peat layers.

Mineral layers

Exchangeable manganese in mineral layers ranges from less than 0.02 $cmol_+ kg^{-1}$ (LOQ) up to 3.88 $cmol_+ kg^{-1}$ at most. Figure 3.4.80 clearly shows that a high number of observations belong to the class below LOQ (red bars). This proportion increases from 42 % of the M01 layers up to 69% of the M48 layers. Median values estimated using statistics for censored data reveal decreasing values with depth: 0.04 > 0.03 > 0.02 > 0.01 $cmol_+ kg^{-1}$ for M01, M12, M24 and M48 layers respectively. Consistently, the 97.5 percentile values also decrease with depth indicating less exchangeable manganese in the subsoil. Overall, just as for exchangeable Fe, concentration levels in mineral soil are very low and hard to quantify reliably. More statistical values are summarised in Annex II.

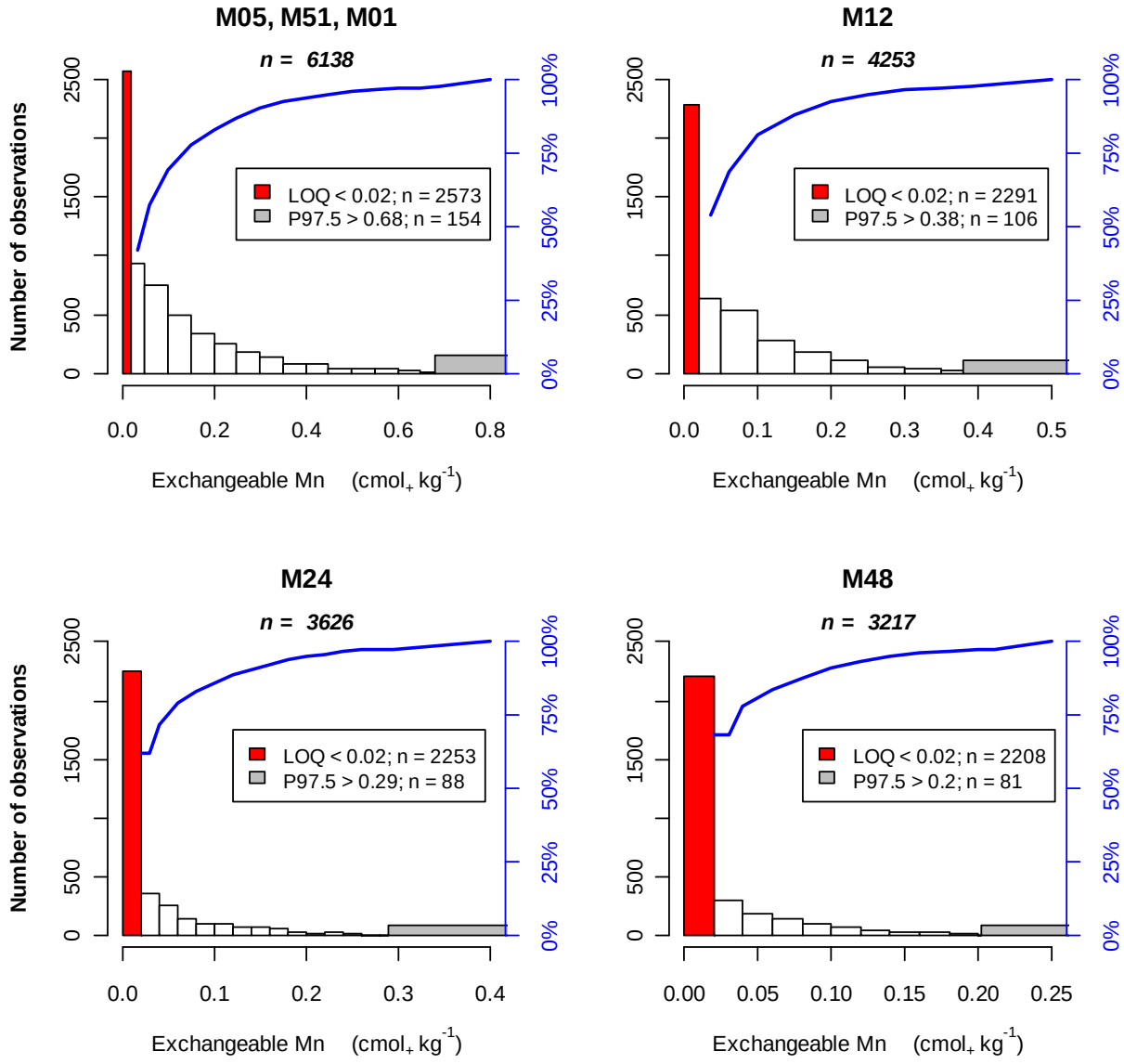


Figure 3.4.80. Absolute and cumulative frequency distribution (in blue) of exchangeable manganese in mineral soil layers of all BioSoil⁺ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

Peat soils

The median concentrations of exchangeable manganese in peat layers is similar to those of mineral layers. The distributions are shown in Figure 3.4.81. Again, a large proportion of the observations is below LOQ, ranging from 35% in H01 to 58% in H12. Less than 2.5 % of the observations exceed 1.13 $cmol_+$ kg^{-1}. The estimated median values for all layers are between 0.02 and 0.05 $cmol_+$ kg^{-1} while the means range from 0.09 to 0.18 $cmol_+$ kg^{-1}. More statistical values are tabularised in Annex II.

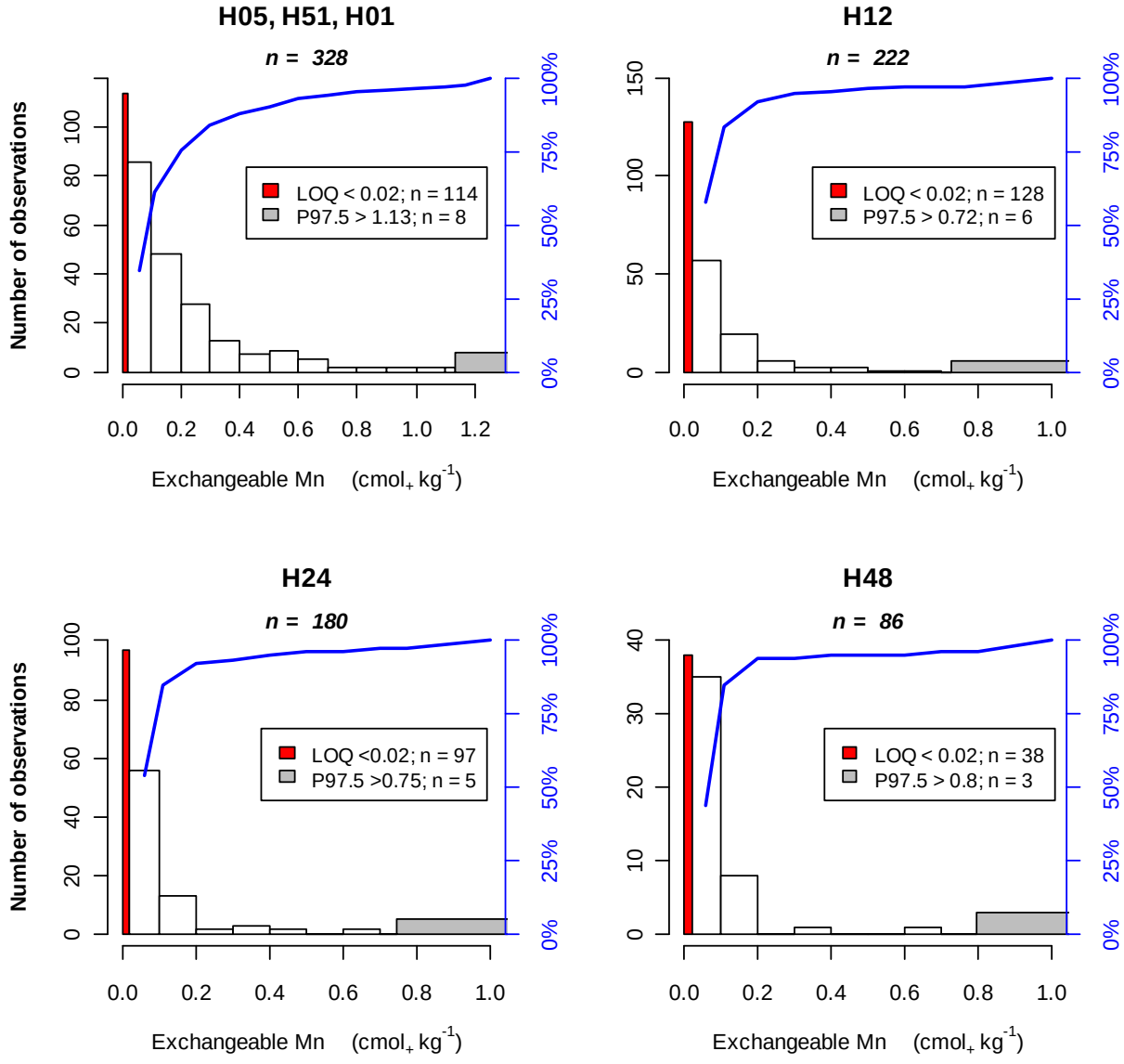


Figure 3.4.81. Absolute and cumulative frequency distribution (in blue) of exchangeable manganese in peat layers of all BioSoil⁺ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

3.4.10 Aqua regia extractable elements

3.4.10.1 Extractable Phosphorus

The extractable phosphorus concentration was determined in the organic and mineral layers. Figure 3.4.82 shows the concentration range, median and quartiles for each layer according to a logarithmic scale (base 10). Concentrations are generally greater in organic compared to mineral layers, but the range is larger for the latter. Hydromorphic forest floor (H) layers show the highest concentrations and subsoil M48 layers the lowest.

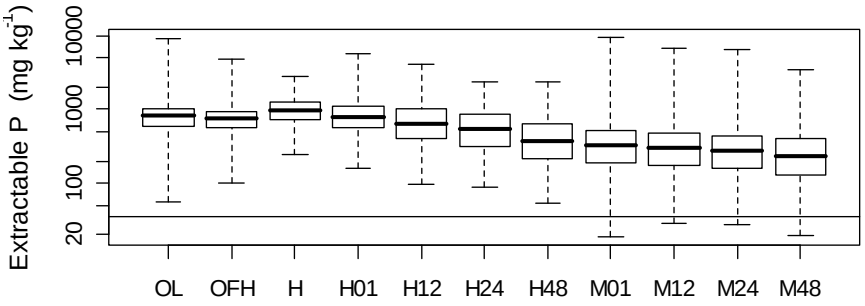


Figure 3.4.82. Box plot of extractable P for all layers. The Y-axis is logarithmic. The overall horizontal line indicates the LOQ at 35 mg kg^{-1}.

Forest Floor

Phosphorus concentration in the forest floor layers ranges from ~50 mg kg^{-1} to 9000 mg kg^{-1} at most. The 95 % range for extractable P in OL and OFH layers is 200 – 1500 mg kg^{-1} as shown by the distribution functions in Figure 3.4.83. Traces of phosphorus and zero values reported for OFH layers were considered as observations below LOQ, representing 4 % of the samples.

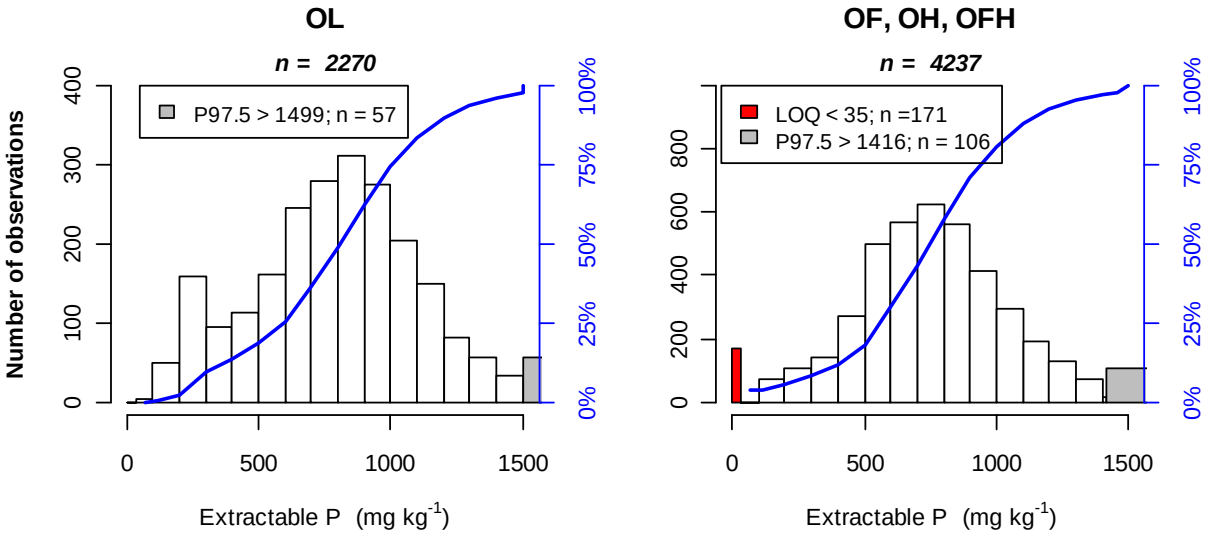


Figure 3.4.83. Absolute and cumulative frequency distribution (in blue) of extractable P in OL (left) and OF, OH and OFH layers (right) of all BioSoil^{+} plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

Both distributions are unimodal with median values of 810 and 746 mg P kg^{-1} for OL and OFH layers respectively. Respective means are 806 and 757 mg P kg^{-1}.

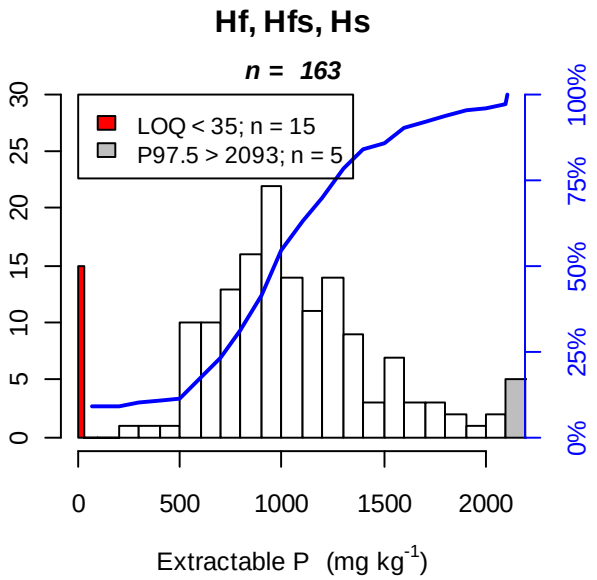


Figure 3.4.84. Absolute and cumulative frequency distribution (in blue) of extractable P in hydromorphic forest floor layers of all BioSoil+ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

The phosphorus concentration is greater in semi-terrestrial humus layers with 95 % of all observations between 380 and 2093 mg P kg^{-1}, a median value of 960 mg P kg^{-1} and a mean of 1013 mg P kg^{-1}. This distribution is predominantly unimodal with ~9 % left censored observations, mainly consisting of reported zeros (Figure 3.4.84).

Mineral layers

The extractable P concentration in mineral layers is substantially lower than in organic layers. All distributions are strongly skewed to the right (skewness ranging from 3.2 to 6.3). Samples with concentrations below LOQ have similar proportions for each layer (~ 3 %). Generally, extractable P concentration tends to decrease with depth (Figure 3.4.85). Median concentrations decrease in the order: 321 > 302 > 276 > 237 mg P kg^{-1} and mean values: 407 > 387 > 358 > 328 mg P kg^{-1}. For these calculations the left censored values are taken into account. All these statistics are tabularised in Annex II.

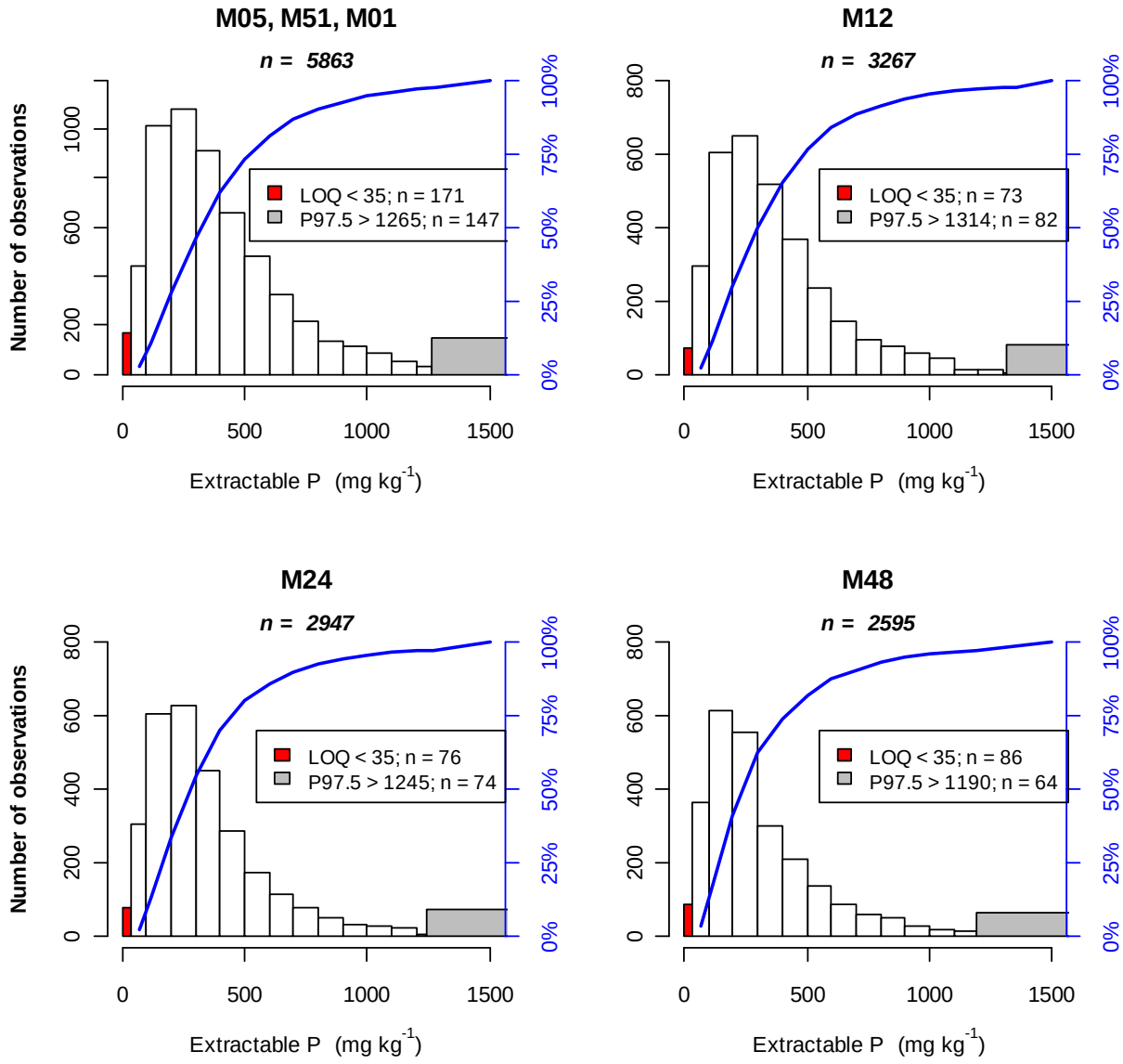


Figure 3.4.85. Absolute and cumulative frequency distribution (in blue) of extractable P in mineral layers of all BioSoil+ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

Peat soils

The distribution of P concentrations in the H layers of peat soils is shown in Figure 3.4.86. Similar to mineral soils, extractable P concentrations decrease with depth. Median values decrease in the order: 790 > 640 > 544 > 366 mg P kg^{-1} and mean values: 872 > 771 > 639 > 479 mg P kg^{-1}. Between 6 and 12 % of all layer observations are below LOQ (mostly reported zeros) and few layers show values exceeding 2000 mg P kg^{-1}. Due to the limited number of observations, distribution patterns are rather unclear, but they are expected to be right skewed.

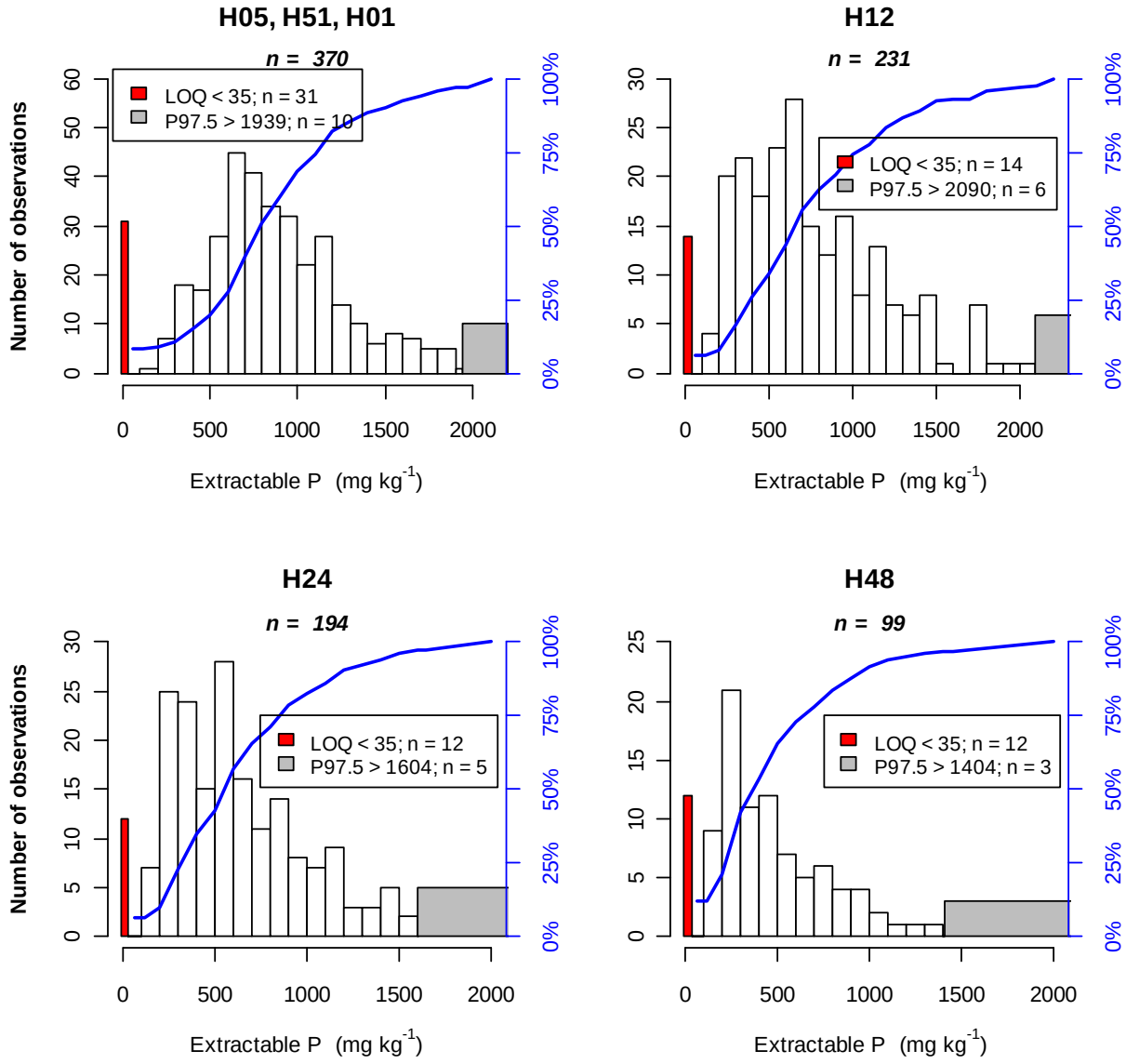


Figure 3.4.86. Absolute and cumulative frequency distribution (in blue) of extractable P in peat layers of all BioSoil⁺ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

The geographical distribution of the aqua regia extractable P in the upper 10 cm of the mineral or peat soils is presented on Map 13 in Annex III. P concentrations are high in Italy, southern Spain, Ireland, Scotland and Wales. They are very low in the Landes in France. In Sweden the P concentrations were often below the LOQ.

3.4.10.2 Extractable Potassium

The extractable potassium concentration for the organic and mineral layers is given in Figure 3.4.87, showing the concentration range, median and quartiles for each layer according to a logarithmic scale (base 10). Concentration ranges are similar for terrestrial forest floors and mineral soil layers. Hydromorphic forest floor (H) and peat layers contain generally lower amounts of K and in deeper layers a substantial proportion of observations are below LOQ.

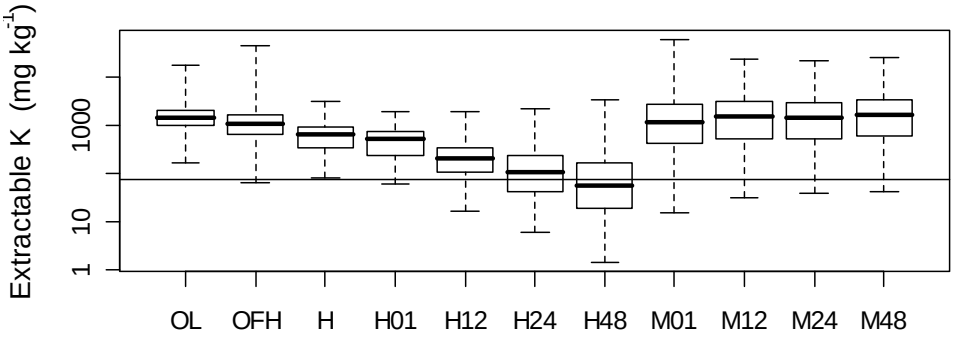


Figure 3.4.87. Box plot of extractable K for all layers. The Y-axis is logarithmic. The overall horizontal line indicates the LOQ at 80 mg kg^{-1}.

Forest Floor

Potassium concentration in the forest floor layers ranges from ~10 mg kg^{-1} to over 20000 mg kg^{-1}. The 95 % range for extractable K in OL and OFH layers is 217 – 5900 mg K kg^{-1} as shown by the distribution functions in Figure 3.4.88. The average limit of reliable quantification (LOQ) of Aqua Regia extractable K in organic layers is estimated at 80 mg K kg^{-1}. About 9 % of observations are below this limit in OFH layers whereas less than 0.4 % in OL layers.

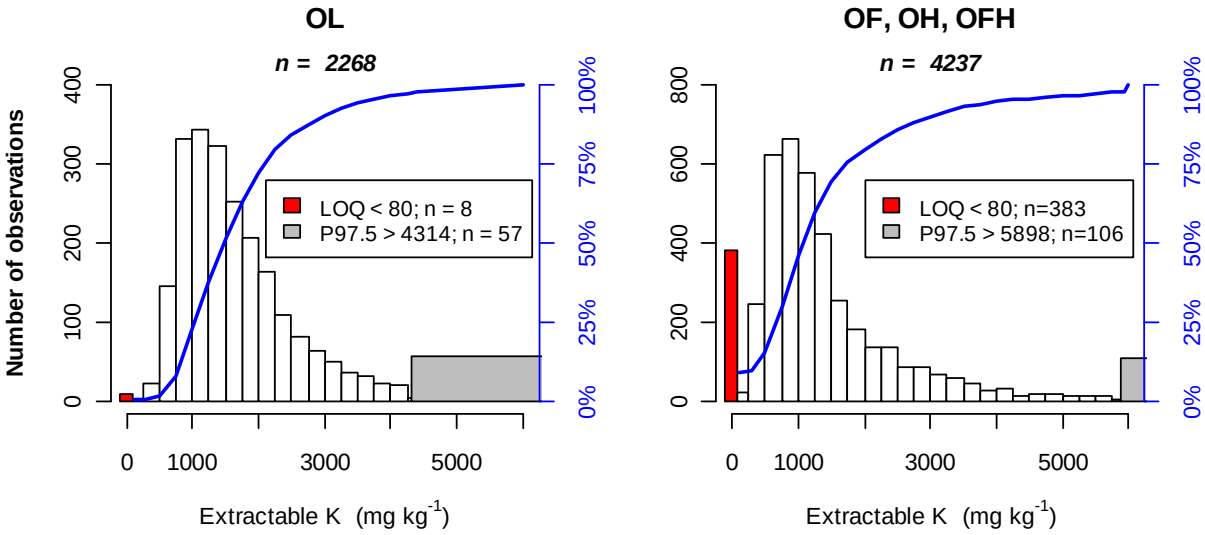


Figure 3.4.88. Absolute and cumulative frequency distribution (in blue) of extractable K in OL (left) and OF, OH and OFH layers (right) of all BioSoil^{+} plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

Both distributions are clearly skewed to the right (skewness 3.3 and 7.2) with median values of 1471 and 1090 mg K kg^{-1} for OL and OFH layers respectively. Respective means are 1724 and 1484 mg K kg^{-1}.

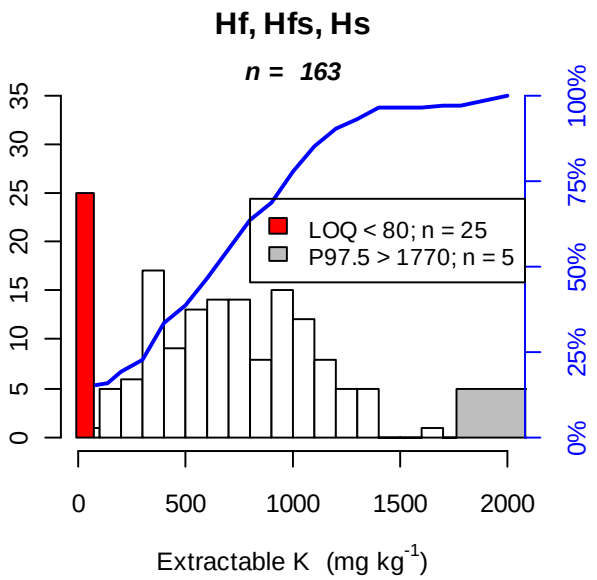


Figure 3.4.89. Absolute and cumulative frequency distribution (in blue) of extractable K in hydromorphic forest floor layers of all BioSoil+ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

The potassium concentration is substantially less in semi-terrestrial humus layers with 95 % of all observations between 122 and 1770 mg kg^{-1}, a median value of 661 mg kg^{-1} and a mean of 689 mg kg^{-1}. The distribution pattern is unclear due to the limited sample number (Figure 3.4.89). About 15 % of all H layer are below LOQ.

Mineral layers

The Aqua Regia extractable K concentration in mineral layers varies from ~100 mg kg^{-1} up to 25000 mg kg^{-1}. All distributions show a monotonic decreasing pattern. Less than 2.7 % of all samples have concentrations below LOQ for mineral layers (Figure 3.4.90). Extractable K concentration is generally lowest in the M01 layer (median: 1192 mg K kg^{-1}), comparable in M12 and M24 layers (median: ~1500 mg K kg^{-1}) and highest in the M48 layer (median: 1713 mg K kg^{-1}). All basic statistics are tabularised in Annex II.

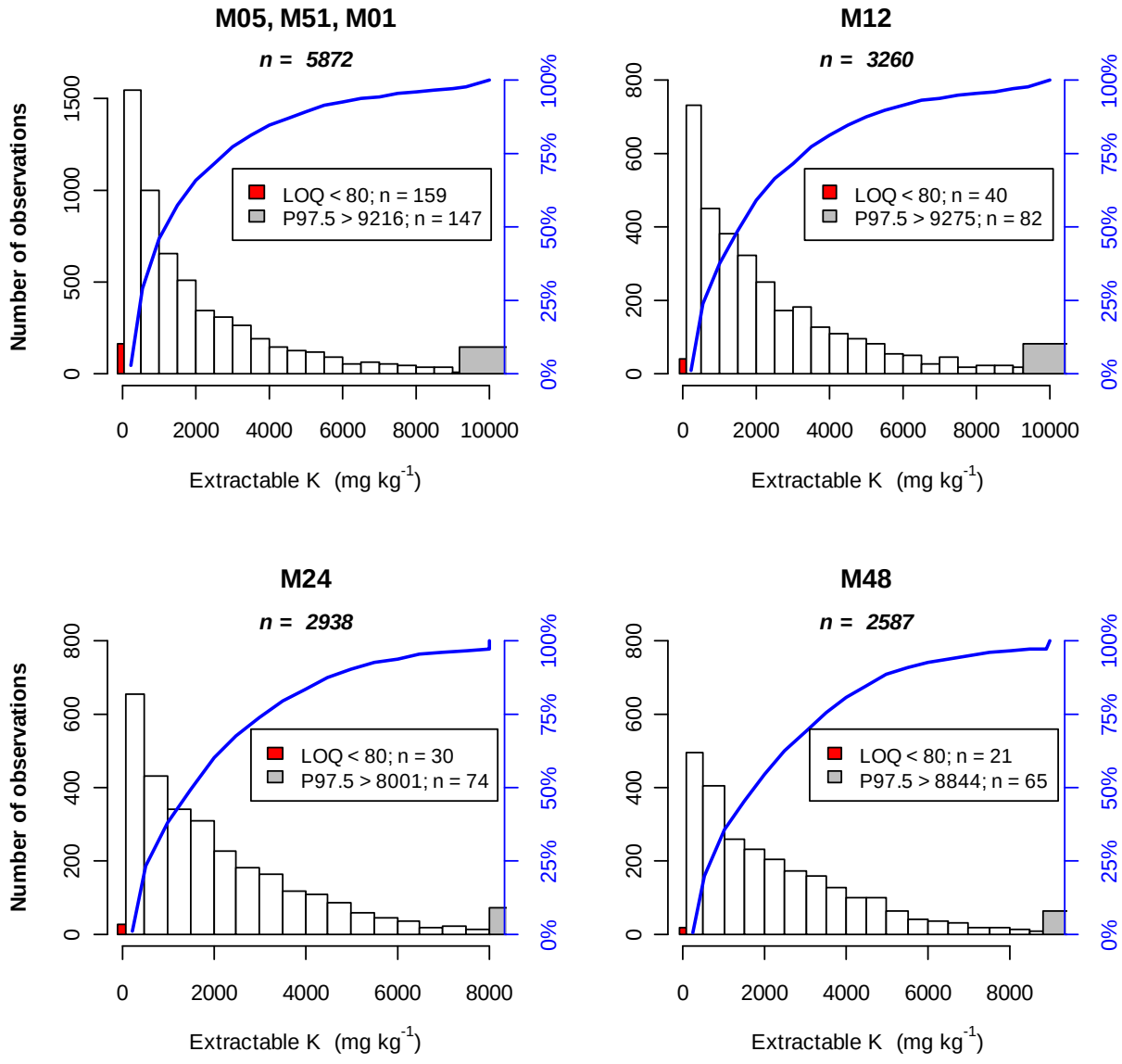


Figure 3.4.90. Absolute and cumulative frequency distribution (in blue) of extractable K in mineral layers of all BioSoil+ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

Peat soils

The distribution of K concentrations in peat layers is shown in Figure 3.4.91. These concentrations are much smaller than in mineral layers and generally tend to decrease with depth. Median values decrease in the order: 539 > 210 > 111 > 59.7 mg K kg^{-1} and mean values: 579 > 320 > 250 > 264 mg K kg^{-1}. Contrasting with mineral layers, between 17 and 51 % of all peat layer observations are below LOQ, increasing with depth. Hence, more sensitive analysis techniques and a lower calibration range is required for analysing K in peat samples.

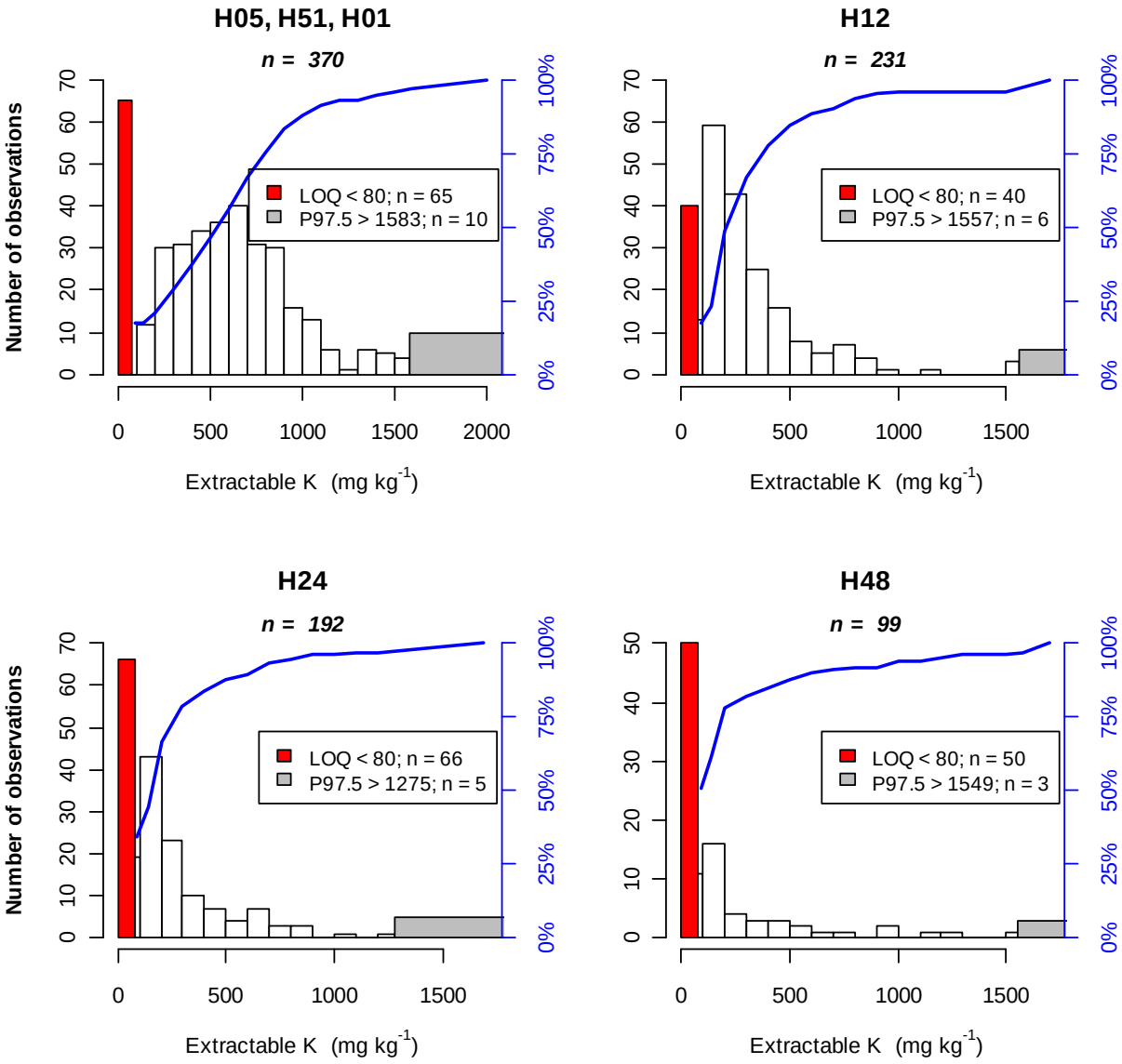


Figure 3.4.91. Absolute and cumulative frequency distribution (in blue) of extractable K in peat layers of all BioSoil+ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

The geographical distribution of the aqua regia extractable K in the upper 10 cm of the mineral or peat soils is presented on Map 14 in Annex III. The map shows a north-south gradient with increasing K concentrations towards the south. Again in Sweden, the concentrations are often below the LOQ.

3.4.10.3 Extractable Calcium

The extractable calcium concentration for the organic and mineral layers is given in Figure 3.4.92, showing the logarithmic concentration range, median and quartiles for each layer. Concentration ranges are generally higher for organic layers compared to mineral layers. Little differentiation with depth is found in peat and mineral soils in contrast to forest floor layers.

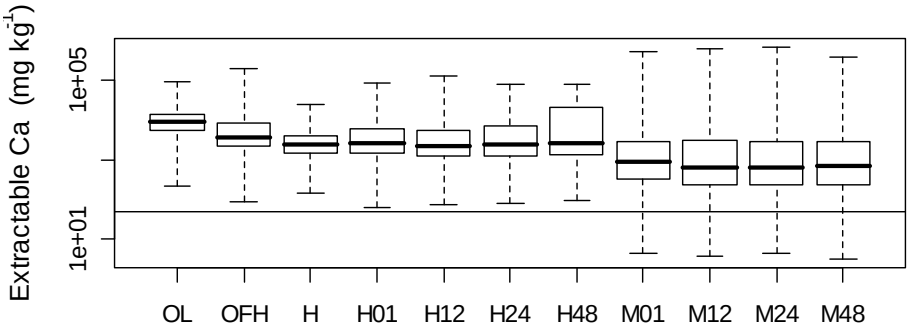


Figure 3.4.92. Box plot of extractable Ca for all layers. The Y-axis is logarithmic. The overall horizontal line indicates the LOQ at 50 mg kg^{-1}.

Forest Floor

Calcium concentration in the forest floor layers ranges from ~600 mg kg^{-1} to over 100000 mg kg^{-1} (i.e. 10 % of DM). The 95 % range for extractable Ca in OL and OFH layers is 661 – 42583 mg Ca kg^{-1} as shown by the distribution functions in Figure 3.4.93.

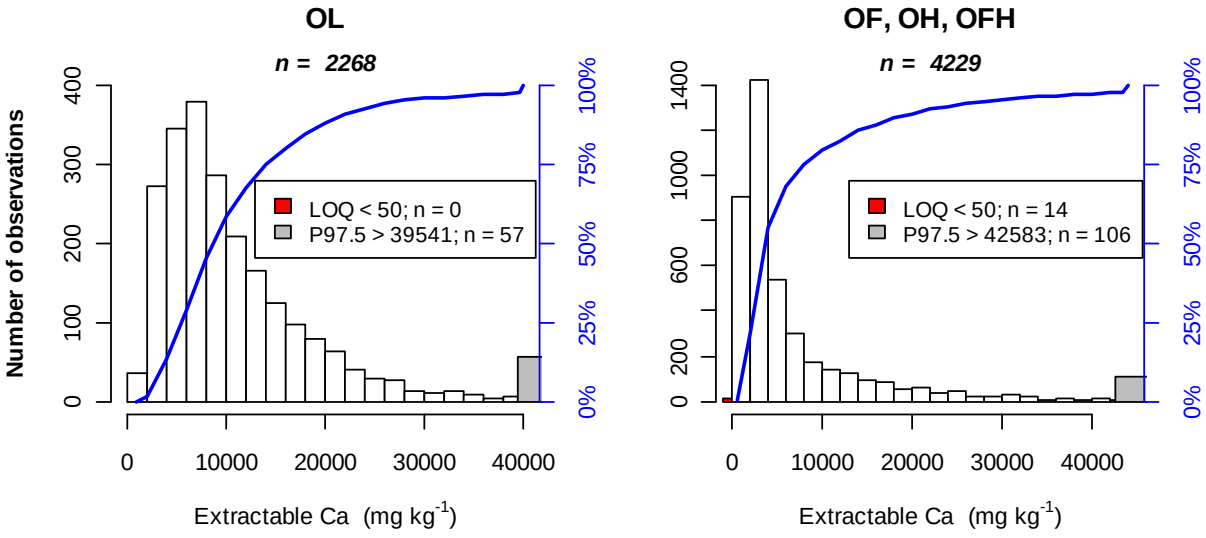


Figure 3.4.93. Absolute and cumulative frequency distribution (in blue) of extractable Ca in OL (left) and OF, OH and OFH layers (right) of all BioSoil^{+} plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

Both distributions show a lognormal pattern and have skewness values of 2.69 and 4.47 for OL and OFH layers respectively. The respective median values are 8726 and 3553 mg Ca kg^{-1} whereas means are 11332 and 7744 mg Ca kg^{-1}. Hence, Ca concentration is generally greater in OL than in OFH layers. No observations in OL layers were below LOQ and only 0.3 % of the OFH layers.

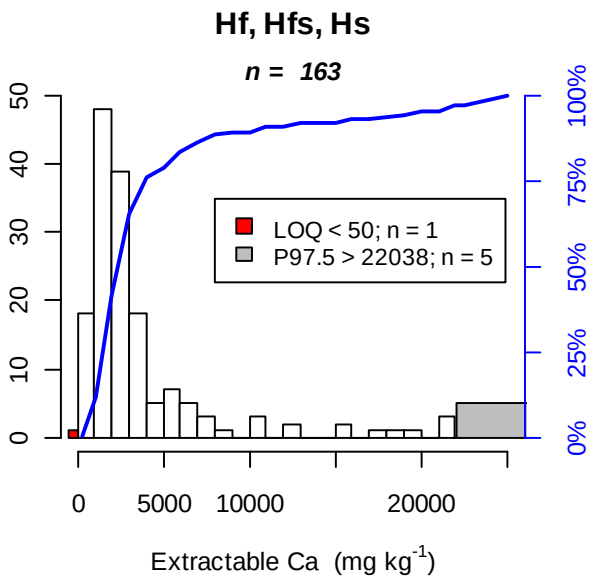


Figure 3.4.94. Absolute and cumulative frequency distribution (in blue) of extractable Ca in hydromorphic forest floor layers of all BioSoil+ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

The Ca concentration is much less in semi-terrestrial humus layers evidenced by a range that is about half of that of terrestrial forest floor layers. Most observations (95 %) are situated between 590 and 22038 mg Ca kg^{-1}. Figure 3.4.94. The median value is 2323 mg Ca kg^{-1} and the mean 4261 mg Ca kg^{-1}.

This distribution looks predominantly lognormal with just one left censored observation. Most Ca values are comprised within 1000 - 2000 mg Ca kg^{-1} interval.

Mineral layers

The range observed for extractable Ca concentration in mineral layers is extremely large. Concentration levels can be as low as 20 mg kg^{-1} but also 30000 times higher in some calcic horizons (with > 60000 mg Ca kg^{-1}) or in soils formed in highly calcareous parent material. For a good representation log scales should be applied. However, the majority of observations (> 75 %) shows Ca concentrations below 5000 mg kg^{-1} (non-calcareous samples) and quite few observations were found above 20000 mg Ca kg^{-1} (Figure 3.4.95). Less than 2.5 % of the observations are below LOQ. For each layer 95-percentiles are given in Figure 3.4.95, showing limited occurrence in the dataset of samples with 7.5 % of extractable Ca or more. The median value for the M01 topsoil layer (913 mg Ca kg^{-1}) is slightly higher than for all other layers with concentrations ~650 mg Ca kg^{-1}. Mean values are about 10000 mg Ca kg^{-1} but have little meaning for such a distribution. All other statistics are tabularised in Annex II.

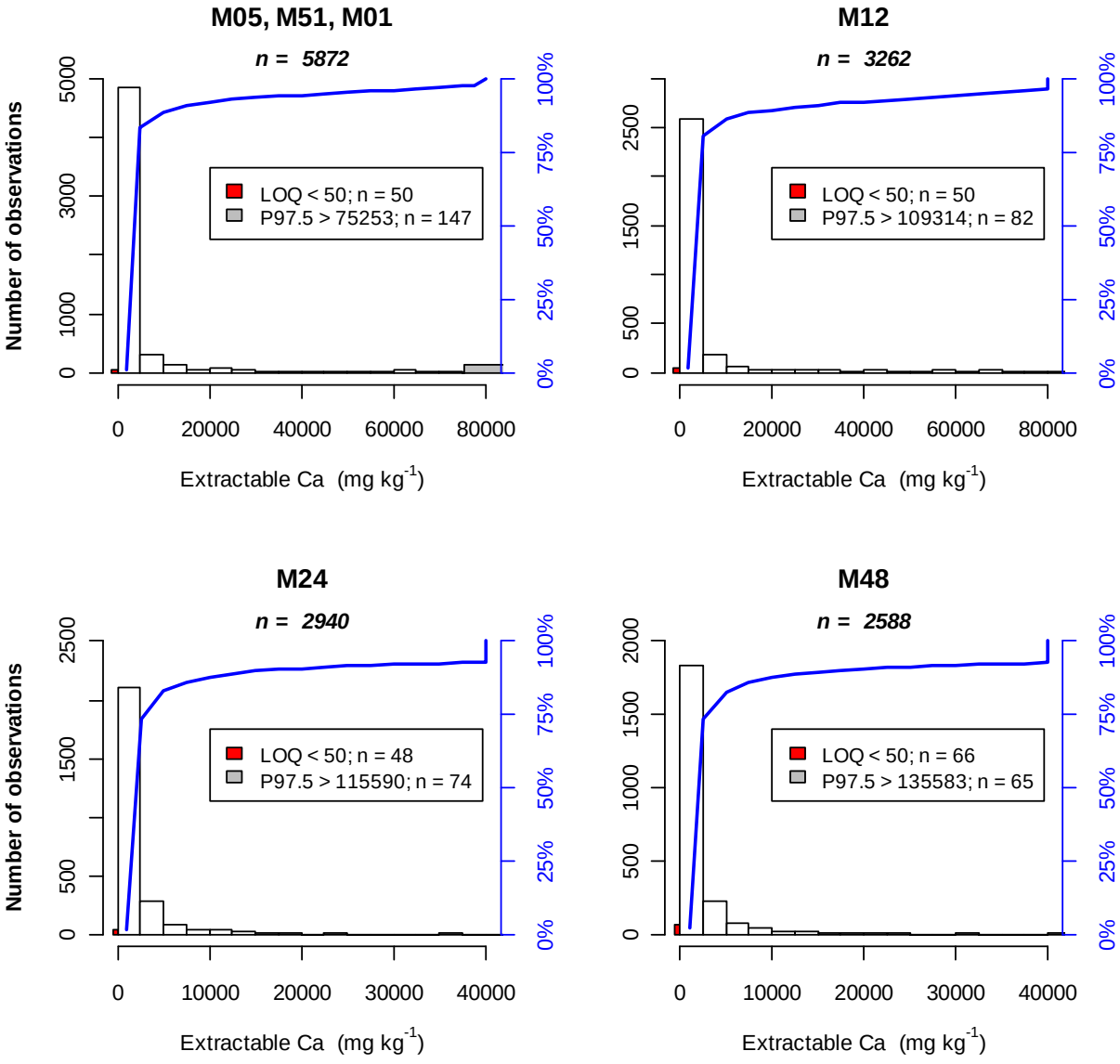


Figure 3.4.95. Absolute and cumulative frequency distribution (in blue) of extractable Ca in mineral layers of all BioSoil+ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

Peat soils

The distribution of extractable Ca concentrations in peat is shown in Figure 3.4.96. Median concentrations (~2500 mg Ca kg^{-1}) are about four times higher than in mineral soils. Very few observations (< 1 %) are below LOQ and less than 2.5 % are exceeding 50000 mg Ca kg^{-1}. Highest frequency of observed values are comprised within the 50 - 2500 mg Ca kg^{-1} interval which is the case for all fixed depth layers.

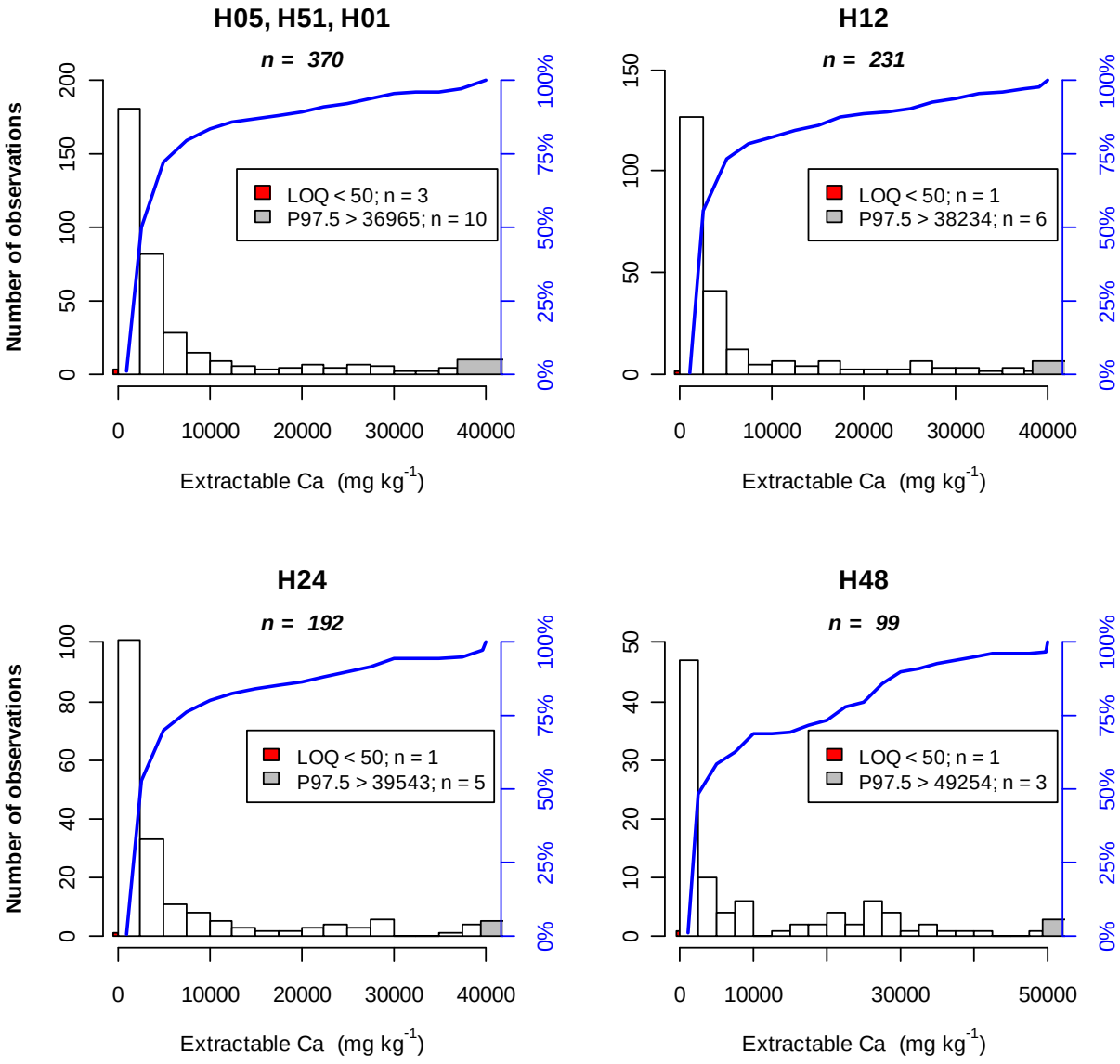


Figure 3.4.96. Absolute and cumulative frequency distribution (in blue) of extractable Ca in peat layers of all BioSoil⁺ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

The geographical distribution of the aqua regia extractable Ca in the upper 10 cm of the mineral or peat soils is presented on Map 15 in Annex III. Calcium concentrations are low in Portugal, the western part of France, Flanders, Northern Germany, Poland and Czech republic. North of this southwestern – northeastern orientated zone Ca concentrations are higher but seldom exceed levels above 5000 mg kg^{-1}. On the opposite the Ca concentrations southeast of this zone reach easily levels of more than 25000 mg kg^{-1}.

3.4.10.4 Extractable Magnesium

The extractable Mg concentration for the organic and mineral layers is given in Figure 3.4.97, showing the concentration range, median and quartiles for each layer according to a logarithmic scale. Median concentration and ranges are generally greater in mineral than in organic layers. Note that observations below LOQ only occur in mineral soils.

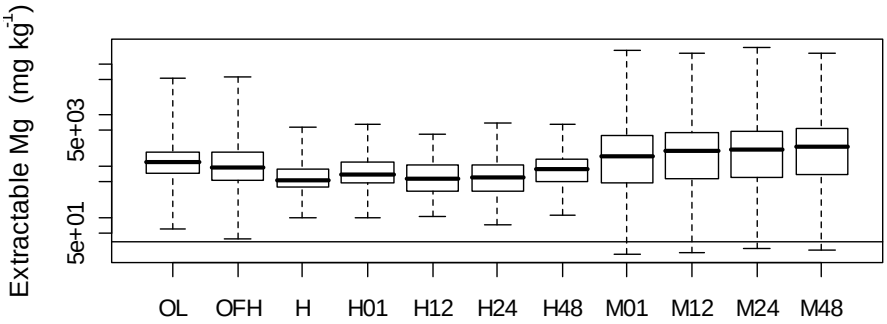


Figure 3.4.97. Box plot of extractable Mg for all layers. The Y-axis is logarithmic. The overall horizontal line indicates the LOQ at 35 mg kg^{-1}.

Forest Floor

Aqua regia extractable Mg concentration in the forest floor layers ranges from ~50 mg kg^{-1} to over 1000 times as much (i.e. 5 % of DM). No observations were reported below the average limit of reliable quantification (LOQ) of 35 mg Mg kg^{-1}. The 95 % range for both OL and OFH layers is 276 – 7602 mg kg^{-1} as shown by the distribution functions in Figure 3.4.98.

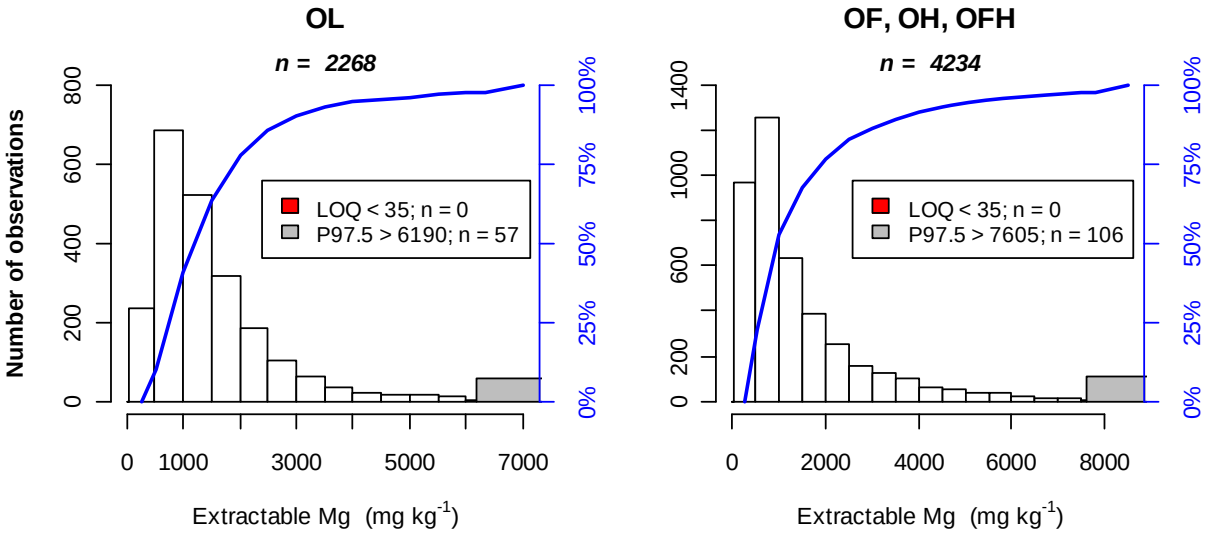


Figure 3.4.98. Absolute and cumulative frequency distribution (in blue) of extractable Mg in OL (left) and OF, OH and OFH layers (right) of all BioSoil^{+} plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

Both distributions show a lognormal pattern and have skewness values of 10.7 and 8.0 for OL and OFH layers respectively. The respective median values are 1187 and 930 mg Mg kg^{-1} whereas means are 1656 and 1762 mg Mg kg^{-1}. Highest frequency of observations was found in the 500 - 1000 mg Mg kg^{-1} interval.

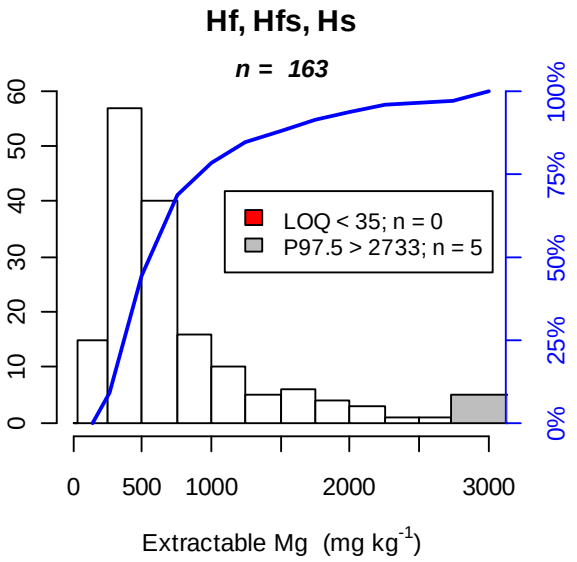


Figure 3.4.99. Absolute and cumulative frequency distribution (in blue) of extractable Mg in hydromorphic forest floor layers of all BioSoil+ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

In hydromorphic humus layers (Figure 3.4.99) the magnesium concentration appears to be less than in aerated humus forms. Most observations (95 %) are situated between 177 and 2733 mg Mg kg^{-1}, mainly comprised in the 250 – 500 mg Mg kg^{-1} interval. The median value is 556 mg kg^{-1} and the mean 792 mg kg^{-1}. There are no left censored values (below LOQ) and just a few observations exceed 2500 mg Mg kg^{-1}.

Mineral layers

The range observed for extractable Mg concentration in mineral layers is wide but not as large as for Ca. Concentration levels can be as low as 80 mg kg^{-1} up to 2500 times higher (i.e 200000 mg kg^{-1}) (instead of 10000 times for Ca). Figure 3.4.100 shows clear logarithmic decreasing distributions with highest observation frequency below 1000 mg Mg kg^{-1}. Less then 1 % of all observations per layer are below LOQ and less than 2.5 % exceed 30477 mg Mg kg^{-1}. The median values increase slightly with depth in the order: 1550 > 2048 > 2123 > 2480 mg Mg kg^{-1}. All other statistical values are tabularised in Annex II.

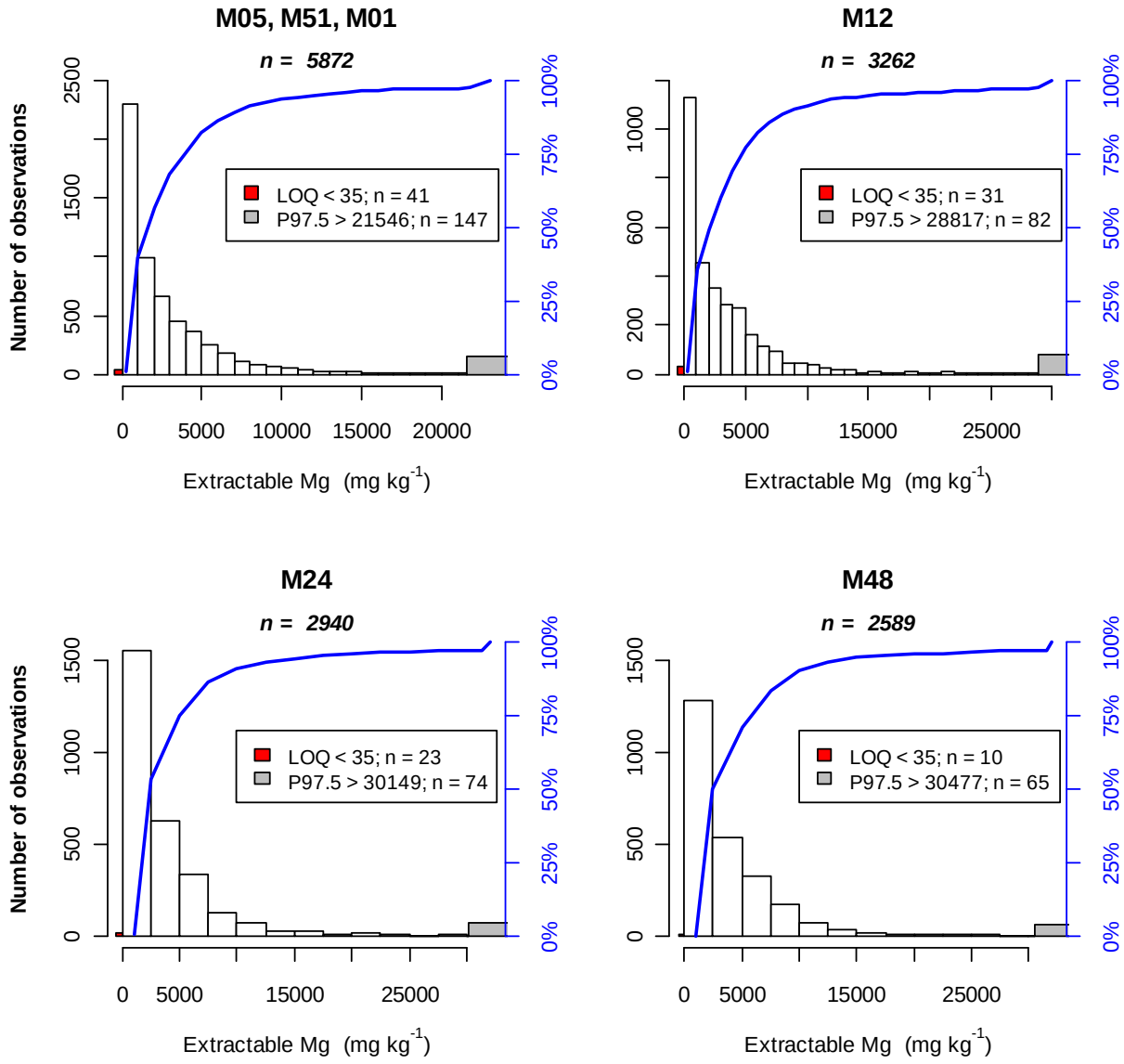


Figure 3.4.100. Absolute and cumulative frequency distribution (in blue) of extractable Mg in mineral layers of all BioSoil+ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

Peat soils

The distribution of extractable Mg concentrations in peats is shown in Figure 3.4.101. Median Mg concentrations (582 - 880 mg kg^{-1}) are about 28 to 46 % those of mineral soils. No observations were below LOQ and less than 2.5 % are exceeding 3838 mg Mg kg^{-1}. Highest frequency of observed values are comprised within the 250 - 500 mg Mg kg^{-1} interval, except for the H48 layer where most are situated between 750 and 1000 mg Mg kg^{-1}.

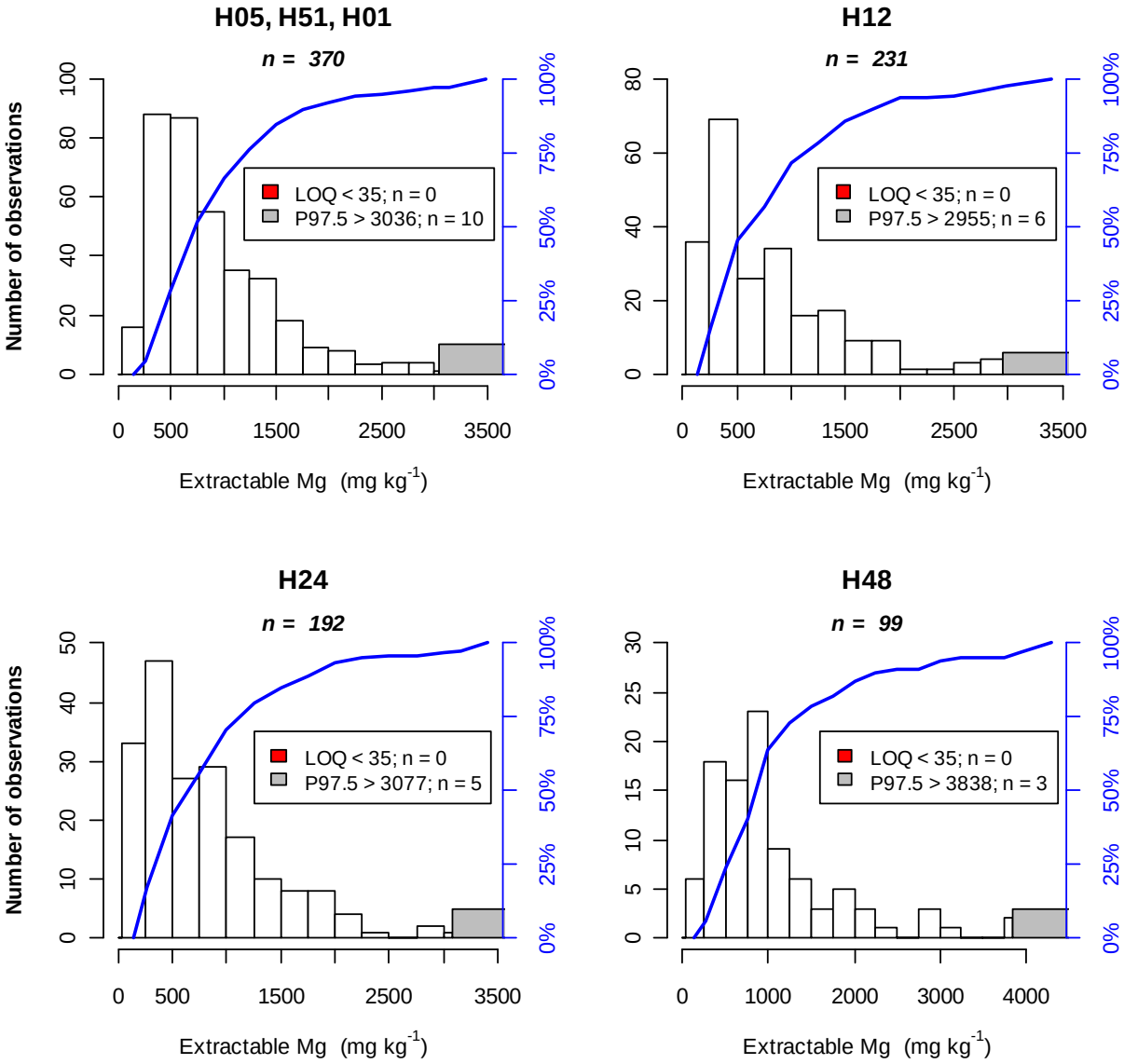


Figure 3.4.101. Absolute and cumulative frequency distribution (in blue) of extractable Mg in peat layers of all BioSoil⁺ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

The geographical distribution of the aqua regia extractable Mg in the upper 10 cm of the mineral or peat soils is shown on Map 16 in Annex III. The spatial pattern is comparable to that of Ca though also in the north high Mg levels are reached.

3.4.10.5 Extractable Sulphur

The extractable S concentration for the organic and mineral layers is given in Figure 3.4.102, showing the concentration range, median and quartiles for each layer according to a logarithmic scale (base 10). As may be concluded from the box plot, substantial differences in S concentrations between organic and mineral matrices were found. Concentrations in organic layers are generally a factor 10 greater than in mineral soil. Sufficient amounts of S allow reliable measurement in organic samples, while part of the mineral samples have S concentrations below LOQ.

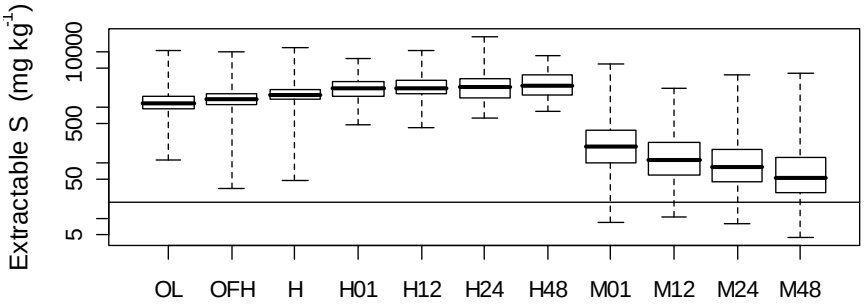


Figure 3.4.102. Box plot of extractable S for all layers. The Y-axis is logarithmic. The overall horizontal line indicates the LOQ at 20 mg kg^{-1}.

Forest Floor

Aqua regia extractable S concentration in the forest floor layers ranges from ~10 mg kg^{-1} to ~10000 mg kg^{-1} at most. Less than 0.1 % of all forest floor observations are below the LOQ of 20 mg kg^{-1}. The 95 % range for extractable S in OL and OFH layers is 463 – 2741 mg S kg^{-1} as shown by the distribution functions in Figure 3.4.103.

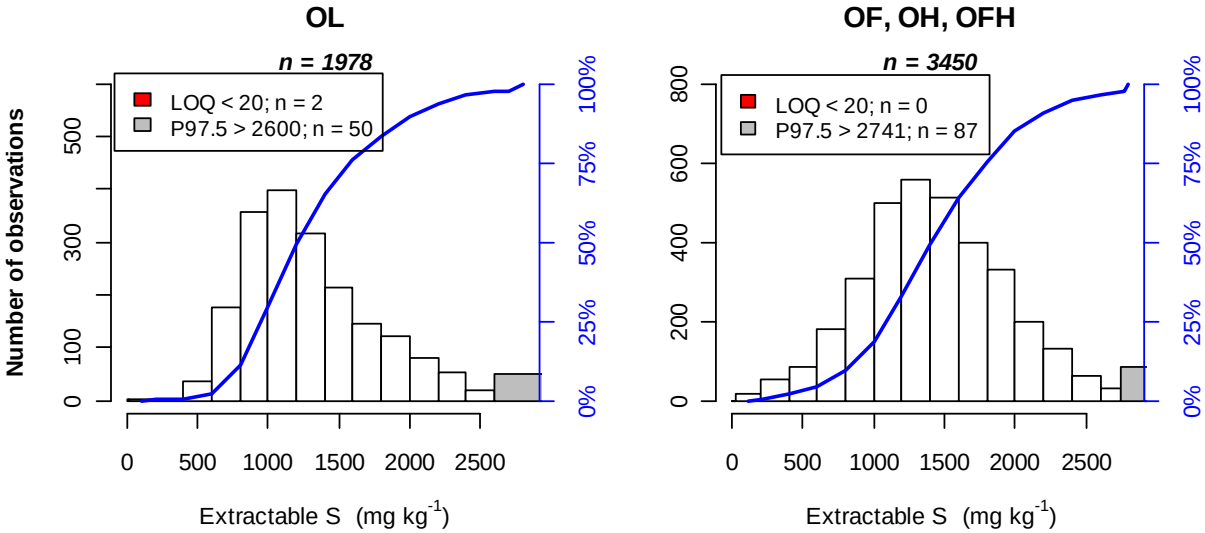


Figure 3.4.103. Absolute and cumulative frequency distribution (in blue) of extractable S in OL (left) and OF, OH and OFH layers (right) of all BioSoil^{+} plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

The median values are 1207 and 1410 mg S kg^{-1} whereas means are 1326 and 1468 mg S kg^{-1} for OL and OFH layers respectively. Most observations are comprised within the 800 - 1200 mg S kg^{-1} for OL and between 1200 - 1400 mg S kg^{-1} for OFH.

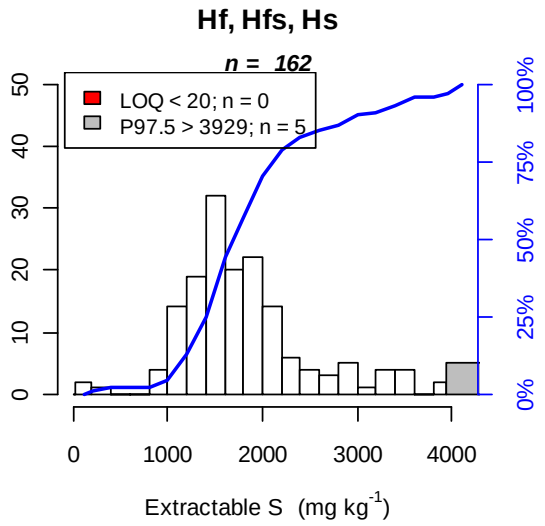


Figure 3.4.104. Absolute and cumulative frequency distribution (in blue) of extractable S in hydromorphic forest floor layers of all BioSoil+ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

In hydromorphic humus layers the S concentration appears to be somewhat higher than in aerated humus forms (Figure 3.4.104). Most observations (95 %) are situated between 930 and 3929 mg S kg^{-1}, mainly in the 1400 – 1600 mg S kg^{-1} interval. The median value is 1682 mg S kg^{-1} and the mean 1968 mg S kg^{-1}.

Few observations occur below 800 mg S kg^{-1} and just a few of them exceed 4000 mg kg^{-1}.

Mineral layers

The range observed for extractable S concentration in mineral layers is from less than 20 mg S kg^{-1} up to 6000 mg kg^{-1}. Figure 3.4.105 shows lognormal distributions with an increasing number of observations (up to 13 %) below LOQ with increasing depth. The median values decrease clearly with depth (M01 to M48) in the order: 198 > 110 > 86 > 53 mg S kg^{-1} while mean values decrease in the order: 292 > 184 > 142 > 106 mg S kg^{-1}. All other statistical values are tabularised in Annex II.

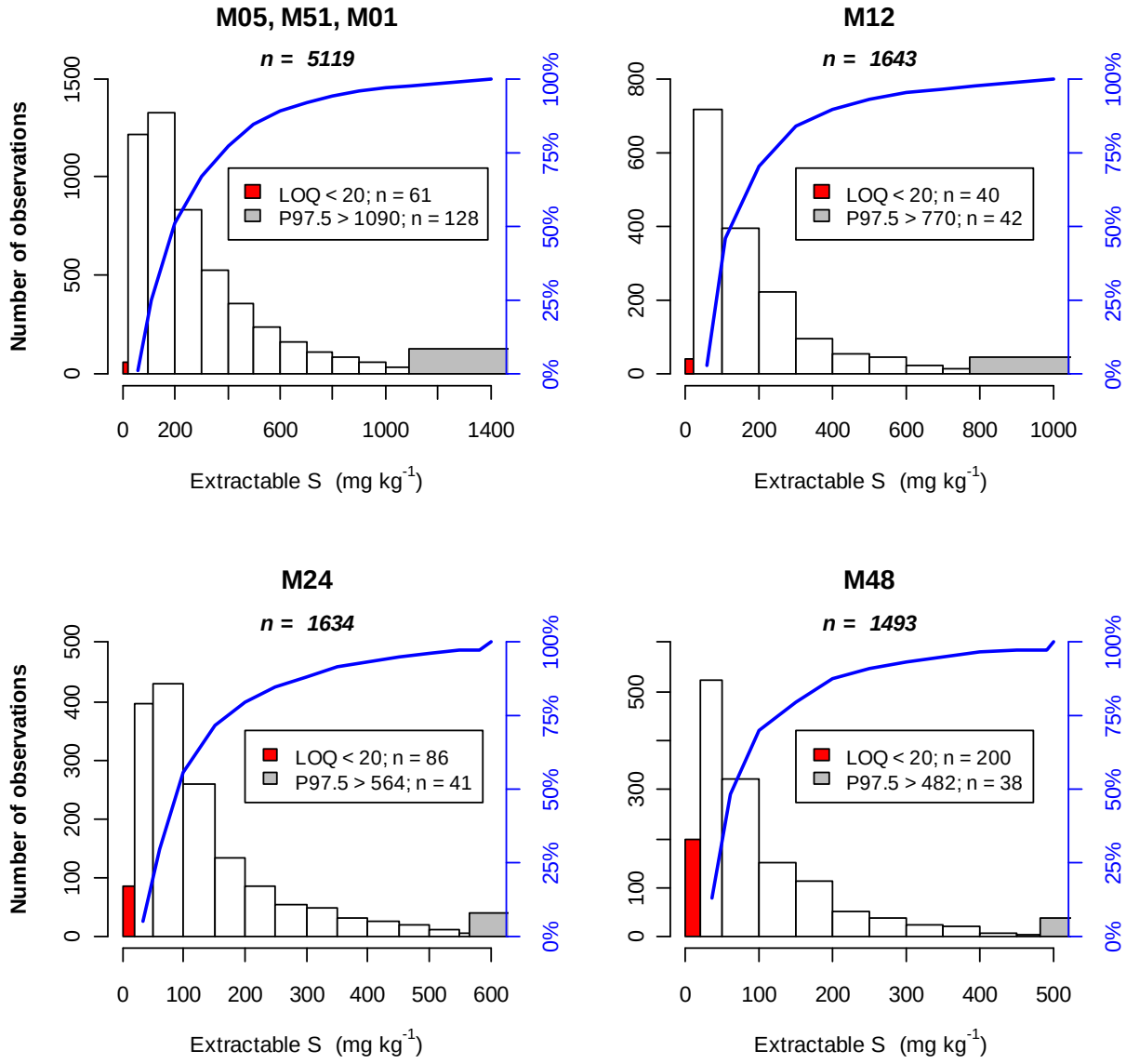


Figure 3.4.105. Absolute and cumulative frequency distribution (in blue) of extractable S in mineral layers of all BioSoil+ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

Peat soils

The distribution of extractable S concentrations in peat layers is shown in Figure 3.4.106. Median concentrations (2173 - 2503 mg S kg^{-1}) are about 10 to 60 times higher than those of mineral soils. Not a single observation was below LOQ and less than 2.5 % of them are exceeding 6747 mg S kg^{-1}. Median values increase slightly with depth while it decreased in mineral soils. All these statistics are listed in Annex II.

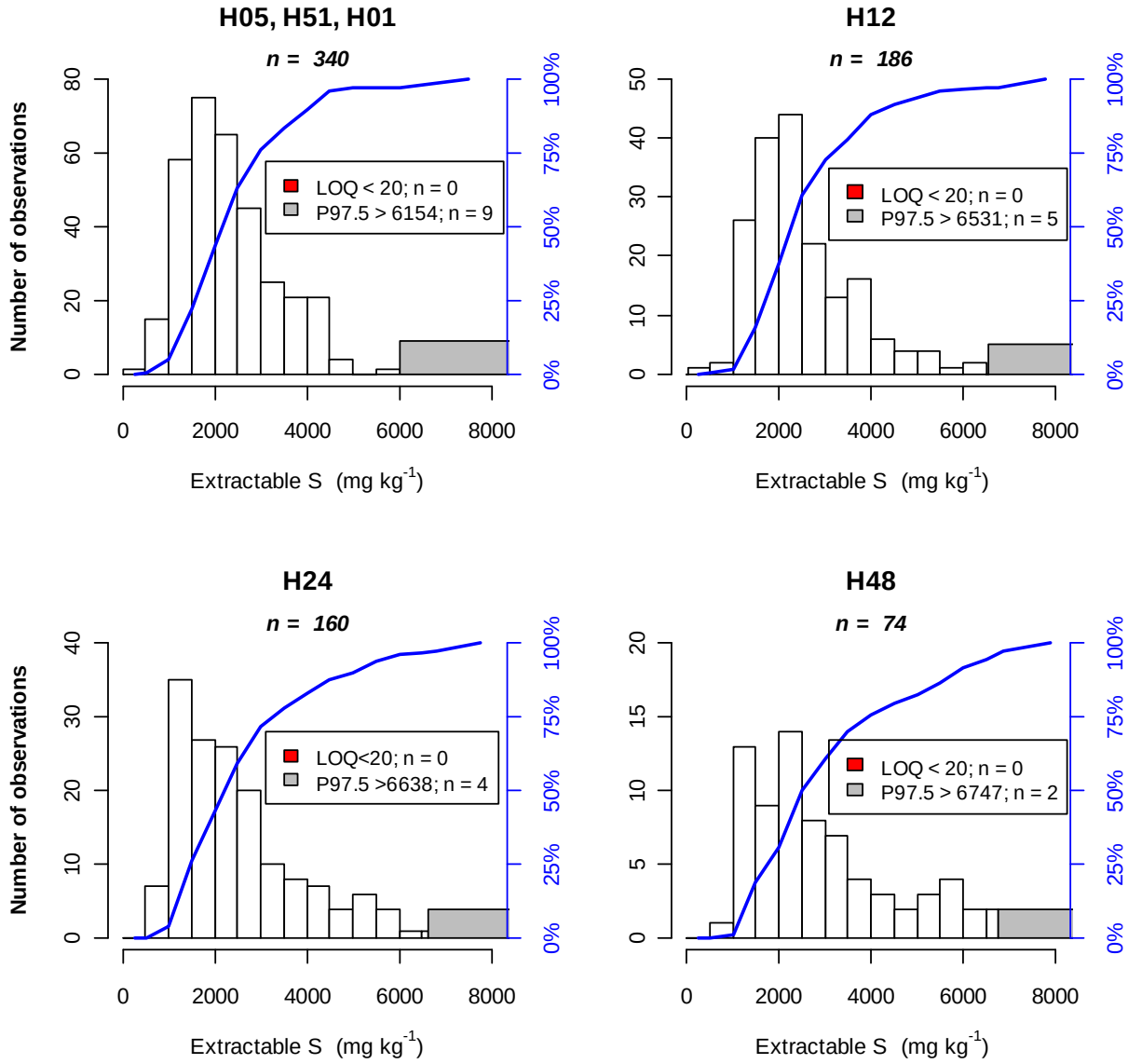


Figure 3.4.106. Absolute and cumulative frequency distribution (in blue) of extractable S in peat layers of all BioSoil+ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

The geographical distribution of the aqua regia extractable S in the upper 10 cm of the mineral or peat soils is presented on Map 17 in Annex III. The geographical extend of the available data is rather limited for S compared to most of the other aqua regia extractable elements. Neither Spain, Portugal, Ireland, Hungary, Serbia or Greece reported any sulphur results for the 0 -10 cm layer. The highest sulphur concentrations are found in Great Britain followed by the eastern part of the Alps and Slovenia. The S concentrations in northeast Germany, Poland; Slovak Republic are on the lower end of the scale with very low S content in the north of Scandinavia.

3.4.10.6 Extractable Sodium

The extractable Na concentration for the organic and mineral layers is given in Figure 3.4.107, showing the concentration range, median and quartiles for each layer according to a logarithmic scale (base 10). Concentration ranges and medians do not differ substantially among layers. For all investigated layers, part of their observations are below LOQ.

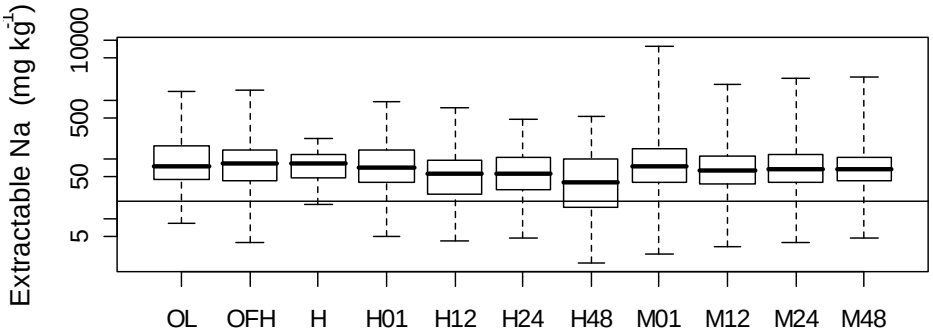


Figure 3.4.107. Box plot of extractable Na for all layers. The Y-axis is logarithmic. The overall horizontal line indicates the LOQ at 20 mg kg^{-1}.

Forest Floor

Aqua regia extractable Na concentration in the forest floor layers ranges from ~10 mg Na kg^{-1} to ~1500 mg kg^{-1} at most. Exactly 2.4 % of OL layers and 17.6 % of OFH observations are below LOQ as indicated by the red bars in Figure 3.4.108. The 95 % range for extractable Na in OL and OFH layers is 14.4 – 538 mg kg^{-1}.

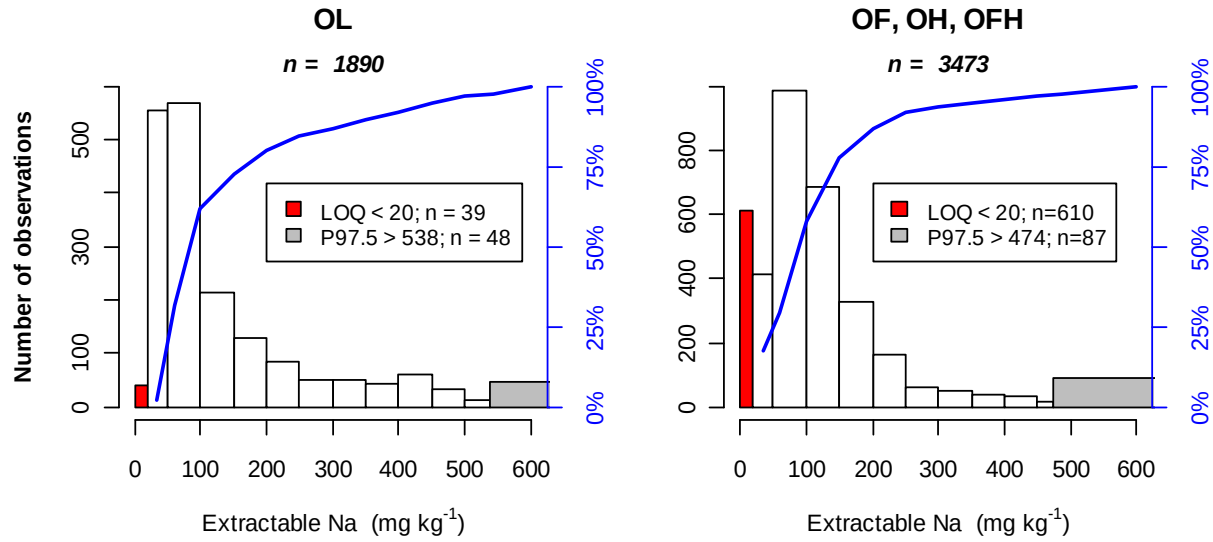


Figure 3.4.108. Absolute and cumulative frequency distribution (in blue) of extractable Na in OL (left) and OF, OH and OFH layers (right) of all BioSoil^{+} plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

The distributions show lognormal patterns with skewness of 2.6 and 3.5 for OL and OFH respectively. The median values are 74.7 and 86.0 mg Na kg^{-1} whereas means are 136 and 117 mg Na kg^{-1} respectively. Highest frequency of observations is situated within the 50 - 100 mg Na kg^{-1} interval.

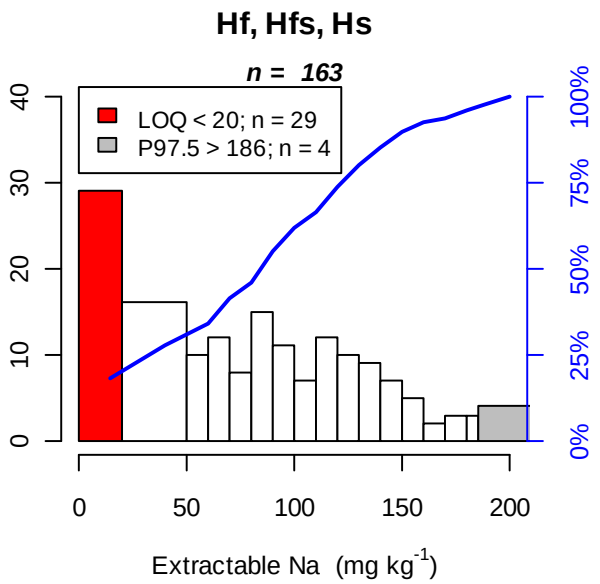


Figure 3.4.109. Absolute and cumulative frequency distribution (in blue) of extractable Na in hydromorphic forest floor layers of all BioSoil+ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

In hydromorphic humus types the median Na concentration (84.2 mg kg^{-1}) is comparable to that of aerated OFH layers, but the $P_{97.5}$ is substantially lower as indicated in Figure 3.4.109. Most observations (95 %) are situated between 25.5 and 186 mg Na kg^{-1}. The proportion of censored values (below LOQ) is 17.8 % of all observations, similar as for the OFH layers.

Mineral layers

The ranges observed for extractable Na concentration among mineral layers are comparable. Ninety-five percent of all observations are comprised within 11.9 – 650 mg Na kg^{-1} and medians do not differ substantially among fixed depths (62.9 – 75.8 mg Na kg^{-1}).

Figure 3.4.110 shows lognormal distributions with similar $P_{97.5}$ values and similar proportions below LOQ (10 – 12 % of observations). As for the OL and OFH layers, most observations are comprised within the 50 - 100 mg Na kg^{-1} interval. All other statistical values are tabularised in Annex II.

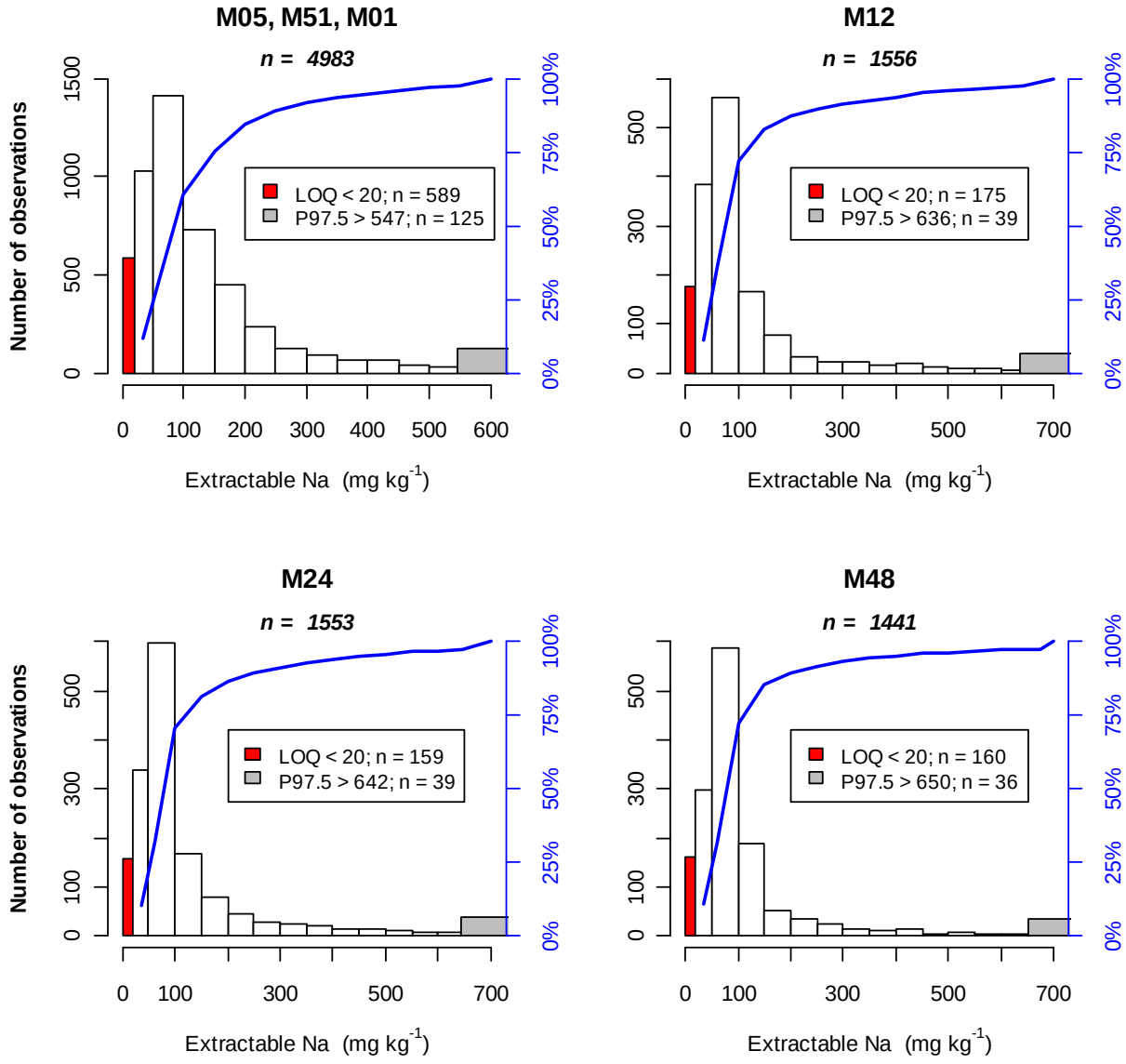


Figure 3.4.110. Absolute and cumulative frequency distribution (in blue) of extractable Na in mineral layers of all BioSoil+ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

Peat soils

The distribution of extractable Na concentrations in peat layers is shown in Figure 3.4.111. Between 20 and 41 % of the values are below LOQ, which is substantial. Median Na concentrations (41.0 – 72.6 mg Na kg^{-1}) are comparable to those of mineral soils. Less than 2.5 % of observations

are exceeding 485 mg Na kg^{-1}, and few peats contain more than 100 mg Na kg^{-1}. All these statistical data are listed in Annex II.

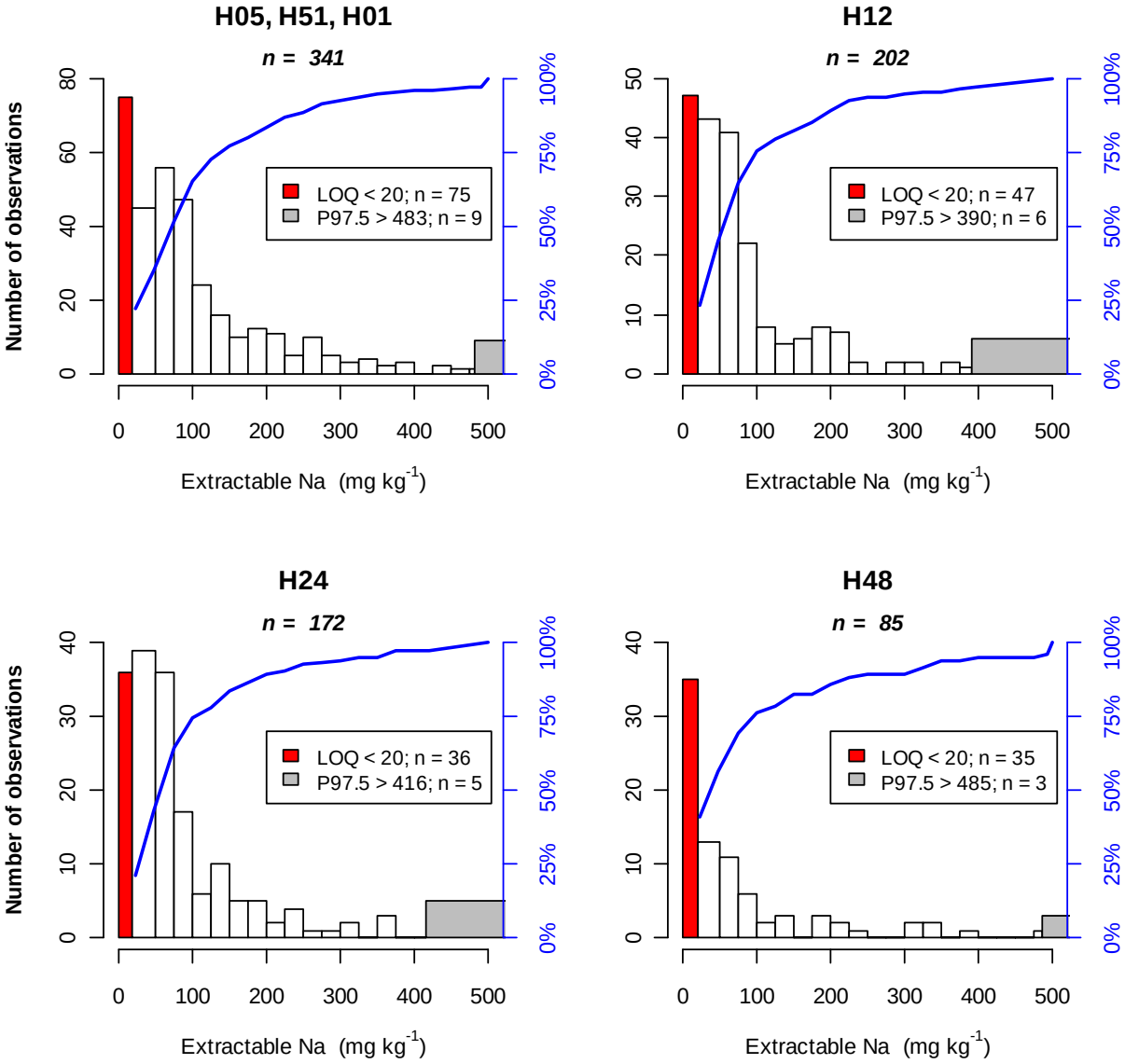


Figure 3.4.111. Absolute and cumulative frequency distribution (in blue) of extractable Na in peat layers of all BioSoil+ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

Map 18 in annex III shows the geographical distribution of the aqua regia extractable Na in the upper 10 cm of the mineral and peat soils. As these data were not available for Austria, Hungary, Ireland, Spain, Serbia and Greece, these countries were blanked in the Krieged map. Italy and Baden-Württemberg appear then as countries with very high sodium content in their soils. Sodium concentrations are also high on the northern coast of Scotland. The abrupt differences between Sweden and Finland rather suggests an anomaly in the data than natural differences between these two Scandinavian countries. Sweden reported for the majority of its plots values below the LOQ. In the last FSCC ring test (Cools et al. 2010) the laboratory reported LOQ values of 31 mg kg^{-1}. This is clearly higher than the LOQ levels that are maintained in this report which is 20 mg kg^{-1}. Probably the sodium content in the upper 10 cm of the Swedish soils is very low but not as low as one would expect from Map 18.

3.4.10.7 Extractable Aluminium

The extractable Al concentration for the organic and mineral layers is given in Figure 3.4.112, showing the concentration range, median and quartiles for each layer according to a logarithmic scale (base 10). Clearly, highest concentrations are observed for mineral soil layers and lowest in the most organic matrices: OL and peat layers.

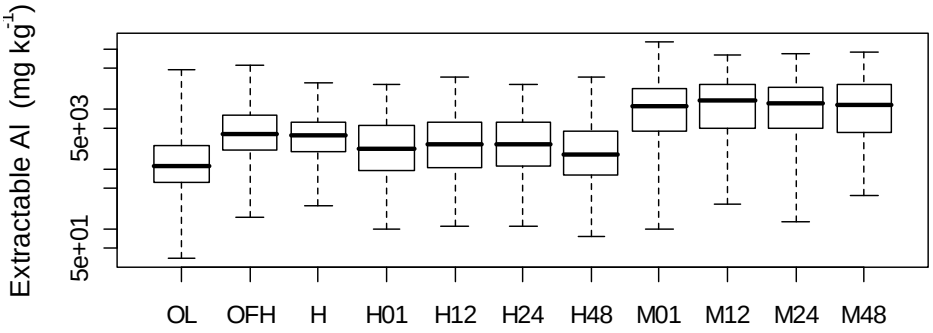


Figure 3.4.112. Box plot of extractable Al for all layers. The Y-axis is logarithmic.

Forest Floor

Aqua regia extractable Al concentration in the forest floor layers ranges from ~200 mg kg^{-1} to ~50000 mg kg^{-1} at most. Less than 3 % of the OL and OFH observations are below LOQ of 10 mg Al kg^{-1} and less than 2.5 % of observations exceed 25635 mg kg^{-1} (Figure 3.4.113). OL layers contain much less extractable Al than OFH layers, which might be explained by mixing of the latter by mineral soil particles containing much more Al than organic material. The 95 % range for in OL layers is 208 – 11290 mg Al kg^{-1} whereas in OFH layers this is 781 – 25635 mg Al kg^{-1}.

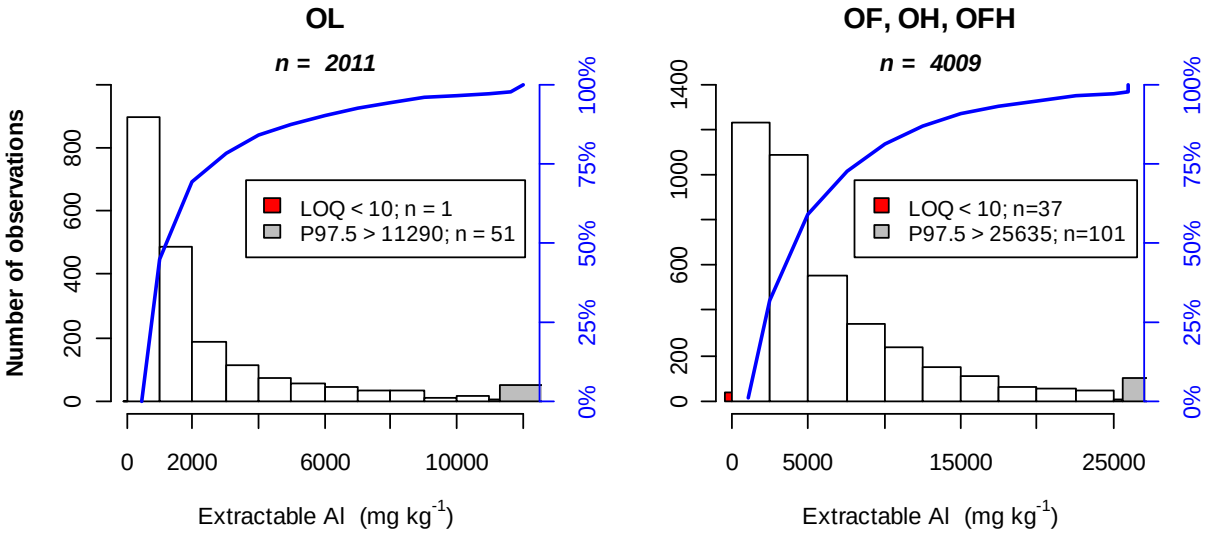


Figure 3.4.113. Absolute and cumulative frequency distribution (in blue) of extractable Al in OL (left) and OF, OH and OFH layers (right) of all BioSoil+ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

An intermediate distribution is found for the hydromorphic humus layers (Figure 3.4.114)

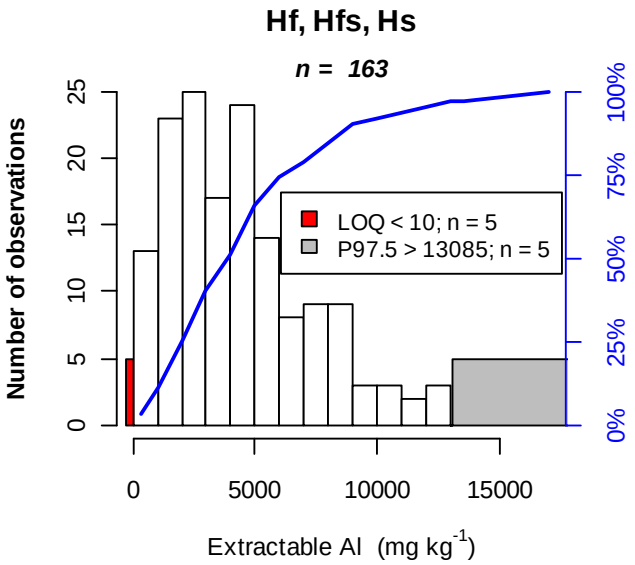


Figure 3.4.114. Absolute and cumulative frequency distribution (in blue) of extractable Al in hydromorphic forest floor layers of all BioSoil+ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

showing predominantly observations below 5000 mg Al kg^{-1}. The median value is 3792 mg Al kg^{-1} and 95 % range: 372 – 13085 mg Al kg^{-1}. So, few values (< 5 %) were found outside this range and 3.1 % of the observations are below LOQ.

Mineral layers

The range generally observed for extractable Al concentration is between ~130 mg kg^{-1} and ~ 100000 mg Al kg^{-1} (about 10% of DM). This is not surprising since Al is a major constituent of soil minerals and aqua regia is a quite aggressive reagent. However, 95-percent of all observations are comprised within 1100 – 55187 mg Al kg^{-1}. Median values differ slightly among fixed depths (11634 - 14160 mg Al kg^{-1}) and also $P_{97.5}$ values are highly comparable (Figure 3.4.115). The distribution patterns are similar, showing consistently most observations in the 0 - 5000 mg Al kg^{-1} class. Extractable Al is easily quantifiable since very few observations are below LOQ.
All other statistical values are tabularised in Annex II.

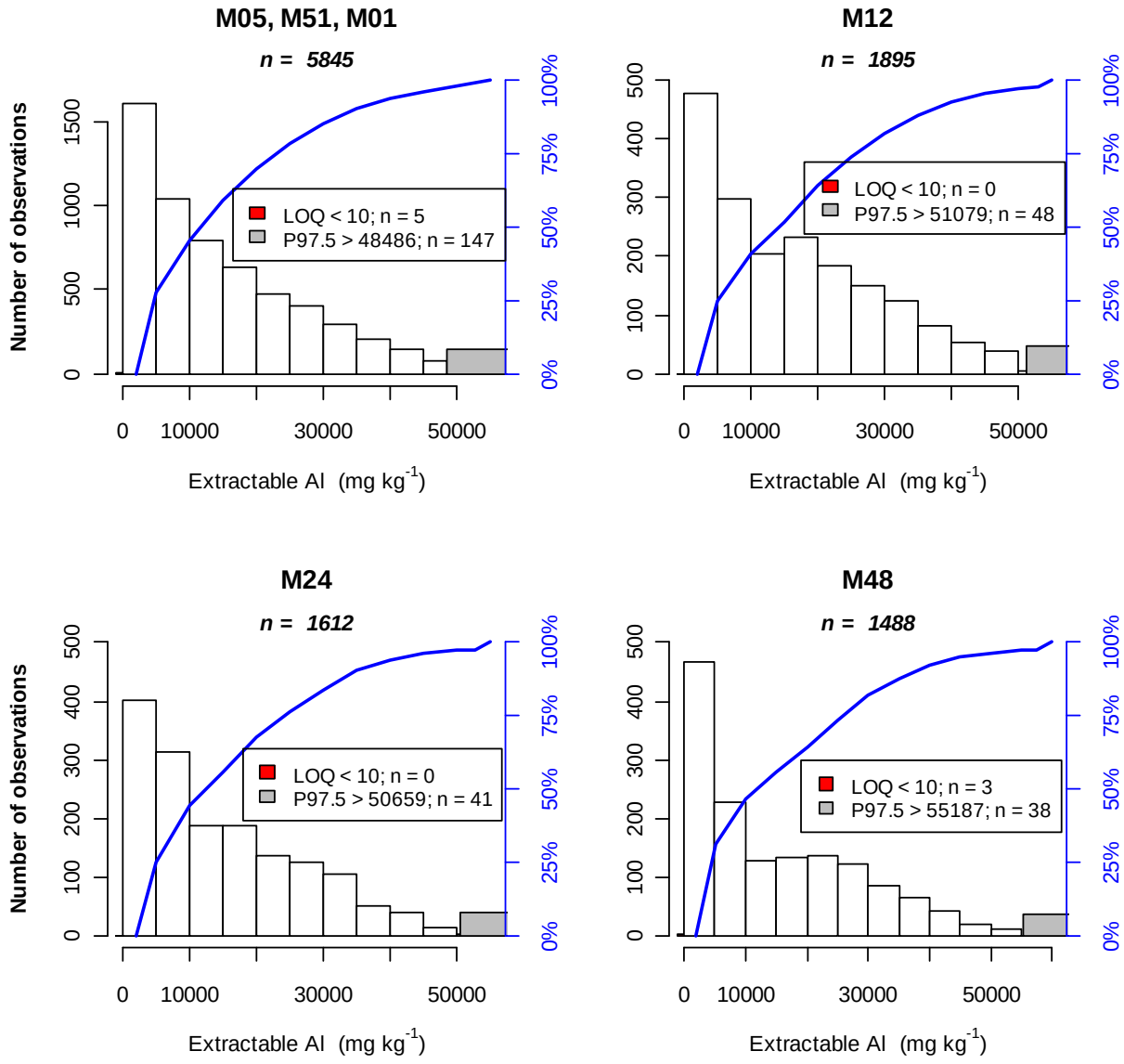


Figure 3.4.115. Absolute and cumulative frequency distribution (in blue) of extractable Al in mineral layers of all BioSoil+ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

Peat soils

The distribution of extractable Al concentrations in peats is shown in Figure 3.4.116. It is immediately clear that the concentration range is less than half that of mineral soils, generally below 20000 mg Al kg^{-1}. The percentage of observations below LOQ is up to 9.2 % (in H48). The 95 % 'plausible' range is 141 – 26000 mg Al kg^{-1}. Median Al concentrations vary between 1782 mg kg^{-1} and 2592 mg kg^{-1} which is about one fifth of the medians observed in mineral soils. Highest frequencies of observations are below 2500 mg Al kg^{-1}.

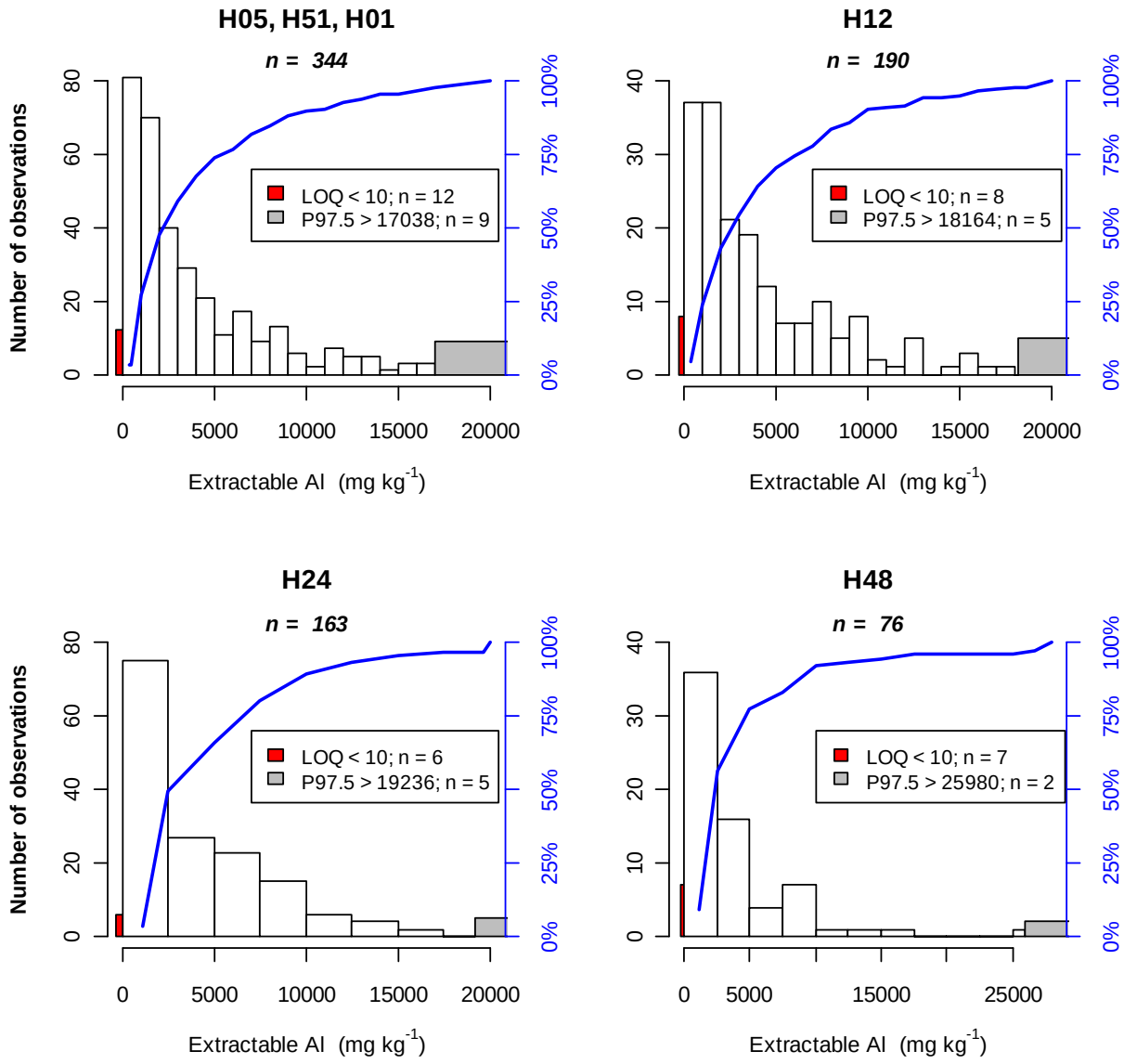


Figure 3.4.116. Absolute and cumulative frequency distribution (in blue) of extractable Al in peat layers of all BioSoil⁺ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

Map 19 in Annex III shows the geographical distribution of the aqua regia extractable Al in the upper 10 cm of the mineral and peat soils. The lowest concentrations are seen in the sandy soils of northern Germany and Poland, the Landes in Frances and parts of Sweden. Concentrations of more than 32000 mg kg^{-1} are observed in extensive areas in Spain, southeast France, southern Germany, Slovak republic, Austria, Italy and Slovenia. Scandinavia, the Baltic states rather show intermediate levels.

3.4.10.8 Extractable Iron

An overview of extractable Fe concentrations for the organic and mineral layers is given in Figure 3.4.117. Distinct concentration ranges are observed between organic and mineral layers. Iron concentrations in mineral soils are 3 to 4 times greater than in forest floors or peats. Almost no values below a LOQ of 10 mg kg^{-1} were observed, indicating easily measurable concentrations.

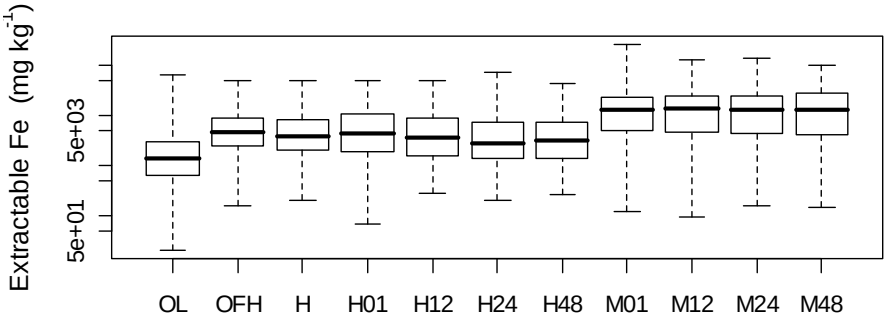


Figure 3.4.117. Box plot of extractable Fe for all layers. The Y-axis is logarithmic. The overall horizontal line indicates the LOQ at 10 mg kg^{-1}.

Forest Floor

Aqua regia extractable Fe concentration in the forest floor layers ranges from ~150 mg kg^{-1} to ~50000 mg kg^{-1} at most. Only three observations are below LOQ for OL and less than 2.5 % of them exceed 23148 mg Fe kg^{-1} (Figure 3.4.118*).* Just as for extractable Al, OL layers contain much less extractable Fe than OFH layers. Again, this is explained by the mixing of OFH layers with mineral soil particles containing higher amounts of Fe than litter.

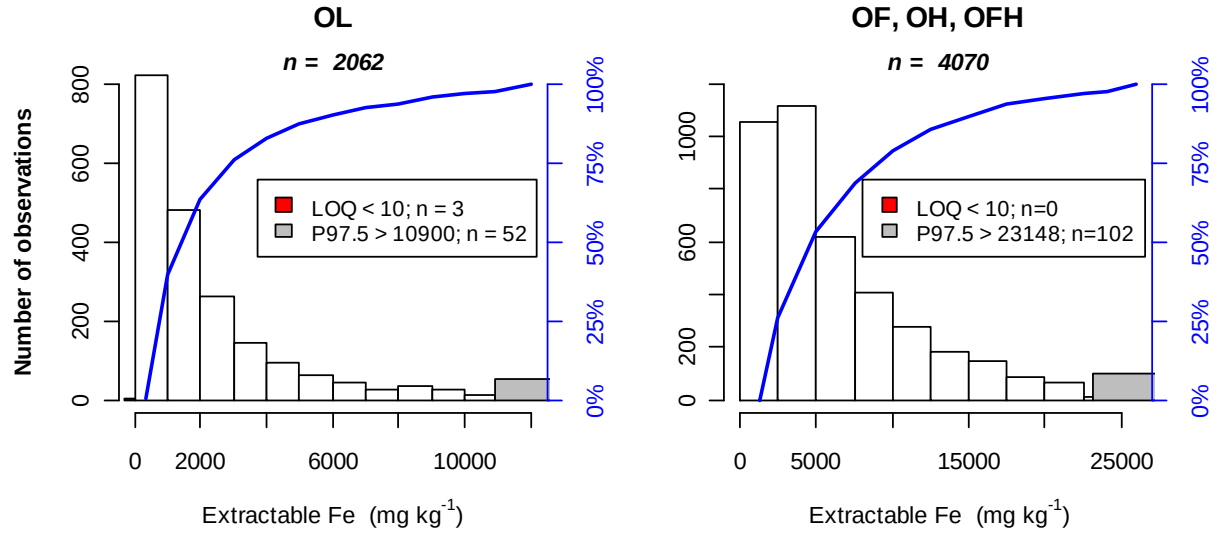


Figure 3.4.118. Absolute and cumulative frequency distribution (in blue) of extractable Fe in OL (left) and OF, OH and OFH layers (right) of all BioSoil+ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

The 95 % range in OL layers is 140 – 10900 mg Fe kg^{-1} whereas in OFH layers this is 850 – 23148 mg Al kg^{-1}. In OL the 0 - 1000 mg kg^{-1} class shows the highest frequency, whereas it is the 2500 - 5000 mg kg^{-1} class for OFH layers. The respective medians are 1349 and 4513 mg Fe kg^{-1}.

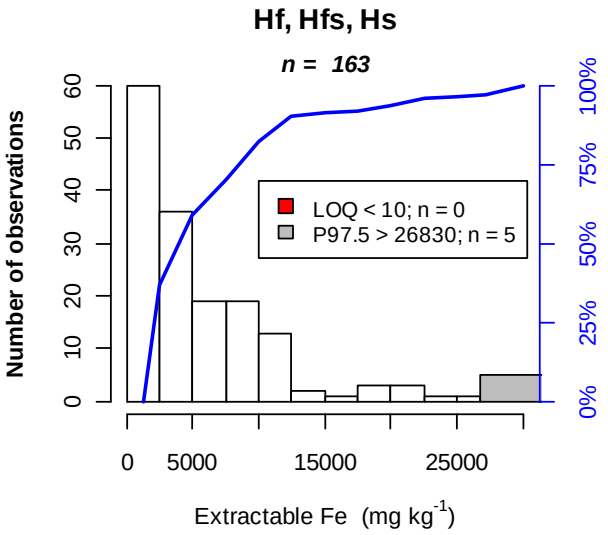


Figure 3.4.119. Absolute and cumulative frequency distribution (in blue) of extractable Fe in hydromorphic forest floor layers of all BioSoil+ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

In hydromorphic humus layers, Fe concentrations have values in between those of OL and OFH layers (Figure 3.4.119*)*. Ninety-five percent of the values range from 494 to 26830 mg Fe kg^{-1} while not a single value was found below LOQ.

The median value is 3920 mg Fe kg^{-1} and highest frequency of observations is found below 2500 mg Fe kg^{-1}. Very few forest floor samples contain more than 12500 mg kg^{-1} (1.25 %) of Fe.

Mineral layers

The range generally observed for extractable Fe concentration is between ~100 mg kg^{-1} and ~ 260000 mg kg^{-1} (up to 26 %). However, 95-percent of all observations are comprised within 889 – 62600 mg Fe kg^{-1}. Median values differ slightly among fixed depths (12527 - 13912 mg Fe kg^{-1}) and $P_{97.5}$ values slightly increase with depth (Figure 3.4.120) presumably due to higher occurrence of sesquioxides in deeper layers (e.g. Podsolisation process). The distribution patterns are similar, showing consistently highest frequency of observations in the 0 - 5000 mg Fe kg^{-1} class and a gradual decrease of observations in the next classes, except for M12. Only one observation was found below LOQ (in 0 - 10 cm layer). More statistical measures are tabularised in Annex II.

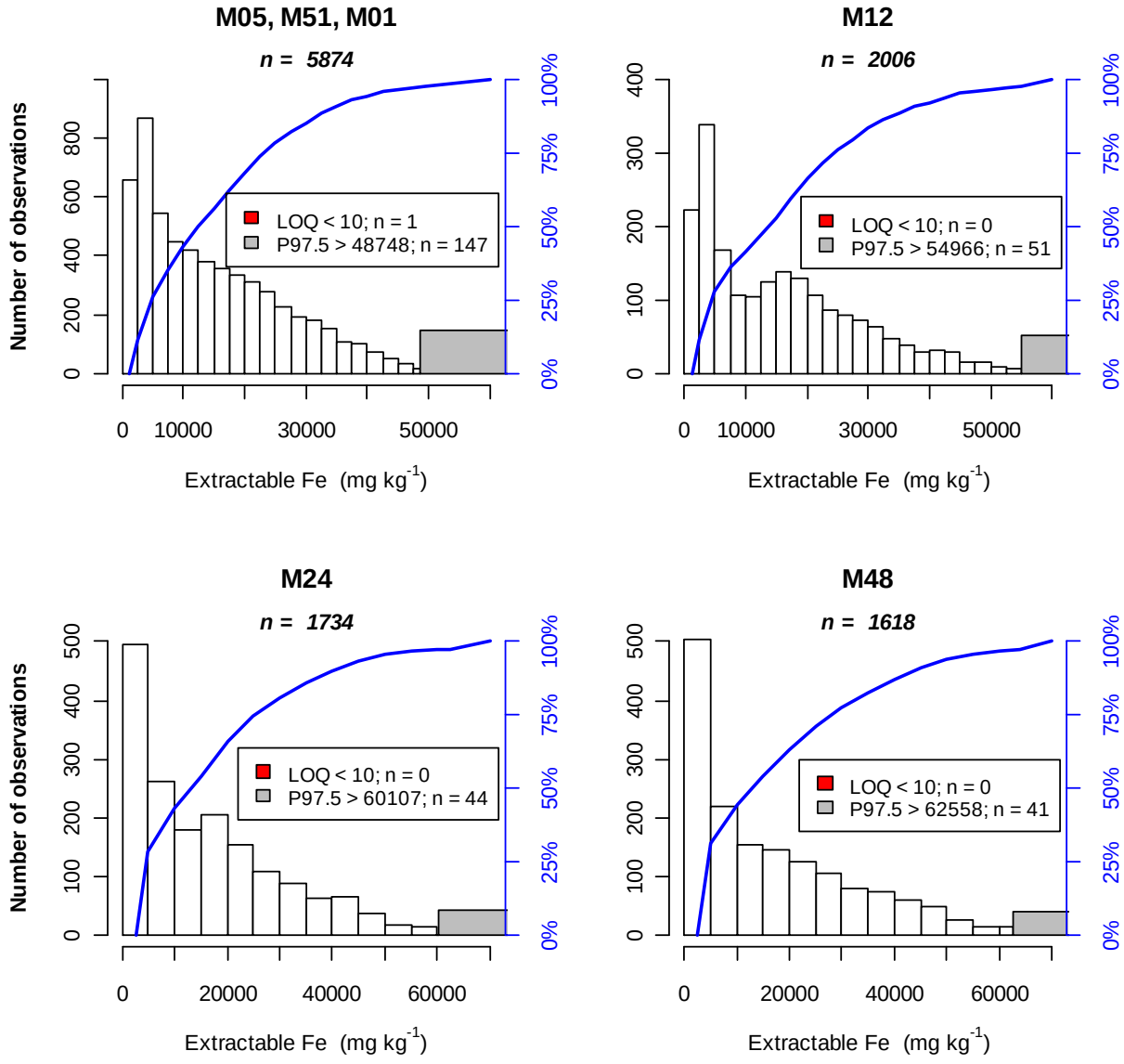


Figure 3.4.120. Absolute and cumulative frequency distribution (in blue) of extractable Fe in mineral layers of all BioSoil+ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

Peat soils

The distribution of extractable Fe concentrations in peat layers is shown in Figure 3.4.121. The concentration range is similar to that of H layers, which are most often associated with peat soils. The 95 % range is 351 – 42277 mg Fe kg^{-1}. No observations occur below LOQ. Median Fe concentrations vary between 2775 and 3587 mg kg^{-1} which is about one quarter of the medians observed in mineral soils. For all depths, highest number of observations are found below 2500 mg Fe kg^{-1} and as the distributions indicate, few of them exceed 2 % Fe.

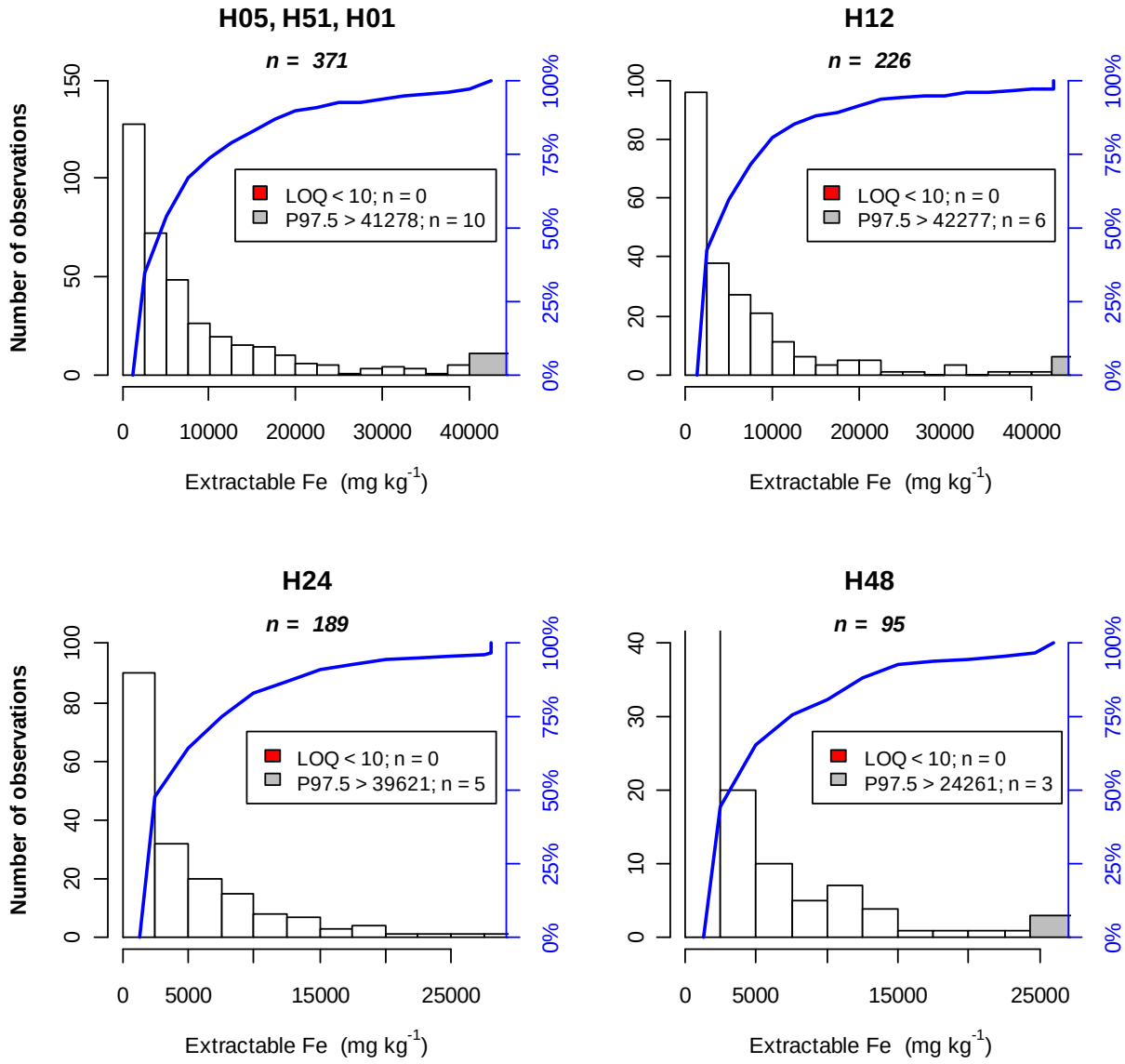


Figure 3.4.121. Absolute and cumulative frequency distribution (in blue) of extractable Fe in peat layers of all BioSoil+ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

Map 20 in annex III shows the geographical distribution of the aqua regia extractable Fe in the upper 10 cm of the mineral and peat soils which is very similar with the distribution pattern of Al though less extremely high levels are reached.

3.4.10.9 Extractable Manganese

The extractable Mn concentration for the organic and mineral layers is given in Figure 3.4.122, showing the concentration range, median and quartiles for each layer according to a logarithmic scale. Two distinct groups may be recognised: (i) terrestrial forest floors and mineral soil layers and (ii) hydromorphic forest floors and peat layers. Mn concentrations in the latter are a factor 5 to 10 smaller than the first group of layers.

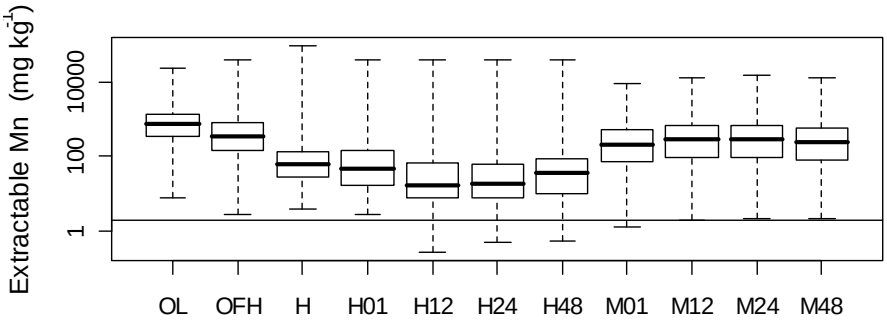


Figure 3.4.122. Box plot of extractable Mn for all layers. The Y-axis is logarithmic. The overall horizontal line indicates the LOQ at 2 mg kg^{-1}.

Forest Floor

Aqua regia extractable Mn concentration in the forest floor layers ranges from ~8 to ~40000 mg kg^{-1} at most. Only one OFH observation is below LOQ and less than 2.5 % of the observations are exceeding 3600 mg kg^{-1} (Figure 3.4.123*).* The median Mn concentration in OL layers (i.e. 718 mg kg^{-1}) is more than double of that in OFH layers (i.e. 331 mg kg^{-1}) but the $P_{97.5}$ values are equivalent. The 95 % range for Mn in OL layers is 71 – 3597 mg Mn kg^{-1} whereas in OFH layers

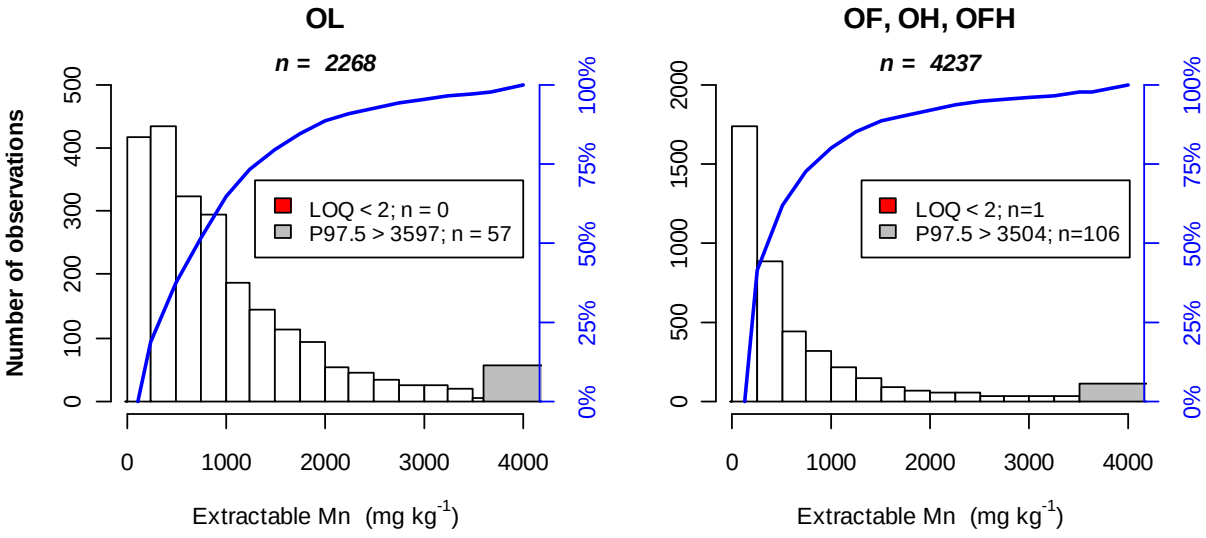


Figure 3.4.123. Absolute and cumulative frequency distribution (in blue) of extractable Mn in OL (left) and OF, OH and OFH layers (right) of all BioSoil^{+} plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

this is 29 – 3504 mg Mn kg^{-1}. Distributions show strong logarithmic decreasing patterns with highest frequencies within 250 - 500 mg Mn kg^{-1} for OL and 0 - 250 mg Mn kg^{-1} for OFH layers.

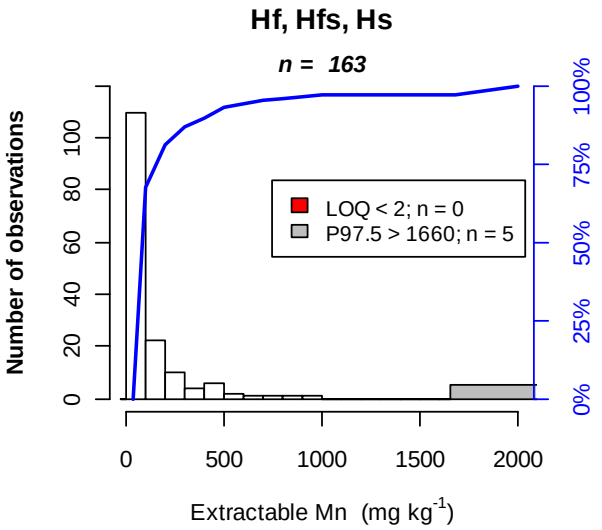


Figure 3.4.124. Absolute and cumulative frequency distribution (in blue) of extractable Mn in hydromorphic forest floor layers of all BioSoil+ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

In hydromorphic humus layers, Mn concentrations are substantially less than in aerated forest floors (Figure 3.4.124). Ninety-five percent of the values range from 3.8 to 1660 mg Mn kg^{-1}. No observations are below LOQ. The 0 – 100 mg Mn kg^{-1} class contains almost all observations while values more than 500 mg Mn kg^{-1} are scarce. The median for all Hf, Hfs and Hs layers is 60.8 mg Mn kg^{-1}.

Mineral layers

The range generally observed for extractable Mn concentration in mineral soils is between ~5 mg kg^{-1} and ~ 15400 mg Mn kg^{-1}. However, 95-percent of all observations are comprised within 8.3 – 1937 mg Mn kg^{-1}. Median values vary among fixed depths from 203 to 293 mg Mn kg^{-1} and $P_{97.5}$ values are comparable and do not seem to increase with depth (Figure 3.4.125).

The distributions show a similar pattern, showing consistently highest frequency in the 0 - 100 mg Mn kg^{-1} class and a gradual decrease of observations in the next classes. Less than 1 % of the observations are found below LOQ, with the highest absolute number of samples in the topsoil (0 - 10 cm). More statistical measures are tabularised in Annex II.

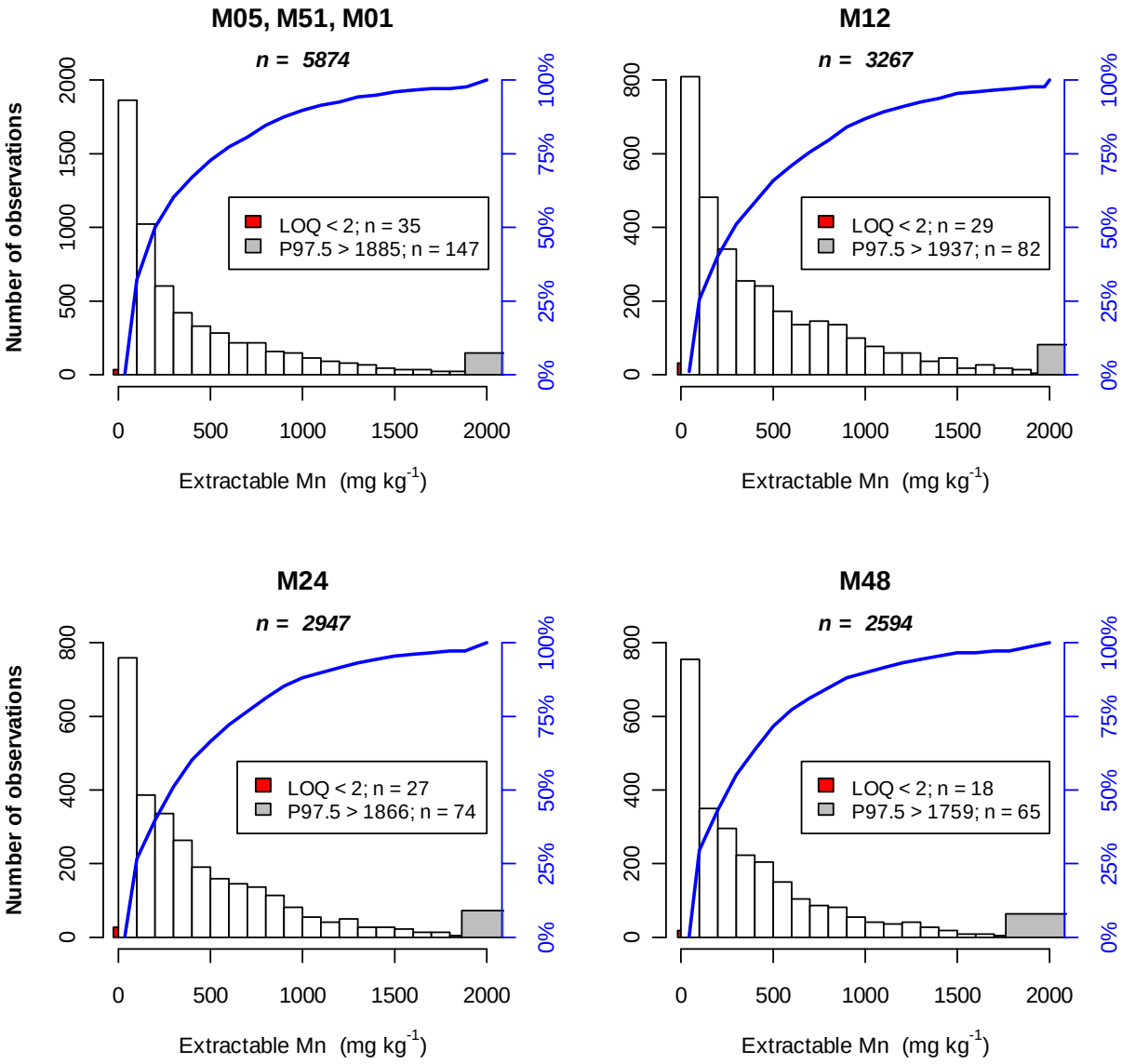


Figure 3.4.125. Absolute and cumulative frequency distribution (in blue) of extractable Mn in mineral layers of all BioSoil+ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

Peat soils

The distribution of extractable Mn concentrations in the peat layers is shown in Figure 3.4.126. The concentration range is more narrow than found in mineral or forest floor layers, with a 95 % range from 2 – 1155 mg Mn kg^{-1}. The proportion of left censored values is less than 2 %. Median Mn concentrations vary from 17.4 to 47.2 mg Mn kg^{-1} which is about 6 to 23 % of the median values observed in mineral soils. For all depths, highest frequency is seen within the 0 - 50 mg Mn kg^{-1} class and as indicated by the distributions, rarely exceed 500 mg Mn kg^{-1}.

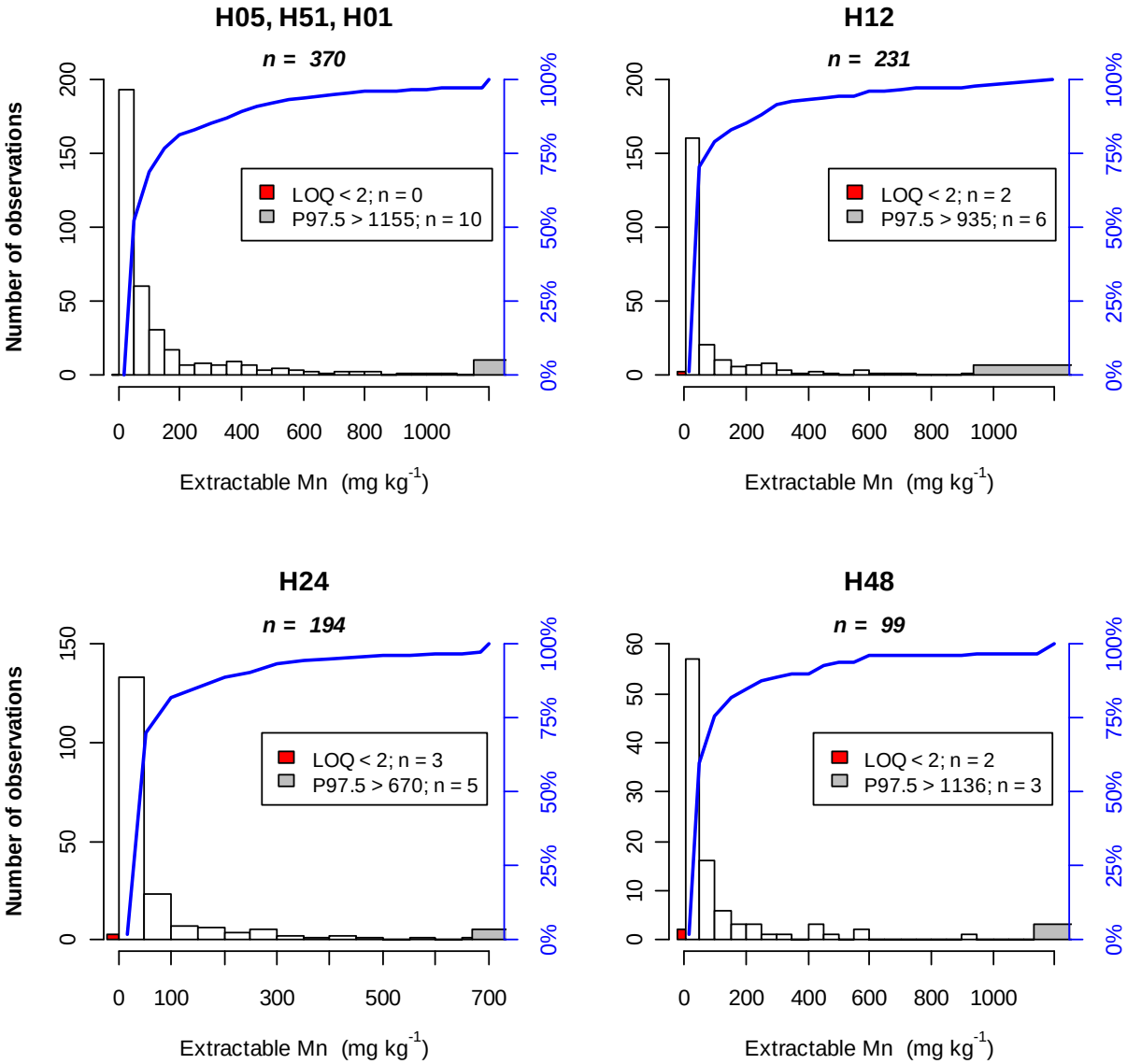


Figure 3.4.126. Absolute and cumulative frequency distribution (in blue) of extractable Mn in peat layers of all BioSoil+ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

Map 21 in Annex III shows the geographical distribution of the aqua regia extractable Mn in the upper 10 cm of the mineral and peat soils. Values above 3000 mg kg-1 are nearly never reached except for one area in northern Sweden.

3.4.10.10 Extractable Copper

The extractable Cu distributions of all organic and mineral layers is given in Figure 3.4.127 providing the concentration range, median and quartiles for each layer according to a logarithmic scale. Concentration levels are similar for all layers, though slightly higher for forest floors. The interquartile range is also more narrow in forest floors compared to peat and mineral soils. A substantial proportion of observations are below LOQ, although this is set at just 1 mg kg^{-1}.

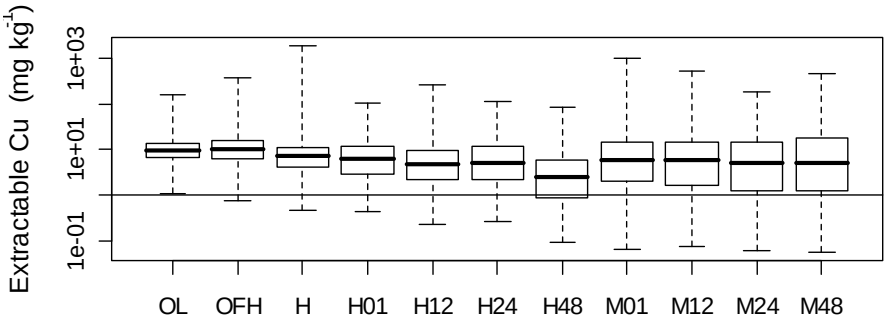


Figure 3.4.127. Box plot of extractable Cu for all layers. The Y-axis is logarithmic. The overall horizontal line indicates the LOQ at 1 mg kg^{-1}.

Forest Floor

Copper is one of the trace metals that may accumulate in forest floors. The Aqua Regia extractable Cu concentration hereof ranges from less than 1 to maximally ~370 mg Cu kg^{-1}. Less than 1 % of OL and 15 % of OFH observations are below LOQ and less than 2.5 % of the observations are exceeding 40 mg Cu kg^{-1} (Figure 3.4.128*).*

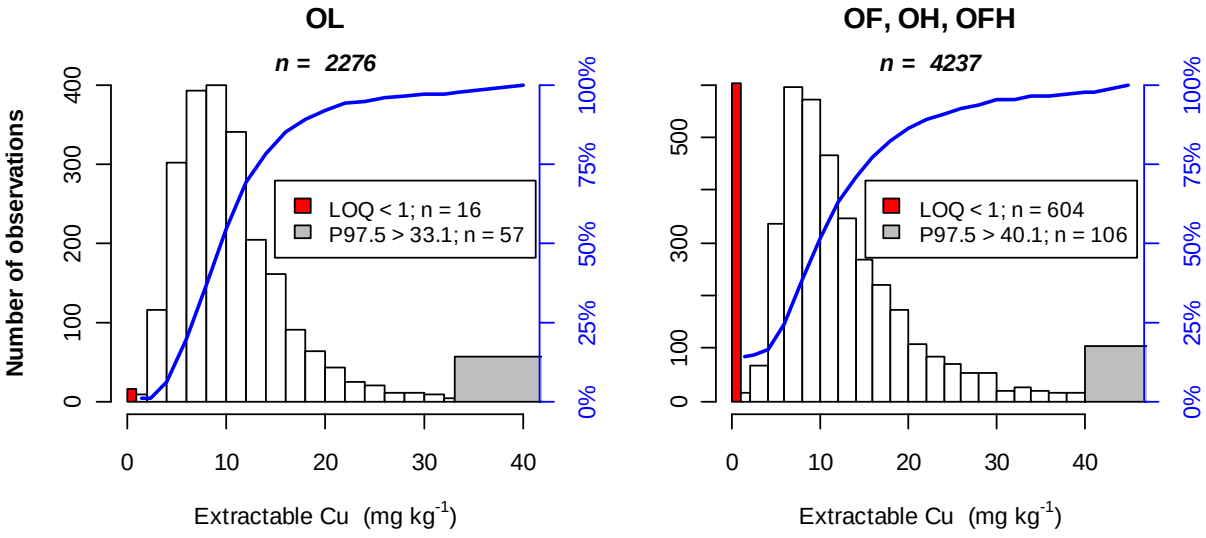


Figure 3.4.128. Absolute and cumulative frequency distribution (in blue) of extractable Cu in OL (left) and OF, OH and OFH layers (right) of all BioSoil^{+} plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

The median Cu concentration is 9.6 mg Cu kg^{-1} in OL layers and 9.9 mg Cu kg^{-1} in OFH layers. The 95 % range in OL layers is 3.2 – 33.1 mg Cu kg^{-1} whereas in OFH layers this is 2.2 – 40.1 mg Cu kg^{-1}. Distributions show nice lognormal patterns, with skewness values of 5.9 and 9.6 for OL and OFH respectively. Most frequently, observations are situated within 6 - 10 mg Cu kg^{-1}.

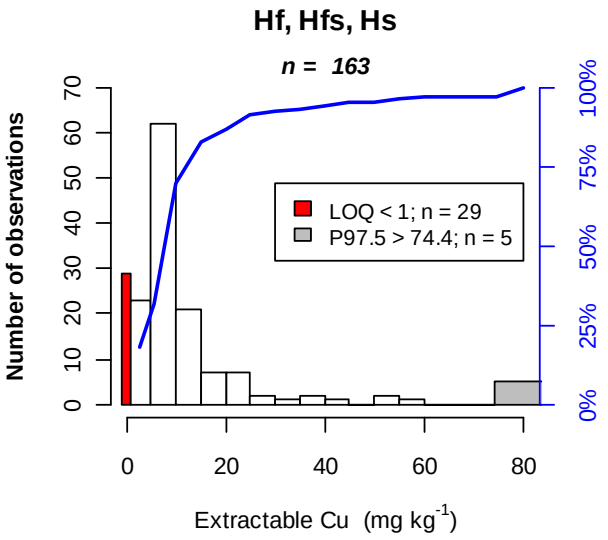


Figure 3.4.129. Absolute and cumulative frequency distribution (in blue) of extractable Cu in hydromorphic forest floor layers of all BioSoil+ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

In hydromorphic humus layers, the range of Cu concentrations is wider than in aerated forest floors (Figure 3.4.129) and some extreme values were reported (up to 1849 mg Cu kg^{-1}). However, 95-percent of the values range from 0.9 to 74.4 mg Cu kg^{-1}.

Almost one fifth of all observations are below LOQ, showing a substantial amount of samples with just traces of Cu, difficult to quantify reliably. Most other observations are contained within the 5 - 10 mg Cu kg^{-1} interval, as for terrestrial forest floors. Values more than 60 mg kg^{-1} are scarce. The median for all Hf, Hfs and Hs layers is 7.3 mg Cu kg^{-1}

Mineral layers

In mineral layers, extractable Cu ranges from ~0.5 mg kg^{-1} to 980 mg Cu kg^{-1}. However, 95-percent of all observations are comprised within 0.3 – 55.1 mg Cu kg^{-1}. Median values vary slightly among layers from 5.2 to 6.0 mg Cu kg^{-1} and $P_{97.5}$ values are ranging from 48.0 to 55.1 mg kg^{-1} (Figure 3.4.130). The distributions show a similar logarithmically decreasing pattern, consistently having highest observation frequency in the 1 – 5 mg Cu kg^{-1} bin and 13 to 23 % of observations below quantification limit. More statistical measures are tabularised in Annex II.

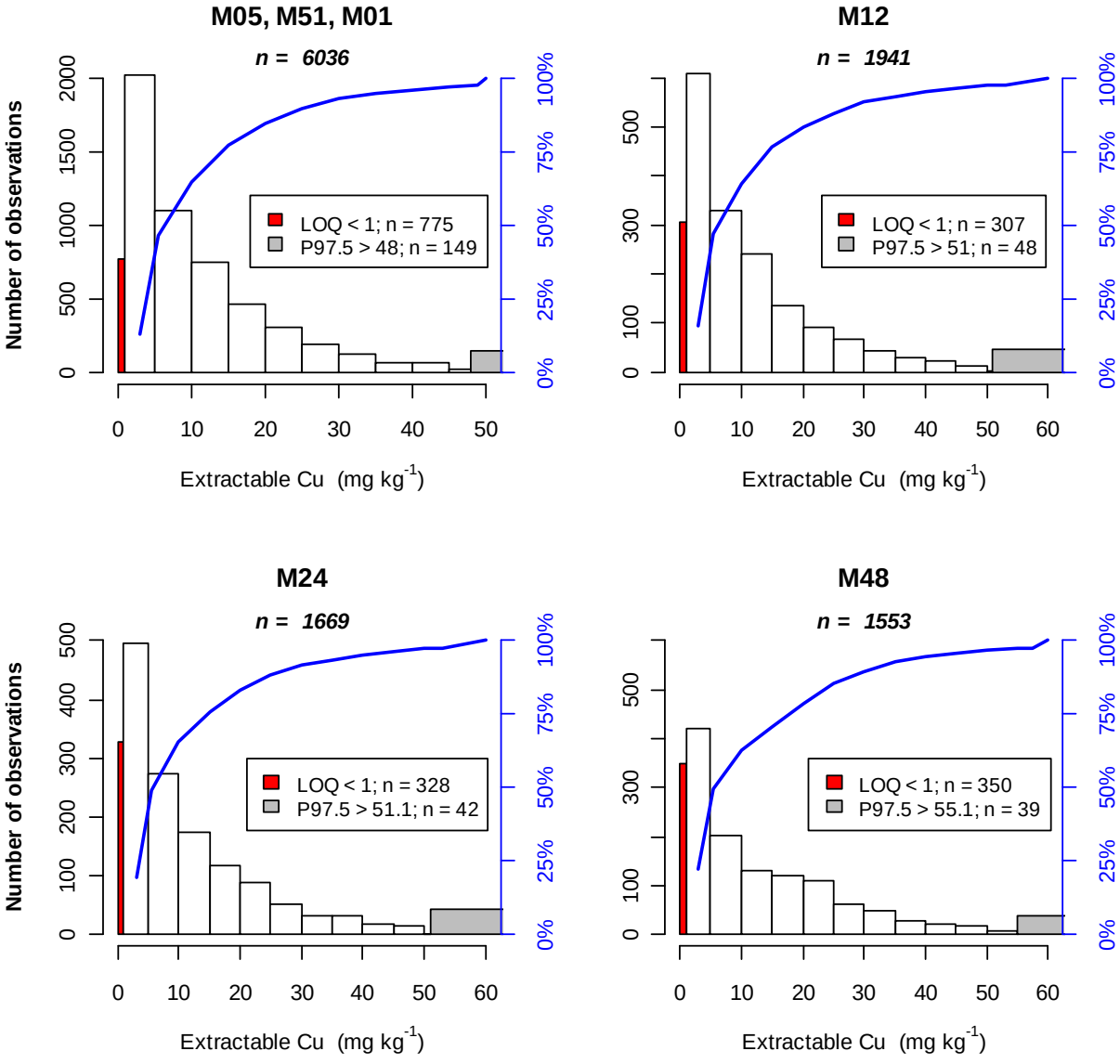


Figure 3.4.130. Absolute and cumulative frequency distribution (in blue) of extractable Cu in mineral layers of all BioSoil+ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

Peat soils

In peat layers, the extractable Cu concentration range is more narrow than for mineral soils (Figure 3.4.131). Ninety-five percent of all observations are comprised within 0.2 – 35.1 mg Cu kg^{-1} range and medians vary from 2.5 to 6.4 mg Cu kg^{-1}. Again, the proportion of left censored values (below LOQ) is quite high, ranging from 20 % in H24 to 42 % in H48. So, in the deepest peat layers, Cu concentrations are near detection limit. In that layer, the median value is just 2.8 mg Cu kg^{-1}. Concentrations in peats exceeding 35 mg Cu kg^{-1} are rarely reported.

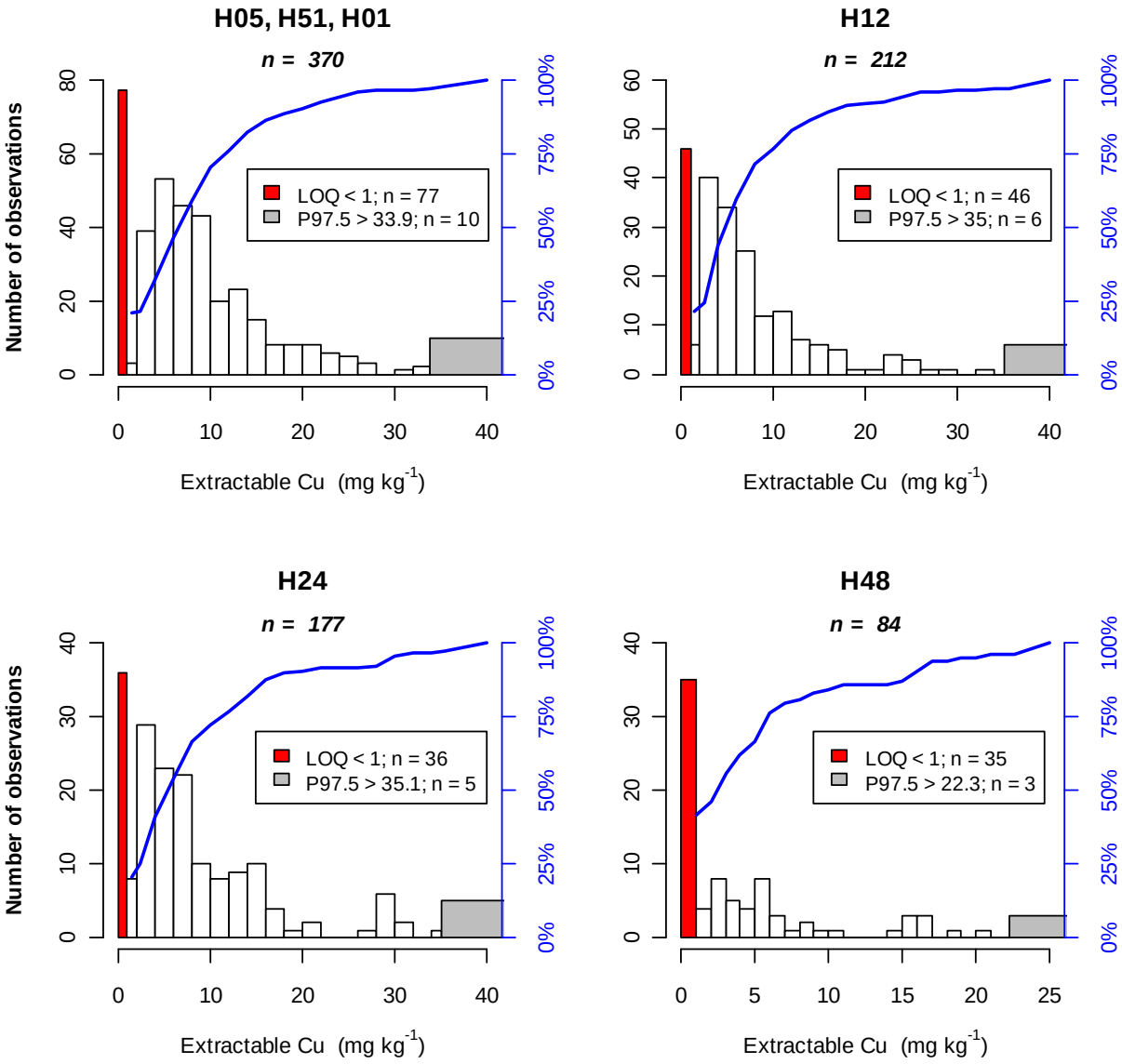


Figure 3.4.131. Absolute and cumulative frequency distribution (in blue) of extractable Cu in peat layers of all BioSoil⁺ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

3.4.10.11 Extractable Lead

An overview of extractable Pb distributions of organic and mineral layers is given in Figure 3.4.132, showing the concentration range, median and quartiles for each layer on a logarithmic scale. Lead concentrations are higher in OFH than in OL layers, and clearly decrease with depth both in peat and mineral soils. Especially in peat layers, a substantial amount of reported values are below LOQ.

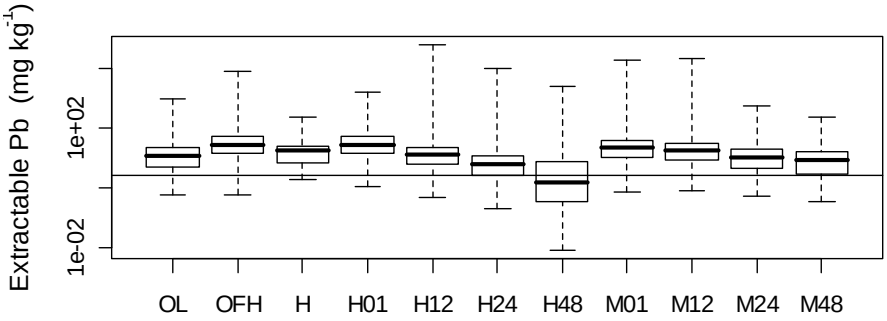


Figure 3.4.132. Box plot of extractable Pb for all layers. The Y-axis is logarithmic. The overall horizontal line indicates the LOQ at 2.5 mg kg^{-1}.

Forest Floor

Lead is known to form strong complexes with organic matter. In forest floors, the Aqua Regia extractable Pb concentration ranges from less than 1.5 mg kg^{-1} to over 1000 mg kg^{-1}. About 12 % of OL and 13 % of OFH observations are below a LOQ of 2.5 mg Pb kg^{-1}. Less than 2.5 % of observations are exceeding 212 mg Pb kg^{-1} (Figure 3.4.133).

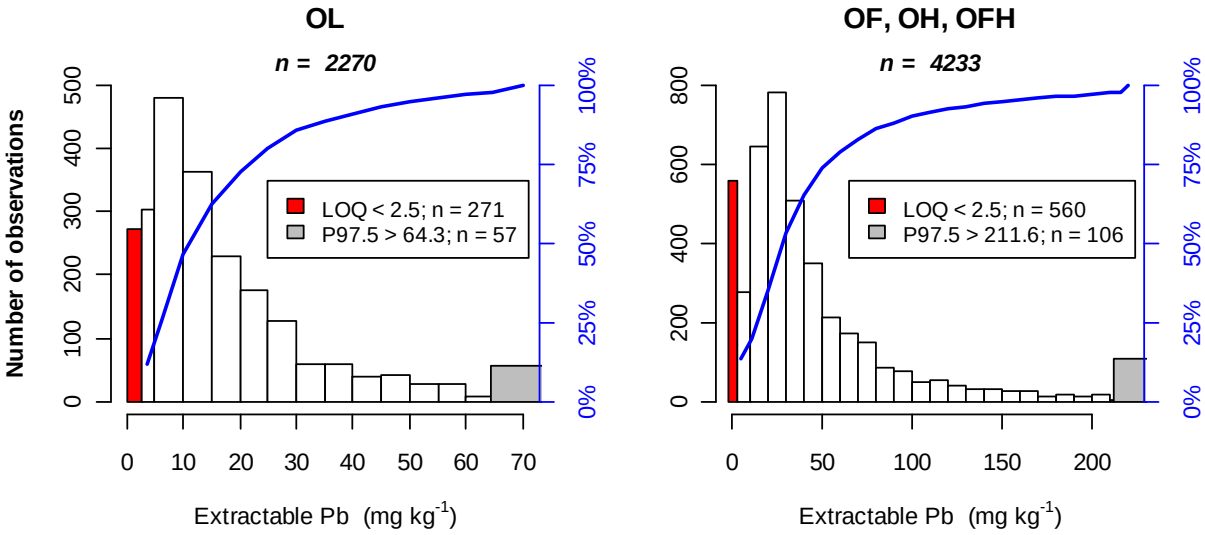


Figure 3.4.133. Absolute and cumulative frequency distribution (in blue) of extractable Pb in OL (left) and OF, OH and OFH layers (right) of all BioSoil^{+} plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

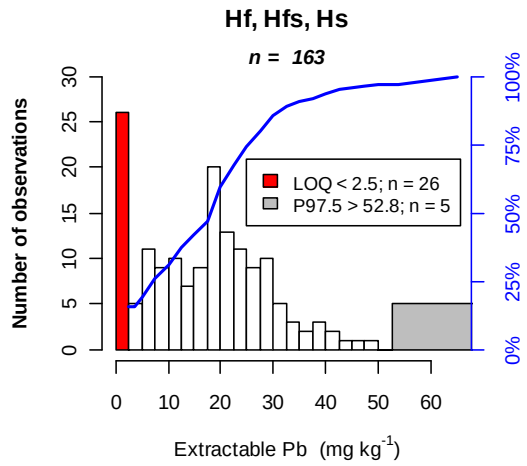


Figure 3.4.134. Absolute and cumulative frequency distribution (in blue) of extractable Pb in hydromorphic forest floor layers of all BioSoil+ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

Almost 16 % of all observations are below LOQ, showing a substantial amount of samples with just traces of Pb, difficult to quantify reliably. A relatively high frequency of observations is situated near the median or the mean (20.1 mg Pb kg^{-1}).

The median Pb concentration is 11.0 mg kg^{-1} in OL layers and 28.1 mg Cu kg^{-1} in OFH layers. The 95 % range for extractable Pb in OL layers is 1.5 – 64.3 mg kg^{-1} whereas in OFH layers it is 3.0 – 212 mg Pb kg^{-1}. Distributions are strongly right skewed, with skewness values of 17 and 26 for OL and OFH respectively. Most frequently, observations are situated within 5 - 10 mg Pb kg^{-1} for OL and 20 - 30 mg Pb kg^{-1} for OFH.

In hydromorphic humus layers, the Pb concentrations are in between those of OL and OFH layers (Figure 3.4.134). The median is 18.1 mg Pb kg^{-1} and 95 % percent of all values range from 3.2 to 52.8 mg Pb kg^{-1}. Few observations are reported above 50 mg Pb kg^{-1}.

Mineral layers

The range observed for extractable Pb concentration in mineral forest soil is between 1 mg kg^{-1} and over 10000 mg kg^{-1}, although the latter is only the case in two Level I plots (11_1596 and 408_8048). All layers in these two plots have elevated Pb concentrations, so the data might be correct. In all, 95-percent of the observations are comprised within 1.2 – 106 mg Pb kg^{-1}. Median values decrease clearly with depth in the order: 21.3 > 17.4 > 10.8 > 8.0 mg Pb kg^{-1} suggesting generally a deposition pathway. The same is observed for the $P_{97.5}$ values, decreasing as follows: 106 > 86.9 > 58.2 > 49.3 mg kg^{-1} as clearly illustrated in Figure 3.4.135.

About 21 % of the M48 observations are below LOQ whereas 7 % in the topsoil. For all depths, the 5 - 10 mg Pb kg^{-1} class has highest frequency, when left-censored values are not considered.

More statistical measures are tabularised in Annex II.

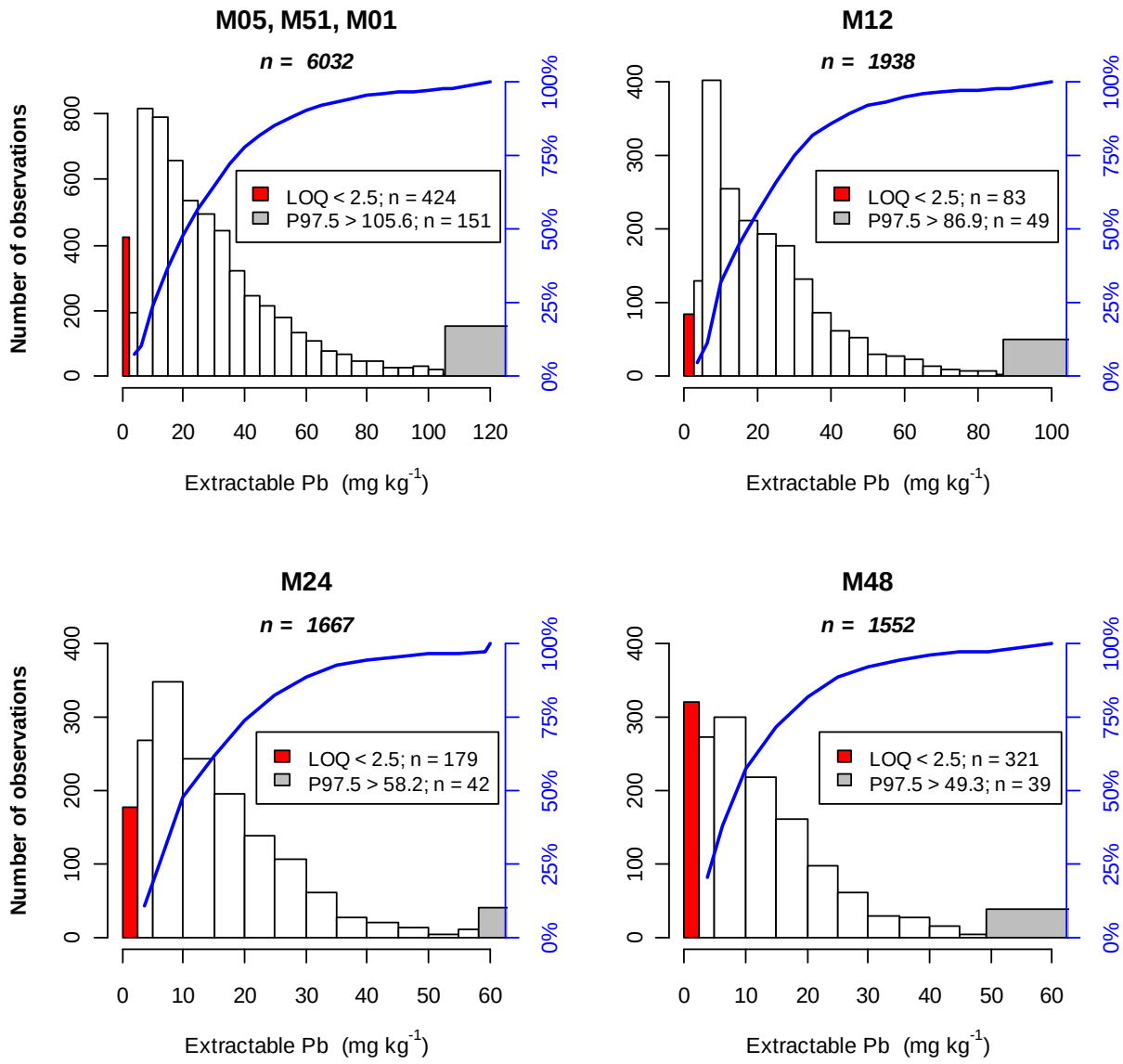


Figure 3.4.135. Absolute and cumulative frequency distribution (in blue) of extractable Pb in mineral layers of all BioSoil+ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

Peat soils

Like in mineral soils, the average extractable Pb concentrations decrease also with depth in Histosols. Notwithstanding fewer observations, the range is slightly wider compared to mineral soils.Ninety-five percent of all observations are comprised within 0.02 – 246 mg Pb kg^{-1} (Figure 3.4.136). The decrease of the median values with depth is: 26.9 > 12.5 > 6.0 > 1.6 mg Pb kg^{-1}. For M01, M12 and M24 layers, the proportion of values below LOQ is ~20 %, and 51 % in H48. So, half of these M48 observations are difficult to quantify reliably with standard analytical techniques.

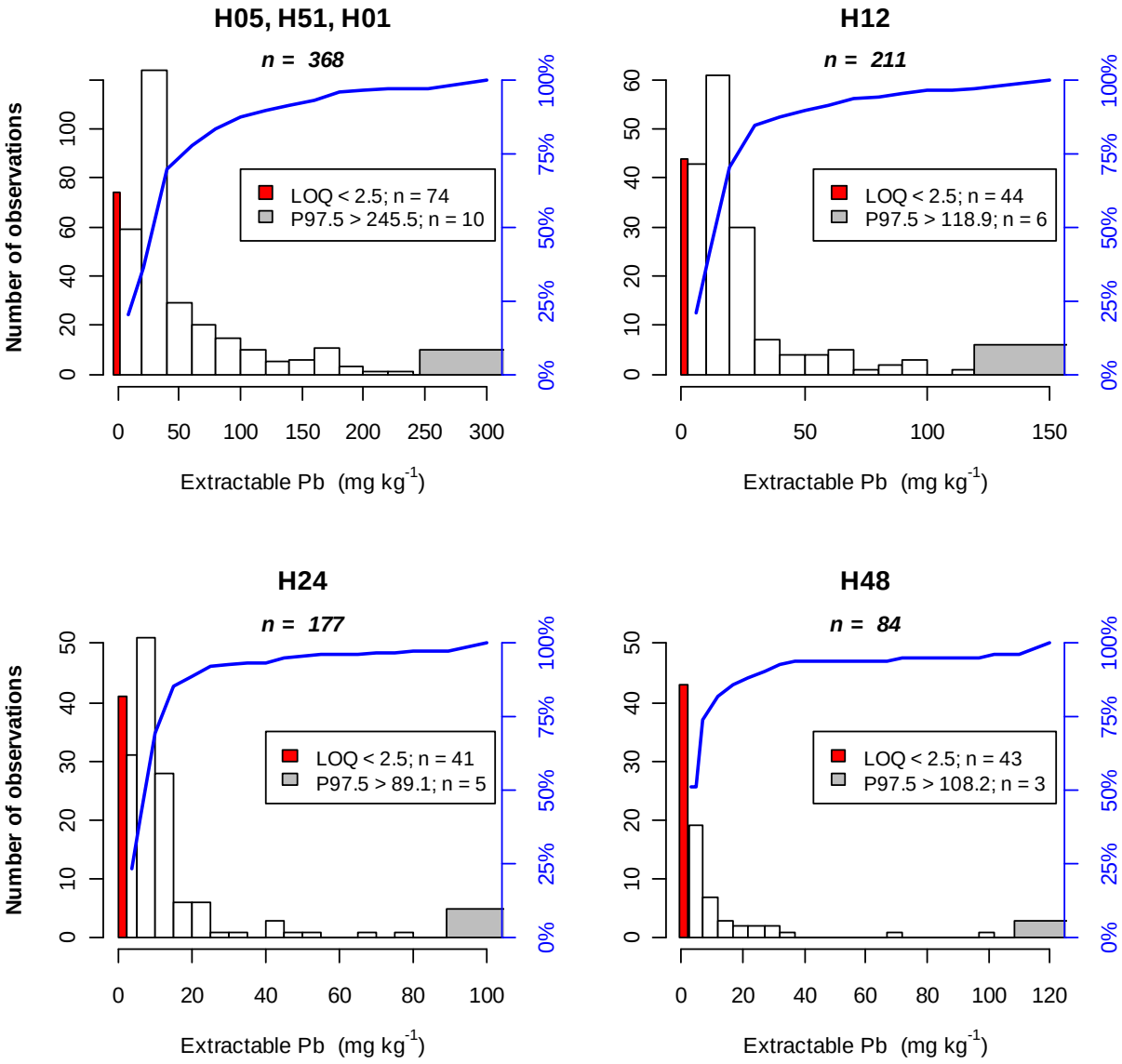


Figure 3.4.136. Absolute and cumulative frequency distribution (in blue) of extractable Pb in peat layers of all BioSoil⁺ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

3.4.10.12 Extractable Nickel

The organic and mineral layers' distributions of extractable Ni concentration is given in Figure 3.4.137. Concentrations are greater in mineral compared to peat layers. Ni also accumulates in the OFH layer. For each layer, a certain proportion of observations is below LOQ and this is most pronounced for the peat layers.

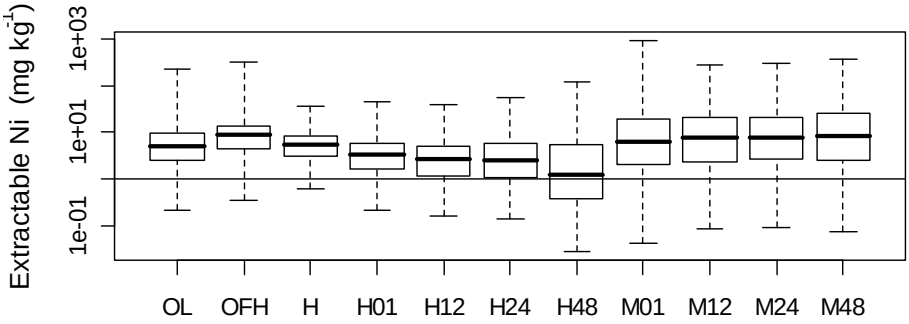


Figure 3.4.137. Box plot of extractable Ni for all layers. The Y-axis is logarithmic. The overall horizontal line indicates the LOQ at 1 mg kg^{-1}.

Forest Floor

In forest floors, the Aqua Regia extractable Ni concentration ranges from less than 1 mg kg^{-1} to maximally 320 mg Ni kg^{-1}, though less than 2.5 % of the observations exceed 45.6 mg Ni kg^{-1}. The average limit of quantification (LOQ) is set at 1.5 mg Ni kg^{-1}. About 8 % of OL and 16 % of OFH observations are below that LOQ (Figure 3.4.138).

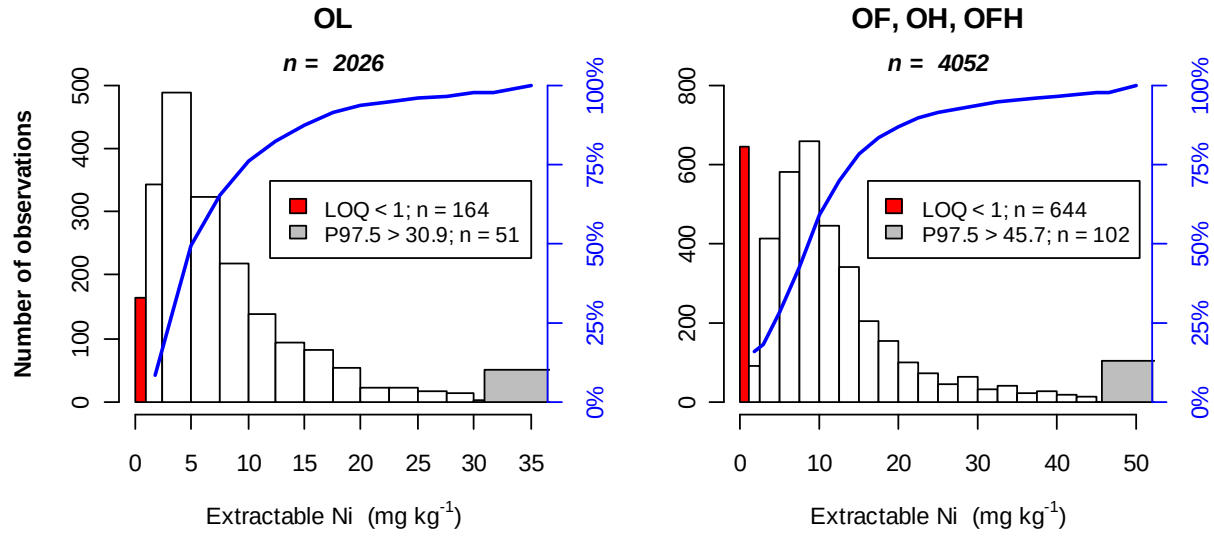


Figure 3.4.138. Absolute and cumulative frequency distribution (in blue) of extractable Ni in OL (left) and OF, OH and OFH layers (right) of all BioSoil^{+} plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

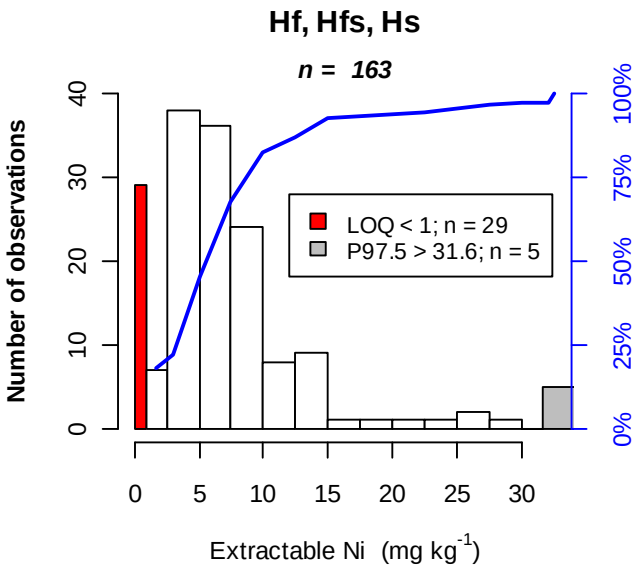


Figure 3.4.139. Absolute and cumulative frequency distribution (in blue) of extractable Ni in hydromorphic forest floor layers of all BioSoil+ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

The median Ni concentration is 5.2 mg kg^{-1} in OL layers and 8.7 mg Ni kg^{-1} in OFH layers. The 95 % range for extractable Ni in OL layers is 0.8 – 30.9 mg kg^{-1} whereas in OFH layers it is 1.3 – 45.6 mg Ni kg^{-1}. Distributions are right skewed, with skewness values of 7.6 and 6.1 for OL and OFH respectively. Most frequently, observations are situated within 2.5 - 5 mg Ni kg^{-1} for OL and 7.5 - 10 mg Ni kg^{-1} for OFH.

In hydromorphic humus layers, the Ni concentrations are in between those of OL and OFH layers (Figure 3.4.139). The median is 5.6 mg Ni kg^{-1} and 95 % of all values range from 1.1 to 31.6 mg Ni kg^{-1}. Few observations are reported above 30 mg Ni kg^{-1}.

Almost one fifth of all observations are below LOQ, showing a substantial amount of samples with just traces of Ni, difficult to quantify reliably. Highest frequency of observations is situated between 2.5 and 7.5 mg Ni kg^{-1}.

Mineral layers

The range observed for extractable Ni concentration in mineral forest soils is between 0.5 mg kg^{-1} and ~920 mg kg^{-1}. Overall, 95 % of the observations are comprised within 0.4 – 79.3 mg Ni kg^{-1} range. Unlike for Pb, median values do not decrease with depth but remain in a small range of 6.4 – 8.3 mg kg^{-1}. The same holds true for the $P_{97.5}$ values, varying between 60.1 and 79.3 mg Ni kg^{-1} (Figure 3.4.140). Between 9.2 and 14.7 % of the observations are below LOQ. For all depths, the 0 - 5 mg Ni kg^{-1} class has highest frequency. A similar distribution pattern is observed for all depths. More statistical measures are tabularised in Annex II.

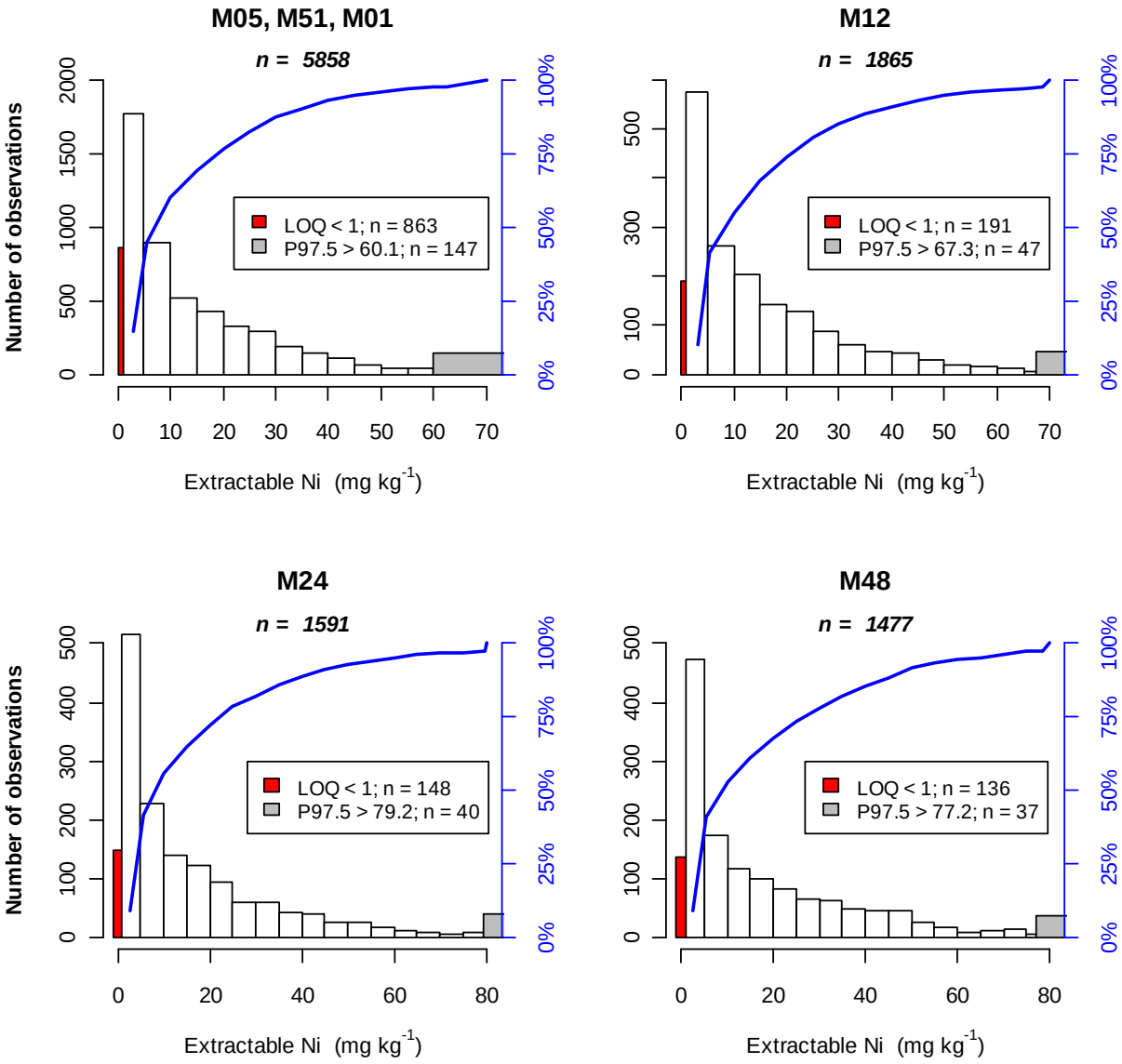


Figure 3.4.140. Absolute and cumulative frequency distribution (in blue) of extractable Ni in mineral layers of all BioSoil⁺ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

Peat soils

Extractable Ni concentrations are substantially lower in peat than in mineral layers (Figure 3.4.141). Ninety-five percent of all observations are comprised within 0.06 – 25.1 mg Ni kg^{-1} bin. A great part of the samples has low Ni concentrations near the detectable capabilities of the standard instruments. For H01 layers, 22 % is below LOQ and in H48 layers this has raised to 46 %. Apart from those left censored background values, the most frequent class is 2 - 4 mg Ni kg^{-1} for all layers but H48.

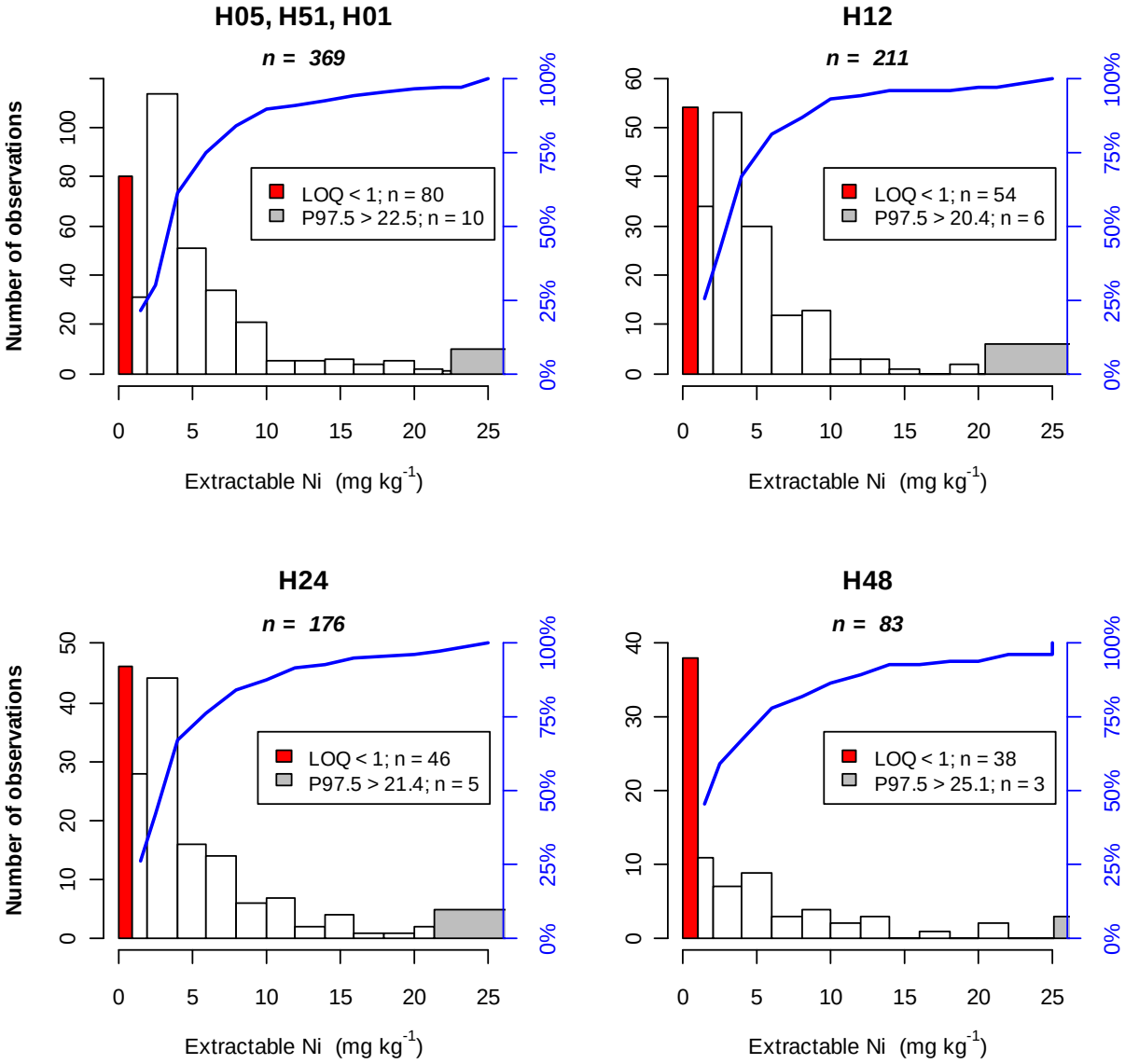


Figure 3.4.141. Absolute and cumulative frequency distribution (in blue) of extractable Ni in peat layers of all BioSoil⁺ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

3.4.10.13 Extractable Chromium

The extractable Cr concentration for the organic and mineral layers is given in Figure 3.4.142, showing the concentration range, median and quartiles for each layer according to a logarithmic scale (base 10). Concentration levels are substantially greater in mineral compared to organic layers. Peat layers have the lowest Cr concentrations and a high proportion of these analyses were reported as left censored.

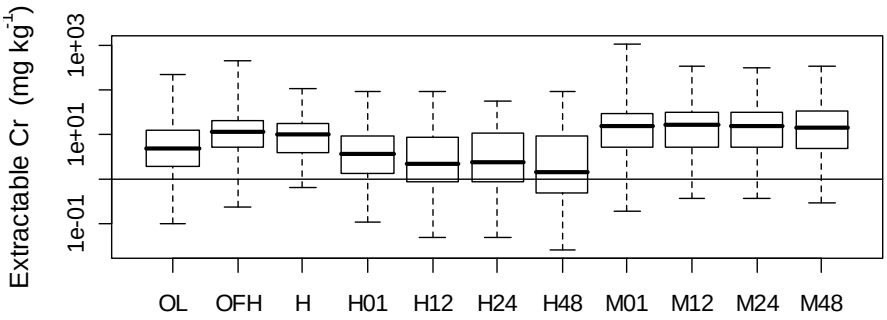


Figure 3.4.142. Box plot of extractable Cr for all layers. The Y-axis is logarithmic. The overall horizontal line indicates the LOQ at 1 mg kg^{-1}.

Forest Floor

The Aqua Regia extractable Cr concentration in forest floors ranges from less than 1 mg kg^{-1} to maximally 464 mg kg^{-1}, though less than 2.5 % of the observations exceed 91.6 mg Cr kg^{-1}. About 12 % of OL and 15 % of OFH observations are below the LOQ of 1 mg kg^{-1} (Figure 3.4.143).

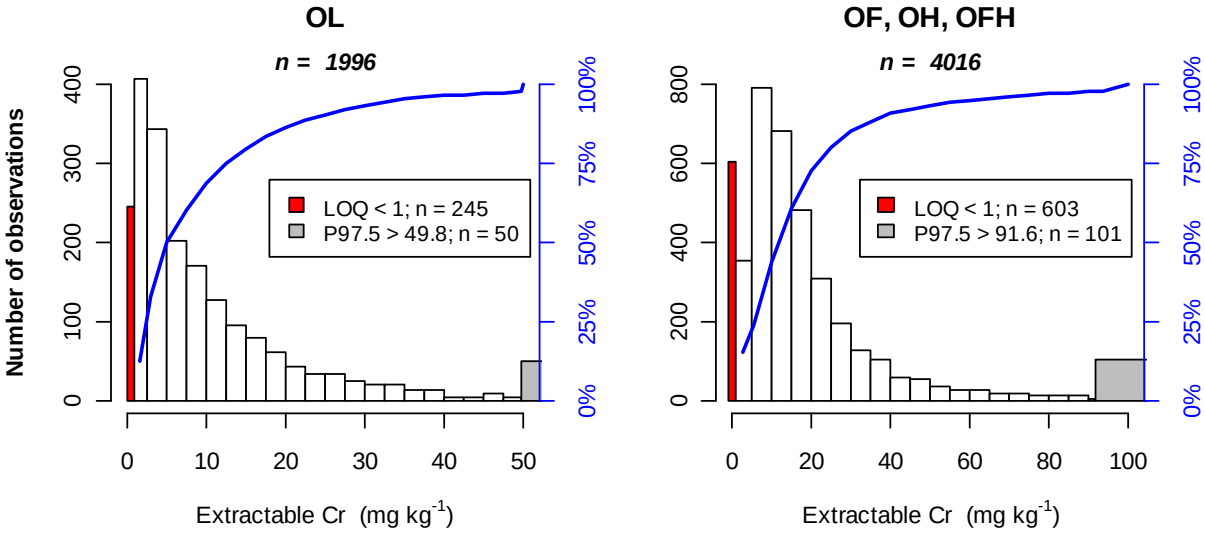


Figure 3.4.143. Absolute and cumulative frequency distribution (in blue) of extractable Cr in OL (left) and OF, OH and OFH layers (right) of all BioSoil^{+} plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

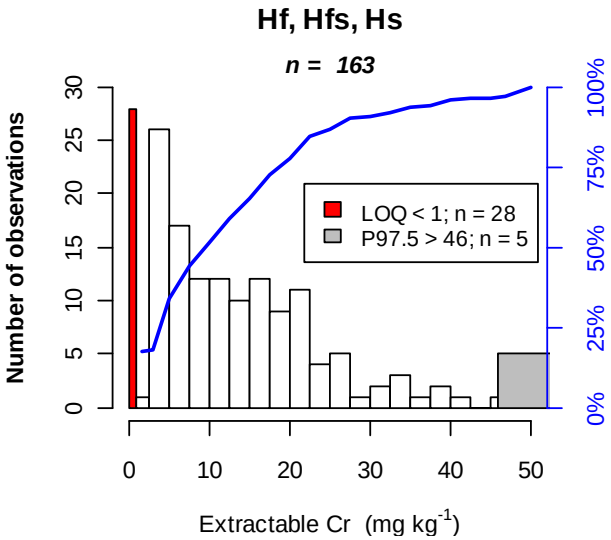


Figure 3.4.144. Absolute and cumulative frequency distribution (in blue) of extractable Cr in hydromorphic forest floor layers of all BioSoil+ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

The median Cr concentration is 5.1 mg kg^{-1} in OL layers and 11.9 mg Cr kg^{-1} in OFH layers. The 95 % range for extractable Cr in OL layers is 0.5 – 49.8 mg kg^{-1} whereas in OFH layers it is 1.3 – 91.6 mg Cr kg^{-1}. Distributions are right skewed, with skewness values of 5.30 and 5.55 for OL and OFH respectively. Most frequently, observations are situated in the 1 - 2.5 mg Cr kg^{-1} bin for OL and 5 - 10 mg Cr kg^{-1} for OFH.

In hydromorphic humus layers, the Cr concentrations are in between those of OL and OFH layers. About 17 % of the observations are below LOQ (Figure 3.4.144). The median is 9.8 mg Cr kg^{-1} and 95 % percent of all values range from 1.24 to 46.1 mg Cr kg^{-1}.

Mineral layers

Extractable Cr concentration in mineral forest soils ranges between ~0.5 mg kg^{-1} and 1067 mg kg^{-1}. Overall, 95 % of the observations are comprised within 1.2 – 80.7 mg Cr kg^{-1}. Median values of all depths show little variation and vary between 14.5 and 17.3 mg Cr kg^{-1}, whereas $P_{97.5}$ values are all close to 80 mg kg^{-1} (Figure 3.4.145). Between 3.3 and 7.3 % of the observations are below LOQ. For all depths, highest frequencies of observations are found below 10 mg Cr kg^{-1}. A slight bimodal distribution pattern, all with second modus between 20 - 25 mg Cr kg^{-1} may be observed for layers below 10 cm of depth. More statistical measures are tabularised in Annex II.

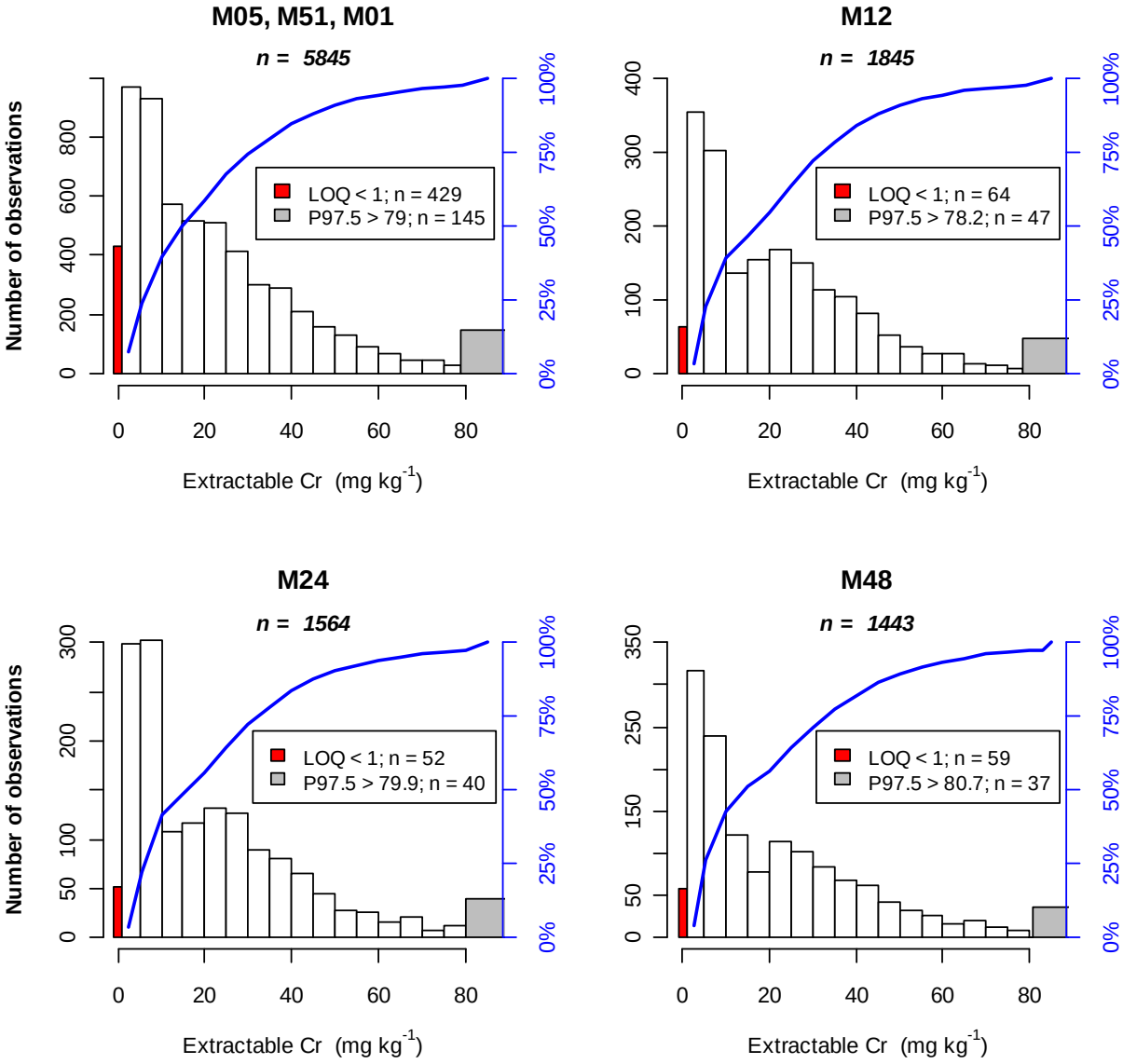


Figure 3.4.145. Absolute and cumulative frequency distribution (in blue) of extractable Cr in mineral layers of all BioSoil⁺ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

Peat soils

Extractable Cr concentrations are substantially lower in peat than in mineral layers (Figure 3.4.146). Ninety-five percent of all observations are comprised within 0.06 – 57.6 mg Cr kg^{-1}. Between 22 and 50 % of the samples have Cr concentrations below LOQ and are statistically treated as left censored. Apart from these background values, scattered observations for all layers are found up to 92 mg Cr kg^{-1}. Median values range between 1.5 and 3.6 mg Cr kg^{-1}.

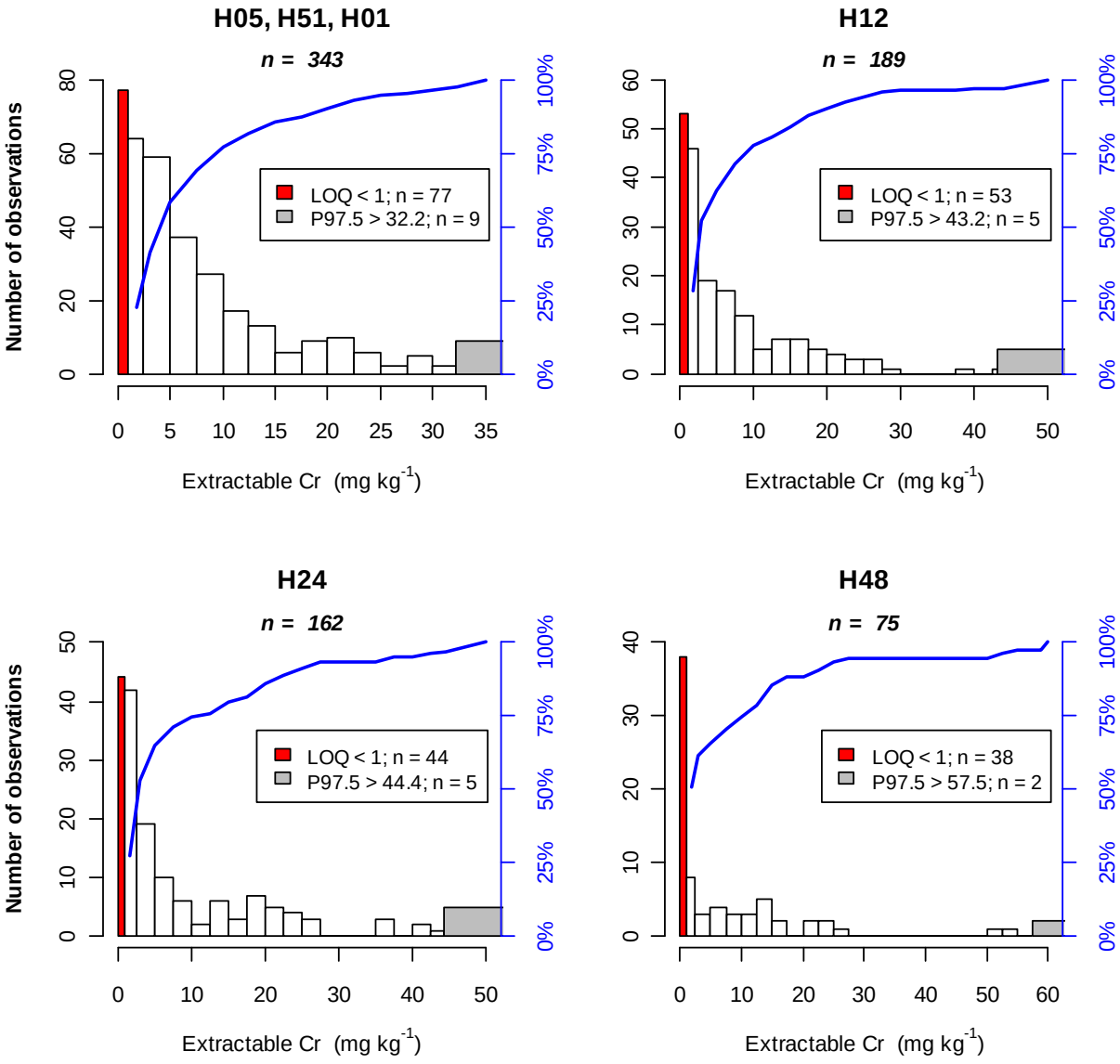


Figure 3.4.146. Absolute and cumulative frequency distribution (in blue) of extractable Cr in peat layers of all BioSoil⁺ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

3.4.10.14 Extractable Zinc

Figure 3.4.147 shows the concentration range, median and quartiles for extractable Zn concentration for all organic and mineral layers. Highest levels are found in terrestrial forest floors, followed by mineral soil layers which have similar ranges for all depths. Conversely, Zn ranges are different among the peat layers depths. Also the highest number of left censored values are observed for those peat layers.

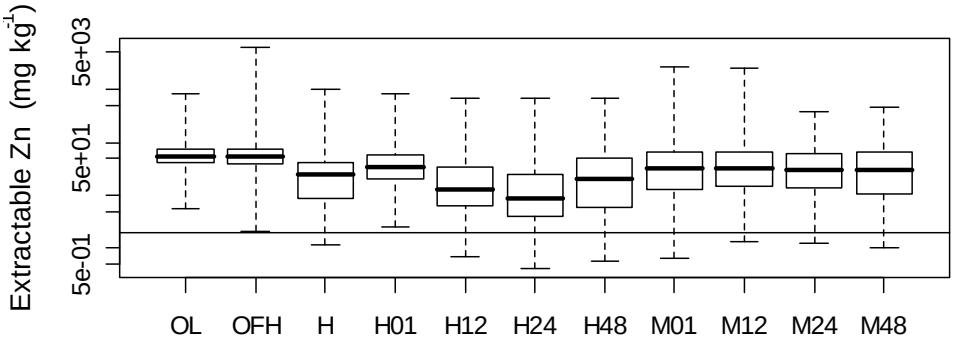


Figure 3.4.147. Box plot of extractable Zn for all layers. The Y-axis is logarithmic. The overall horizontal line indicates the LOQ at 2 mg kg^{-1}.

Forest Floor

Aqua Regia extractable Zn concentration in forest floors ranges from less than 5 mg kg^{-1} to 6151 mg Zn kg^{-1} at a heavily polluted site. However, less than 2.5 % of all observations exceed 172 mg Zn kg^{-1}. At the lower end, very few observations are below the LOQ of 2 mg Zn kg^{-1}, none for OL and 1.3 % of OFH layers (Figure 3.4.148). Hence Zn is easily quantifiable in forest floors in contrast to other trace metals. The median Zn concentration is 55 mg kg^{-1} in OL layers and 53.1 mg Zn kg^{-1} in OFH layers. The 95 % range for extractable Zn in OL layers is 15.8 - 172 mg kg^{-1} whereas in OFH layers this is 14 – 161 mg Zn kg^{-1}. Distributions are unimodal and near normal, skewed to the right (skewness values of 5.97 and 40.3 for OL and OFH respectively). Most frequently, observations are situated within the 40 - 50 mg Zn kg^{-1} class, both for OL and OFH layers. Estimated means for both distributions are 64.7 mg kg^{-1}.

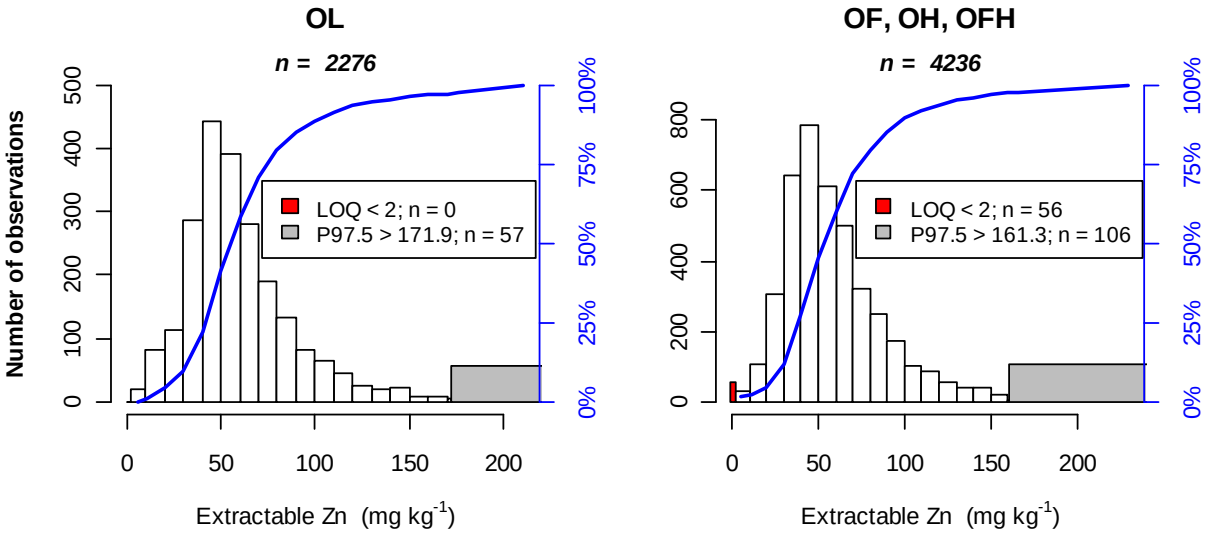


Figure 3.4.148. Absolute and cumulative frequency distribution (in blue) of extractable Zn in OL (left) and OF, OH and OFH layers (right) of all BioSoil+ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

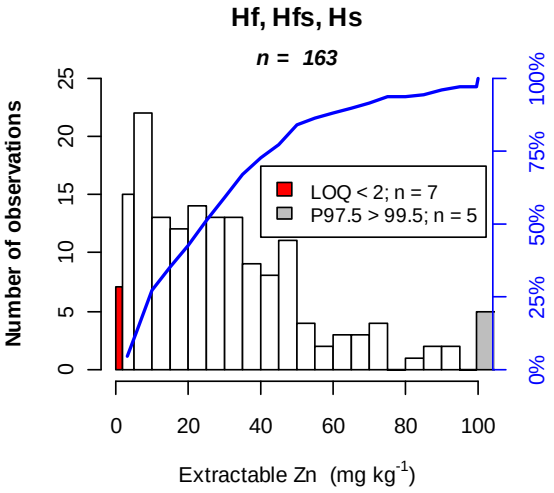


Figure 3.4.149. Absolute and cumulative frequency distribution (in blue) of extractable Zn in hydromorphic forest floor layers of all BioSoil+ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

The unimodal distribution pattern is not recognised anymore in hydromorphic humus layers (Figure 3.4.149). About 4 % of the observations are below LOQ, while less than 2.5 % of the measured values exceed 100 mg Zn kg^{-1}. The median (24 mg Zn kg^{-1}) is less than half that of the terrestrial humus forms whereas 95 % percent of all values range from 2.4 to 99.8 mg Zn kg^{-1}, with the majority below 50 mg Zn kg^{-1}.

Mineral layers

Extractable Zn concentration in mineral forest soils ranges from ~0.5 mg kg^{-1} to 2680 mg kg^{-1}. Overall, 95-percent of the observations are comprised within 2.8 – 166 mg Zn kg^{-1}. Median values of all depths show little variation and vary between 30.9 and 33.0 mg Zn kg^{-1}, whereas $P_{97.5}$ values vary from 127 to 166 mg kg^{-1} (Figure 3.4.150). Less than 3 % of all observations are below LOQ. In the upper 40 cm of mineral soil, the 10 - 20 mg Zn kg^{-1} is most frequently observed whereas 2 - 10 mg Zn kg^{-1} from 40 to 80 cm. More statistical measures are tabularised in Annex II.

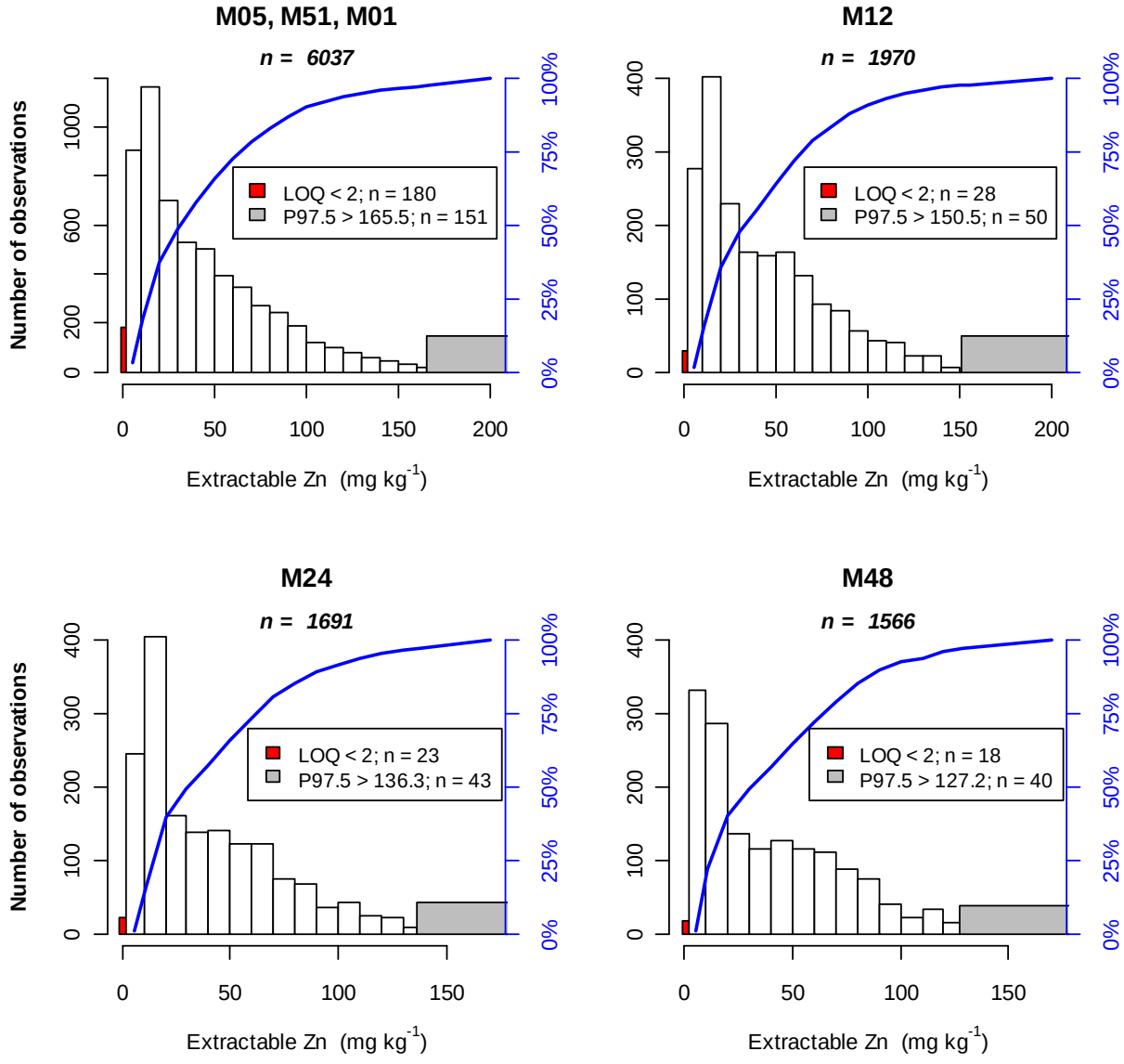


Figure 3.4.150. Absolute and cumulative frequency distribution (in blue) of extractable Zn in mineral layers of all BioSoil+ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

Peat soils

The extractable Zn concentrations of separate peat soils layers are more variable than for mineral soils. Ninety-five percent of all observations are comprised within 0.8 – 288 mg Zn kg^{-1} (Figure 3.4.151). The median is higher in the 0 - 10 cm topsoil layer (33.6 mg Zn kg^{-1}) compared to the deeper layers (less than 20 mg Zn kg^{-1}). In these deeper layers the proportion of left censored values increase, from 2.5 % in H12, over 5 % in H24 to 9 % in H48.

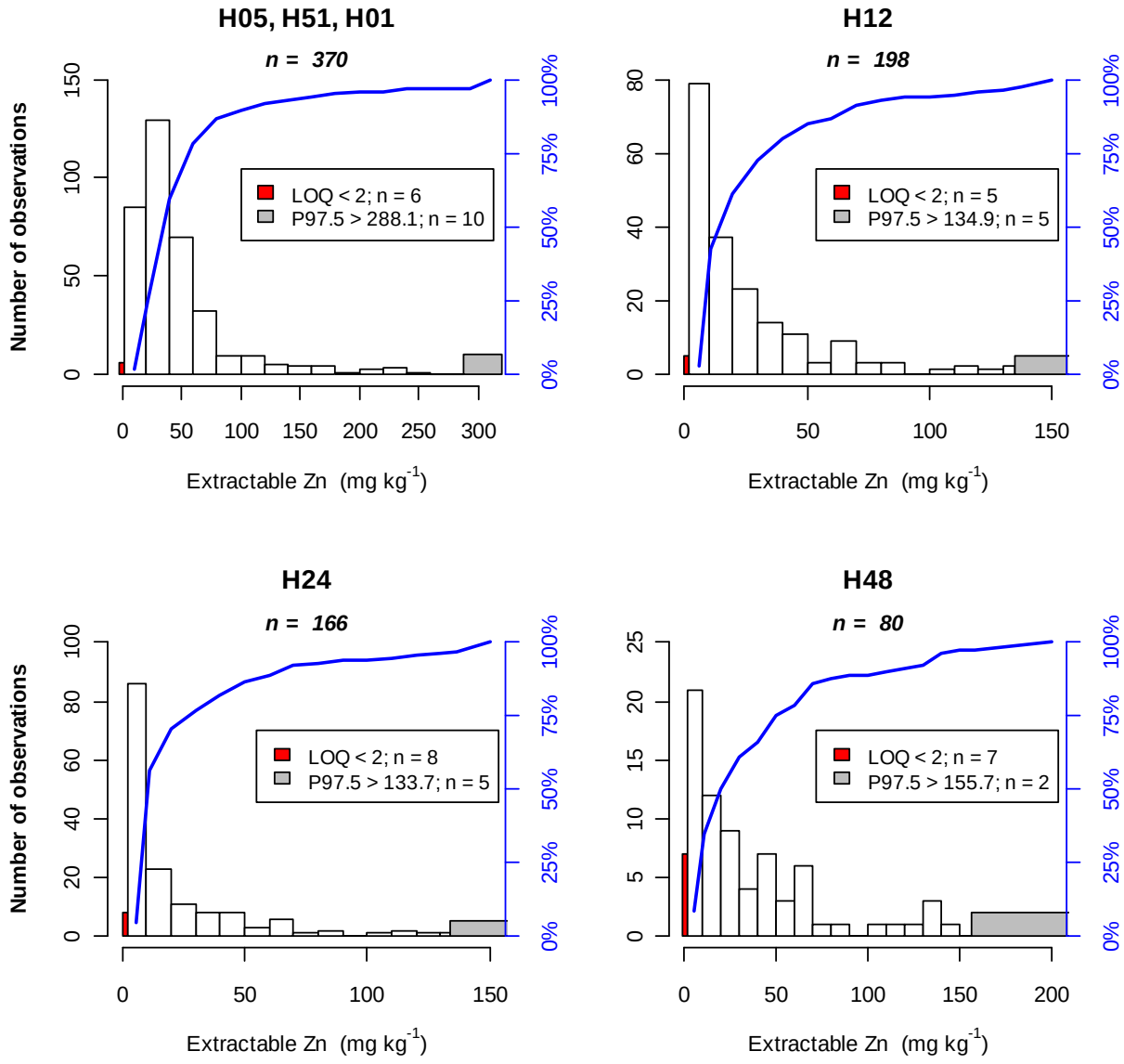


Figure 3.4.151. Absolute and cumulative frequency distribution (in blue) of extractable Zn in peat layers of all BioSoil⁺ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

3.4.10.15 Extractable Cadmium

A synthesis of the extractable Cd distributions for the organic and mineral layers is given in Figure 3.4.152, showing the concentration range, median and quartiles for each layer according to a logarithmic scale (base 10). Censored statistics reveal that most box plots are mainly situated below the LOQ of 0.5 mg Cd kg^{-1} with estimated medians around 0.1 mg kg^{-1} and even lower for peat layers. So most of the Cd concentrations are not reliably quantifiable by most labs but these concentrations are also not ecotoxicologically relevant (See Volume II of this report).

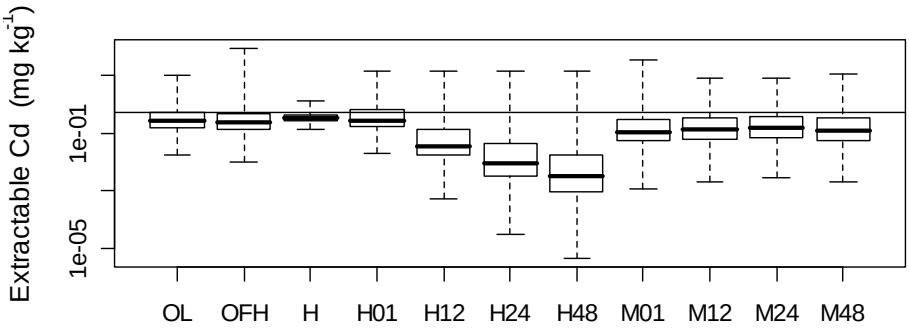


Figure 3.4.152. Box plot of extractable Cd for all layers. The Y-axis is logarithmic. The overall horizontal line indicates the LOQ at 0.5 mg kg^{-1}.

Forest Floor

Aqua Regia extractable Cd concentration in forest floors ranges from less than 0.05 mg kg^{-1} (50 ppb) to 84 mg Cd kg^{-1} in an extreme case. From Figure 3.4.153 it is immediately clear that most observations (> 74%) are in the red bin, i.e. below the averaged reported LOQ of 0.5 mg Cd kg^{-1}. Hence, most labs are unable to quantify accurately the low background levels commonly found in European forest floors. Based on ROS methods applied to these predominantly left censored data, a quarter of the data are estimated to have less than 0.05 mg Cd kg^{-1} in OL layers and 0.04 mg Cd kg^{-1} in OFH layers. Median values are 0.25 and 0.23 mg Cd kg^{-1}, respectively. Less than 2.5 % of all samples exceed 1.6 mg Cd kg^{-1}, which may be considered as polluted (see Volume II).

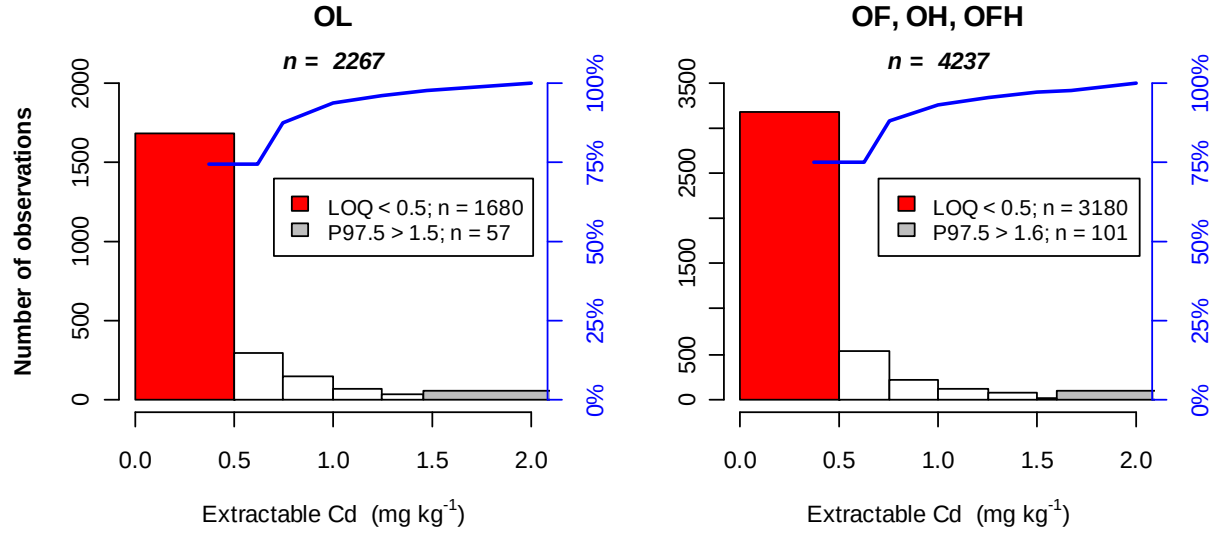


Figure 3.4.153. Absolute and cumulative frequency distribution (in blue) of extractable Cd in OL (left) and OF, OH and OFH layers (right) of all BioSoil+ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

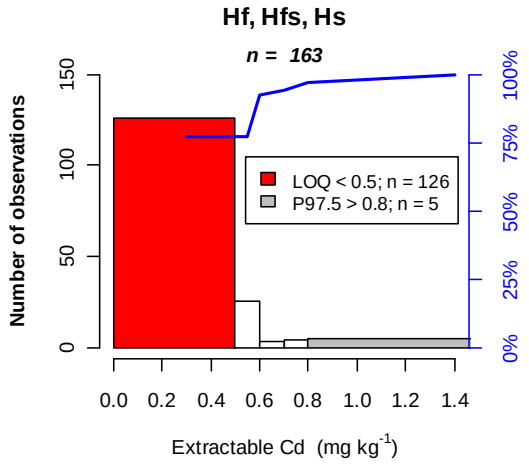


Figure 3.4.154. Absolute and cumulative frequency distribution (in blue) of extractable Cd in hydromorphic forest floor layers of all BioSoil+ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

Similar statistics are found for the hydromorphic humus layers (Figure 3.4.154). About 77 % of all measurements are below 0.5 mg kg^{-1}, ~12 % in the 0.5 - 0.6 mg Cd kg^{-1} class and less than 2.5 % exceeds 0.8 mg Cd kg^{-1}. The median (i.e. 0.33 mg Cd kg^{-1}) is similar those of OL and OFH layers. More statistical measures are tabularised in Annex II.

Mineral layers

In mineral forest soils, extractable Cd concentration ranges from ppb level (<0.01 mg Cd kg^{-1}) to 35.5 mg Cd kg^{-1} at most. Overall, 95 % of the observations are comprised within 0.01 – 2.53 mg Cd kg^{-1} and over 84 % of them are below LOQ as shown in Figure 3.4.155. ROS estimated median values of all depths show little variation, ranging from 0.11 to 0.14 mg Cd kg^{-1}, whereas $P_{97.5}$ values vary from 1.9 to 2.53 mg kg^{-1}. More statistical measures are tabularised in Annex II.

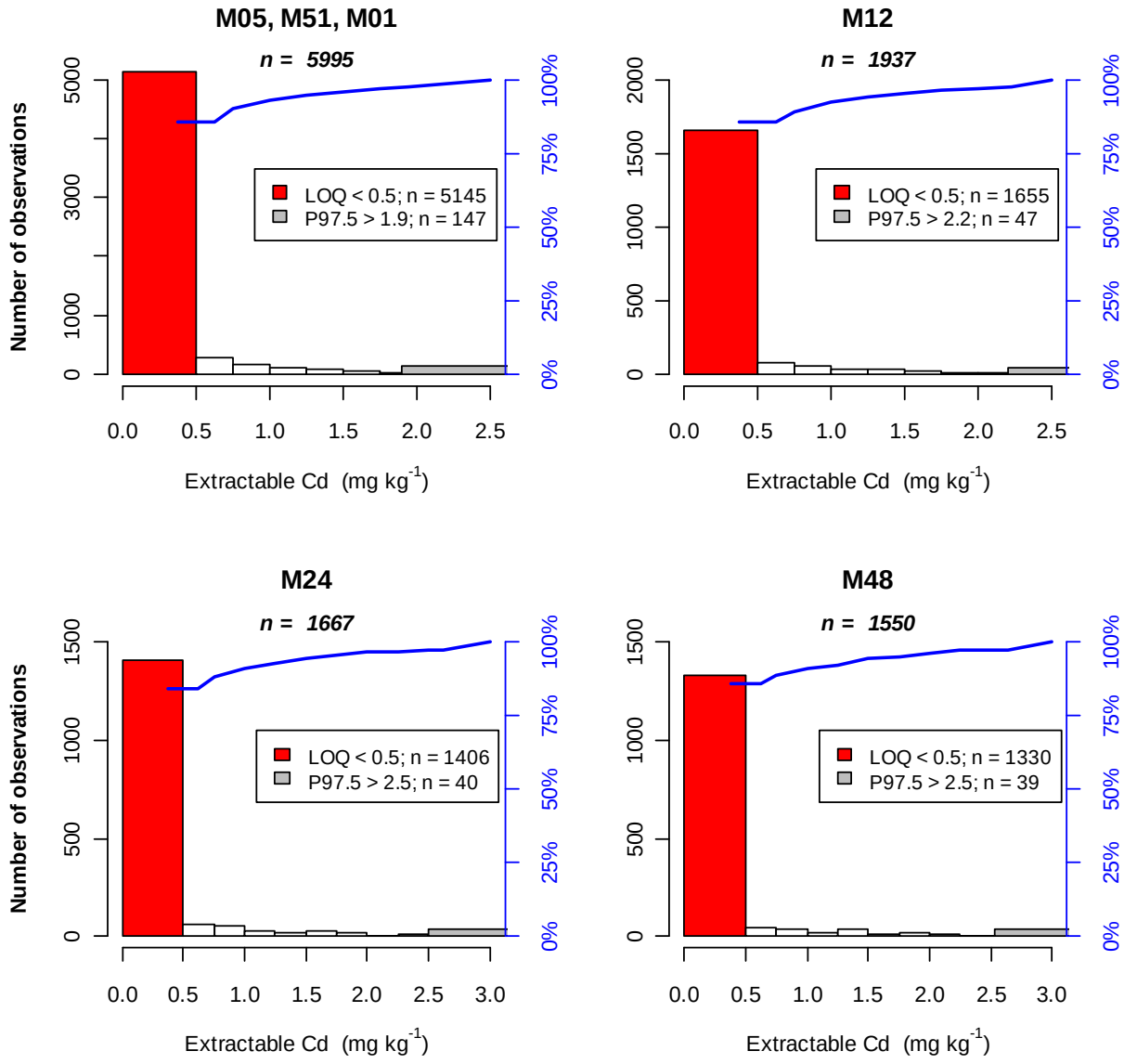


Figure 3.4.155. Absolute and cumulative frequency distribution (in blue) of extractable Cd in mineral layers of all BioSoil+ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

Peat soils

The extractable Cd concentrations in peat layers are estimated to be even lower than mineral soils. Ninety-five percent of all observations are below 2.2 mg Cd kg^{-1} (Figure 3.4.156). The ROS estimated median decreases substantially with depth: 0.27 > 0.04 > 0.01 > 0.004 mg Cd kg^{-1} and also the proportion of left censored values increases from 65 in H01, over 87 % in H12 to over 91 % in H24 and H48. Hence for these deeper peat soil layers, less than 10 % of the samples had quantifiable Cd contents. More precise techniques are required if accurate concentrations are to be determined. For ecotoxicological research these low levels are considered irrelevant.

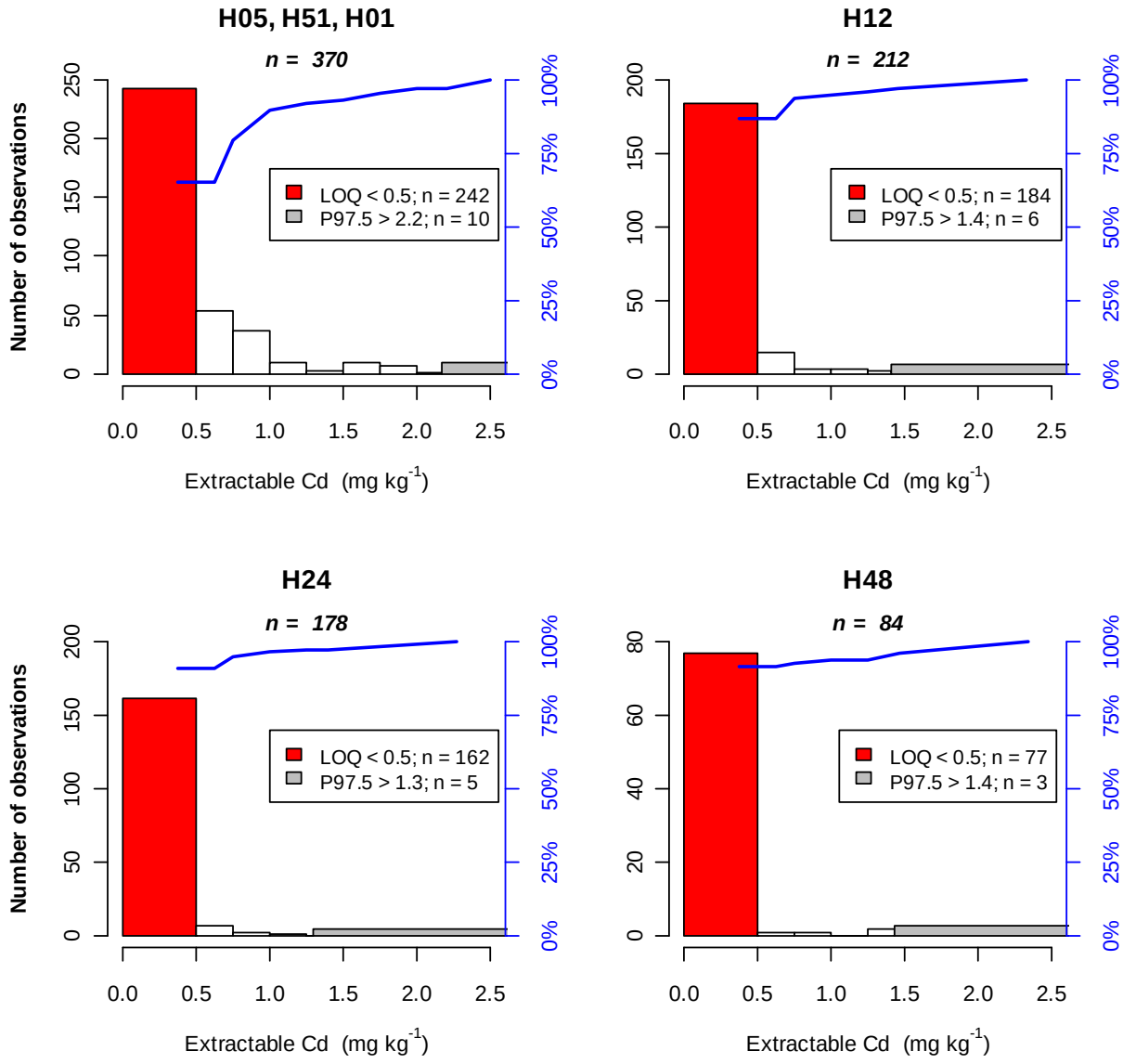


Figure 3.4.156. Absolute and cumulative frequency distribution (in blue) of extractable Cd in peat layers of all BioSoil+ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

3.4.10.16 Extractable Mercury

Extractable Hg is just as Cd present in trace concentrations. These are presented for the organic and mineral layers in Figure 3.4.157, showing the concentration range, median and quartiles for each layer according to a logarithmic scale (base 10). In contrast to Cd, Hg can be measured more reliably thanks to dedicated Hg analysers. In general, mercury levels are highest in forest floors and mineral soils, and least in peat layers. Still a quarter to half of the observations are below LOQ.

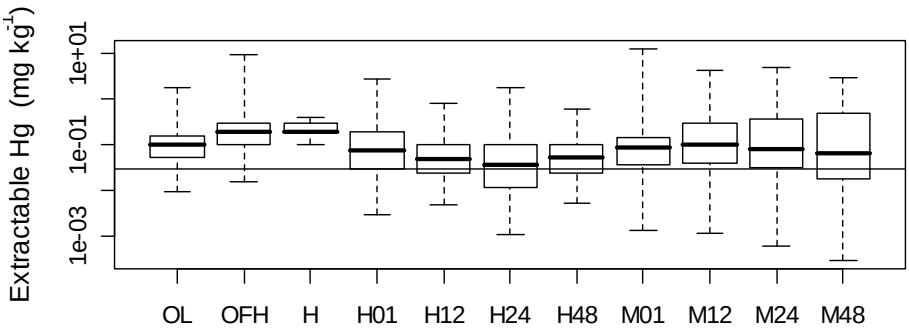


Figure 3.4.157. Box plot of extractable Hg for all layers. The Y-axis is logarithmic. The overall horizontal line indicates the LOQ at 0.03 mg kg^{-1}.

Forest Floor

Aqua Regia extractable Hg concentration in forest floors is generally very low, ranging from less than quantification limit, which is set to 0.3 mg Hg kg^{-1}, to maximally 9.5 mg Hg kg^{-1}. The histogram in Figure 3.4.158 shows that 23 and 13 % of all observations are below this quantification limit. Less than 2.5 % of observations are exceeding 0.4 mg Hg kg^{-1} in OL layers and 0.8 mg Hg kg^{-1} in OFH layers.

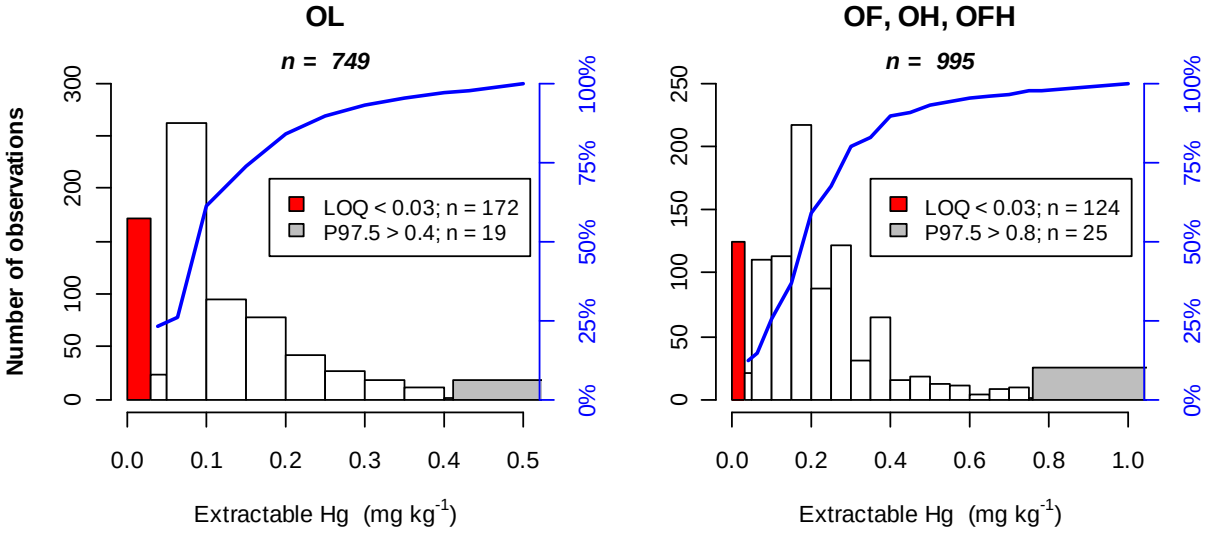


Figure 3.4.158. Absolute and cumulative frequency distribution (in blue) of extractable Hg in OL (left) and OF, OH and OFH layers (right) of all BioSoil^{+} plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

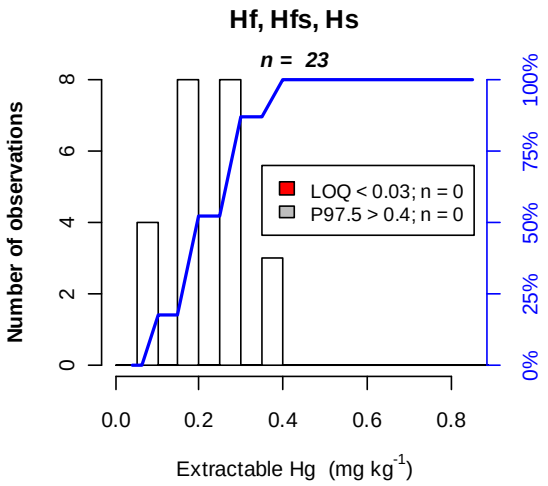


Figure 3.4.159. Absolute and cumulative frequency distribution (in blue) of extractable Hg in hydromorphic forest floor layers of all BioSoil+ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

Highest frequencies are found for the 0.05 - 0.1 mg Hg kg^{-1} and 0.15 – 0.2 mg Hg kg^{-1} bin for OL and OFH layers, respectively. Median values could be somewhere around 0.1 and 0.2 mg Hg kg^{-1} for OL and OFH.

For water saturated forest floors (H layers) illustrated in Figure 3.4.159, no values above 0.4 mg Hg kg^{-1} were found, but only 23 observations were reported for these layers. None of them are below LOQ.

Mineral layers

In mineral forest soils, extractable Hg concentration ranges from below LOQ (i.e. 0.03 mg Hg kg^{-1}) to 12.2 mg kg^{-1} at most. Overall, 95-percent of the observations are comprised within 0.007 to 1.2 mg Hg kg^{-1}. Hence, as shown in Figure 3.4.160, a large majority of the observations is situated in the part per billion (ppb) range and requires therefore precise analytical instruments. ROS estimated statistics indicate median values varying from 0.067 to 0.1 mg Hg kg^{-1} and means between 0.195 and 0.426 mg Hg kg^{-1}. Highest frequency of observation is found in the 0.03 – 0.1 mg Hg kg^{-1} interval and this frequency strongly decreases in the next classes till about 0.5 mg Hg kg^{-1} above which the frequency remains more or less stable.

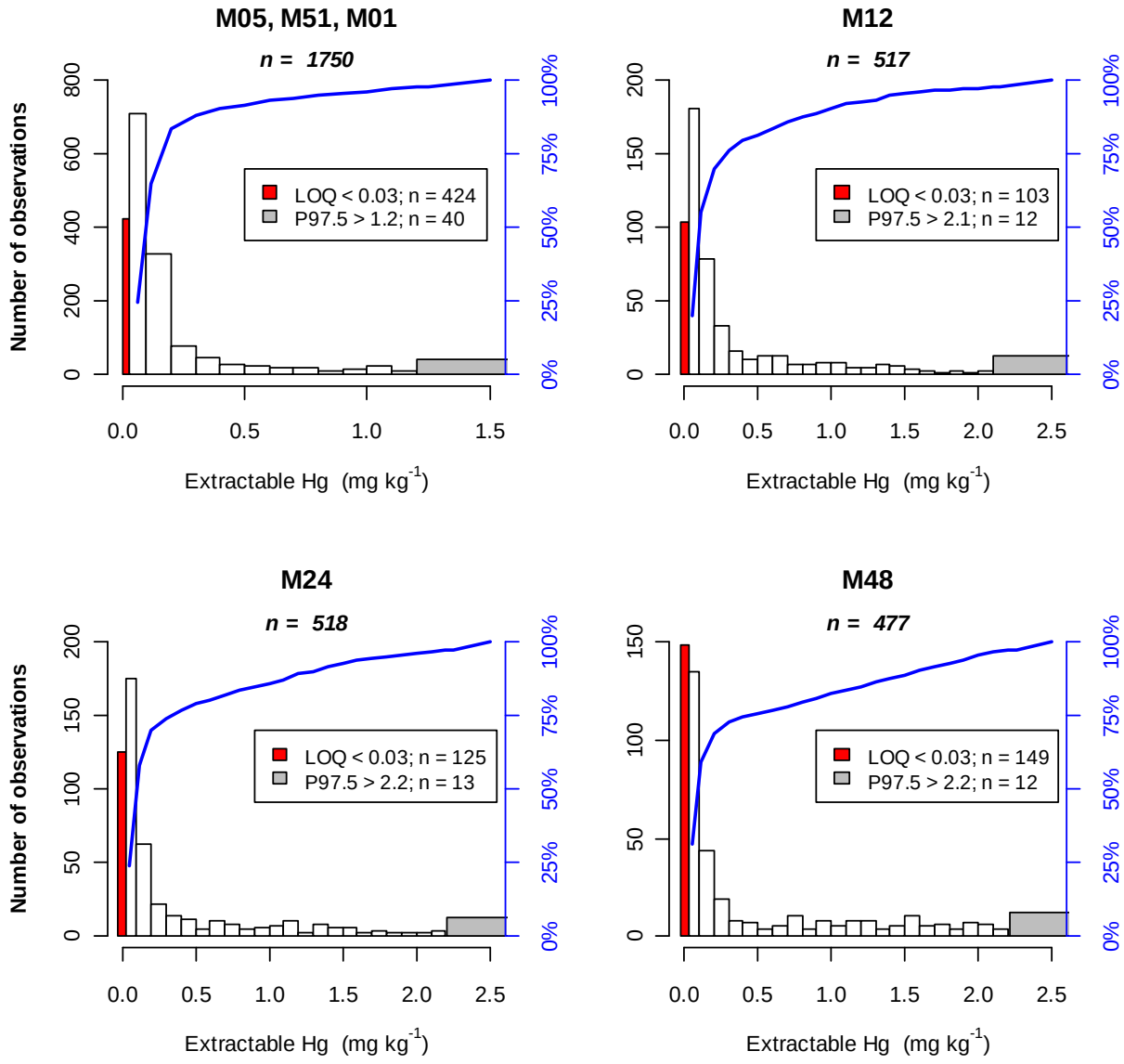


Figure 3.4.160. Absolute and cumulative frequency distribution (in blue) of extractable Hg in mineral layers of all BioSoil+ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

Peat soils

The extractable Hg concentrations in peat layers is generally lower than in mineral soils. Over 55 % of all observations are below LOQ (Figure 3.4.161) indicating that Hg is in peats near the detectable capabilities of the instruments used. Consequently, the ROS predicted statistical values reported in Annex II should be treated with care. The ecotoxicological interpretation of these low concentrations is discussed in Volume II. The estimated median values in peat layers range from 0.038 to 0.074 mg Hg kg^{-1} and the means from 0.138 to 0.224 mg Hg kg^{-1}. Concentrations exceeding 1.6 mg Hg kg^{-1} are rarely found.

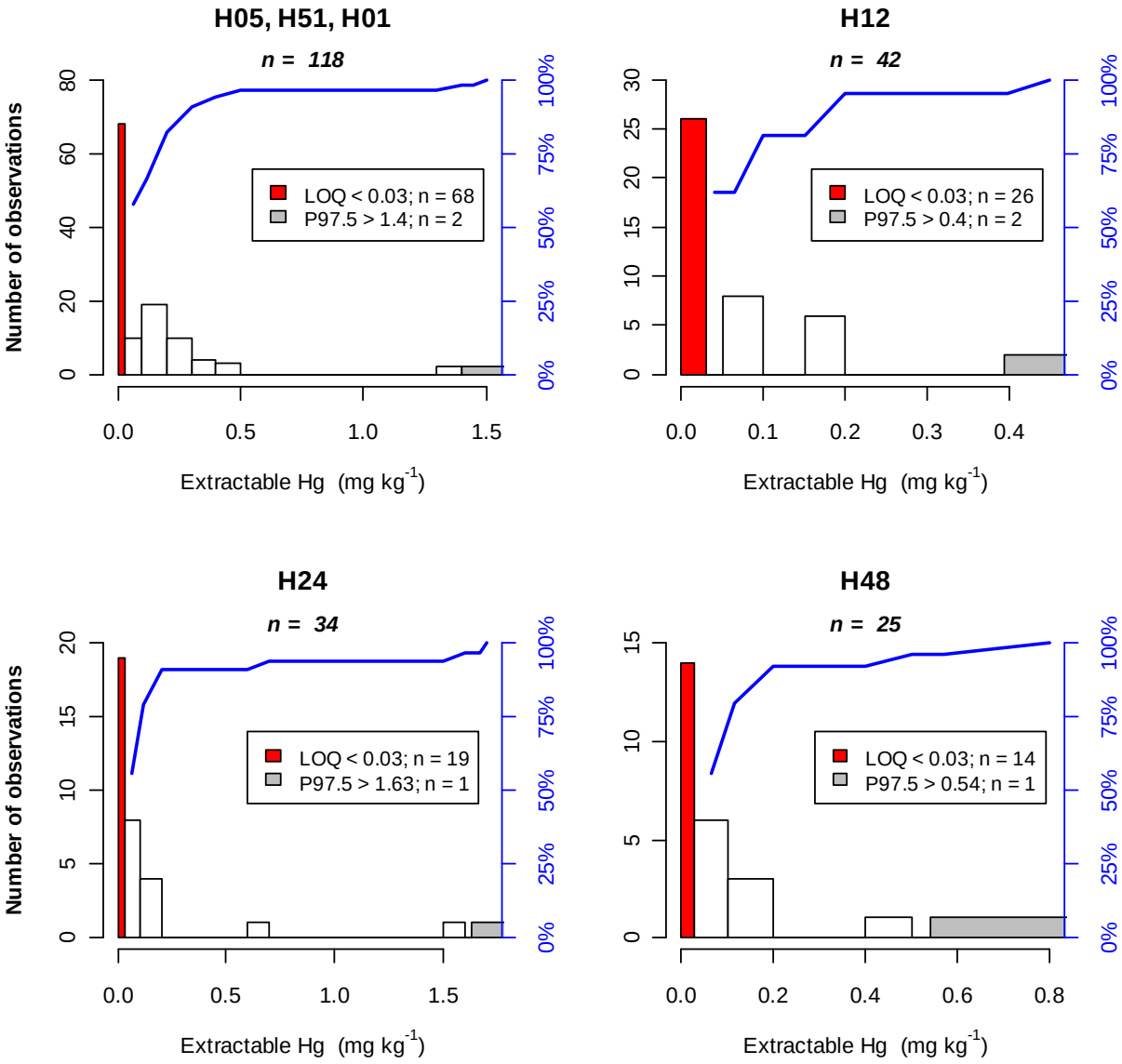


Figure 3.4.161. Absolute and cumulative frequency distribution (in blue) of extractable Hg in peat layers of all BioSoil+ plots (Level I and Level II). Red bars indicate values below LOQ, the grey bars above the 97.5 percentile.

3.4.11 Total Elements

As discussed in Chapter 2.6, very limited data on total elements has been submitted. Mainly France provided data and to a lesser extent Germany and Serbia, but no other countries. Due to the incomplete dataset, only general statistics of mineral layers are reported here. Since the mineral soil data originate from France and Germany only, they are not representative for the whole of Europe. However, they do have indicative value given the extent and intrinsic soil variation within these countries.

3.4.11.1 Total Potassium

Total potassium in mineral layers of French and German plots ranges from ~2000 mg K kg^{-1} to 63000 mg K kg^{-1}. Figure 3.4.162 shows right skewed distributions (skewness ~ 0.9) with less than

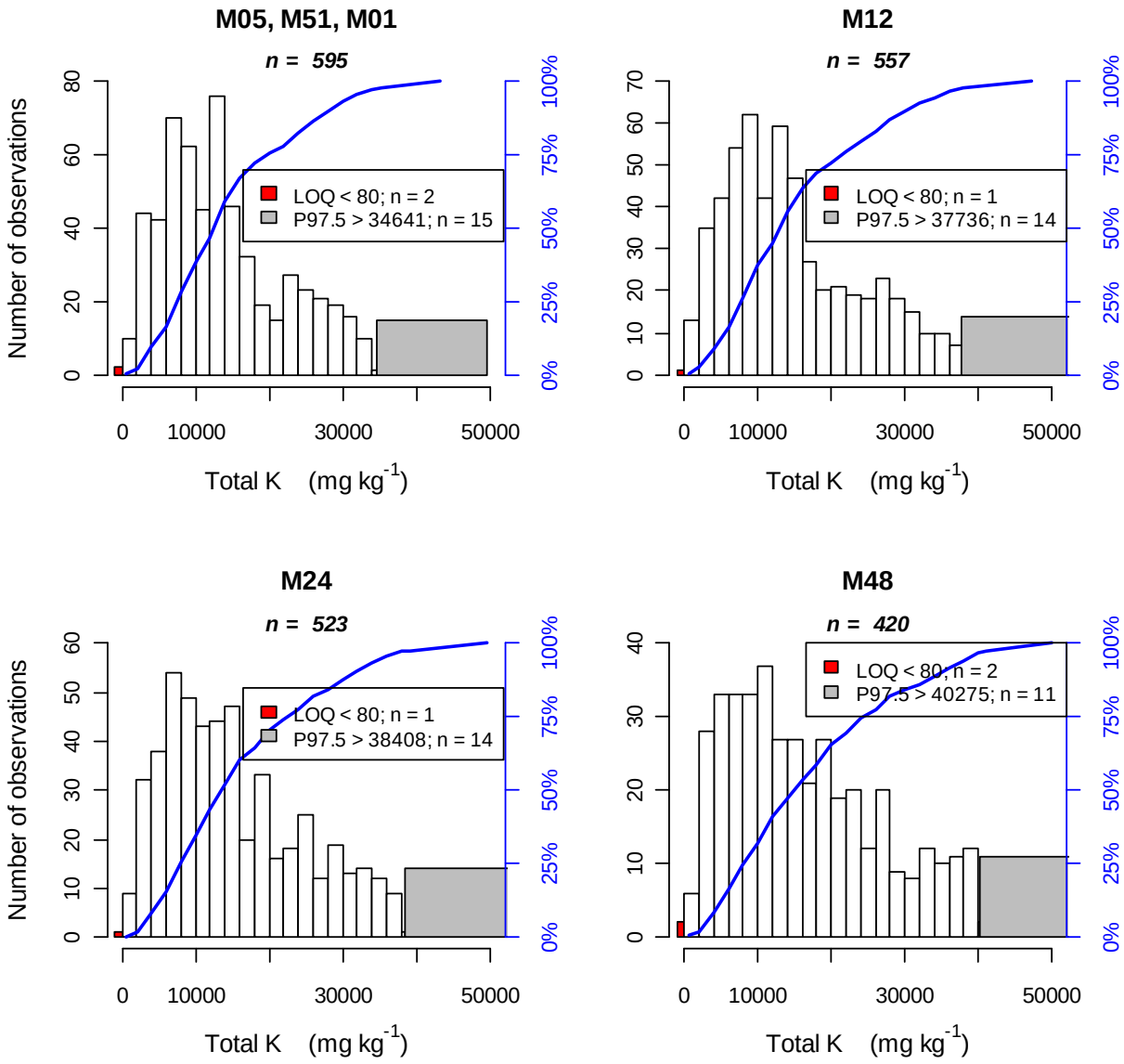


Figure 3.4.162. Absolute and cumulative frequency distribution (in blue) of total K in mineral soil layers of a subset of BioSoil+ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

0.5 % values below LOQ. Median and mean values are similar for M01, M12 and M24 layers, showing medians between 12639 and 13675 mg kg^{-1} and means between 14385 and 15932 mg K kg^{-1}. The median (15171 mg K kg^{-1}) and mean (17232 mg K kg^{-1}) values for M48 layers are slightly higher. Mineral samples with total potassium greater than 4 % are scarcely present on these plots.

3.4.11.2 Total Calcium

Total calcium in mineral layers of French and some German plots ranges from ~350 mg Ca kg^{-1} to 31 % Ca at most. According to WRB 2006 (IUSS WG on WRB, 2006), calcaric soil material is defined as containing 2 % or more $CaCO_3$ which is equivalent to ~8000 mg Ca kg^{-1}. In Figure 3.4.163, the bar width is set to that limit resulting in a first bar of non-calcareous samples and consequently all higher ranges as calcaric.

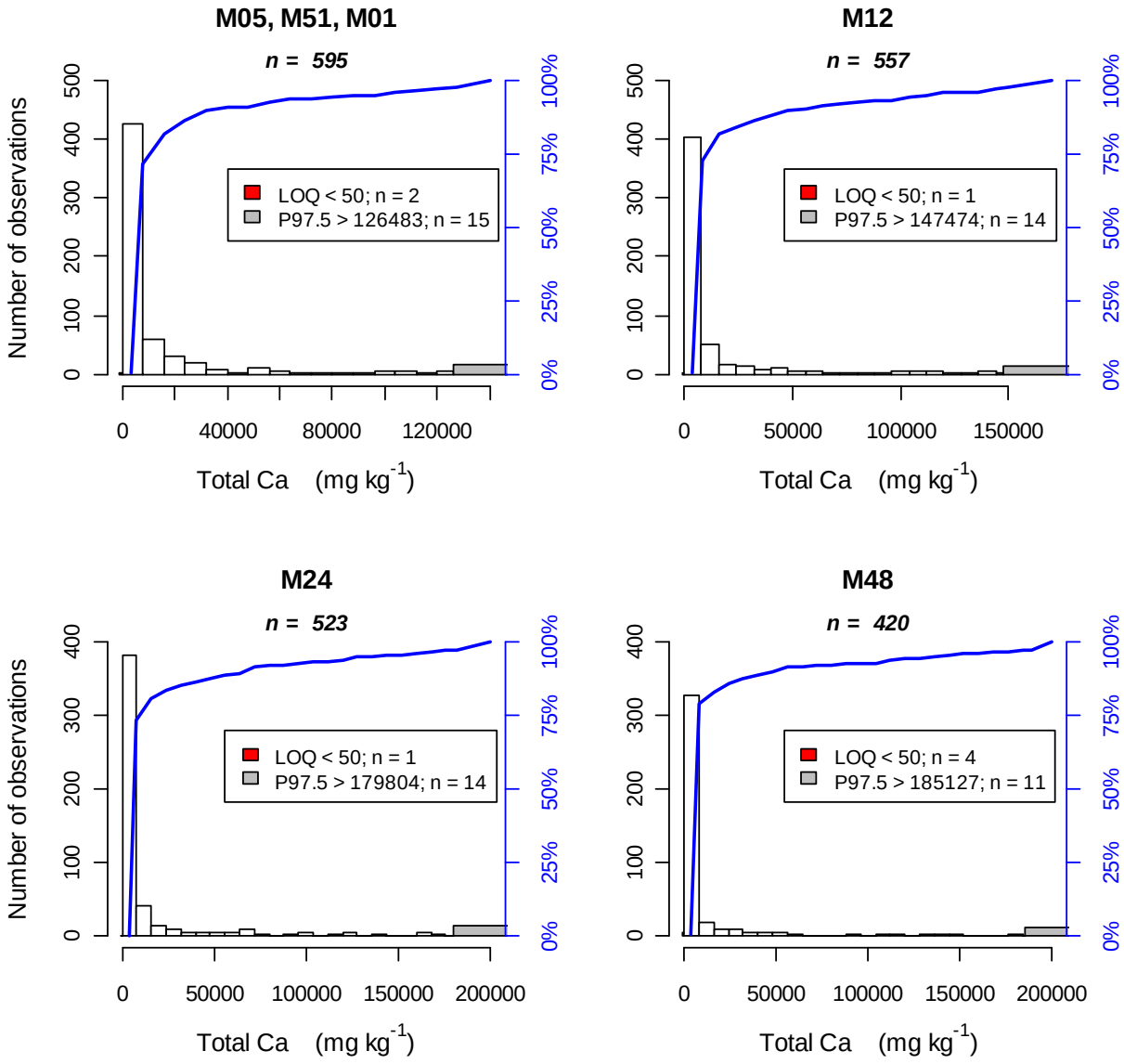


Figure 3.4.163. Absolute and cumulative frequency distribution (in blue) of total calcium in mineral soil layers of a subset of BioSoil+ plots (Level I and Level II). First bar shows non-calcareous layers (< 8000 mg Ca kg^{-1}), whereas next bars all represent calcareous layers. Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

Soil material containing 60000 mg Ca kg^{-1} (15% $CaCO_3$ equivalent) or more can possibly be calcic, which is also present in the dataset for 7 to 10 % of the sampled layers. From Figure 3.4.164, it is clear that most layers (> 70%) are non-calcareous. Median values for all layers are comprised within 2014 and 2471 mg Ca kg^{-1}.

3.4.11.3 Total Magnesium

Total magnesium in the mineral layers of plot subset ranges from ~180 mg Mg kg^{-1} to 12 % Mg at most. Figure 3.4.164 shows the bulk of the samples in the 35 – 7500 mg Mg kg^{-1} range for all layers, mainly associated with carbonate rich soils. About 6 % of the observations are below the 35 mg kg^{-1} quantification limit. Median values increase with layer depth from 2841 mg kg^{-1} in M01 to 3624 mg kg^{-1} in M48. Concentrations over 40000 mg Mg kg^{-1} are seldom found. More statistical data are listed in Annex II.

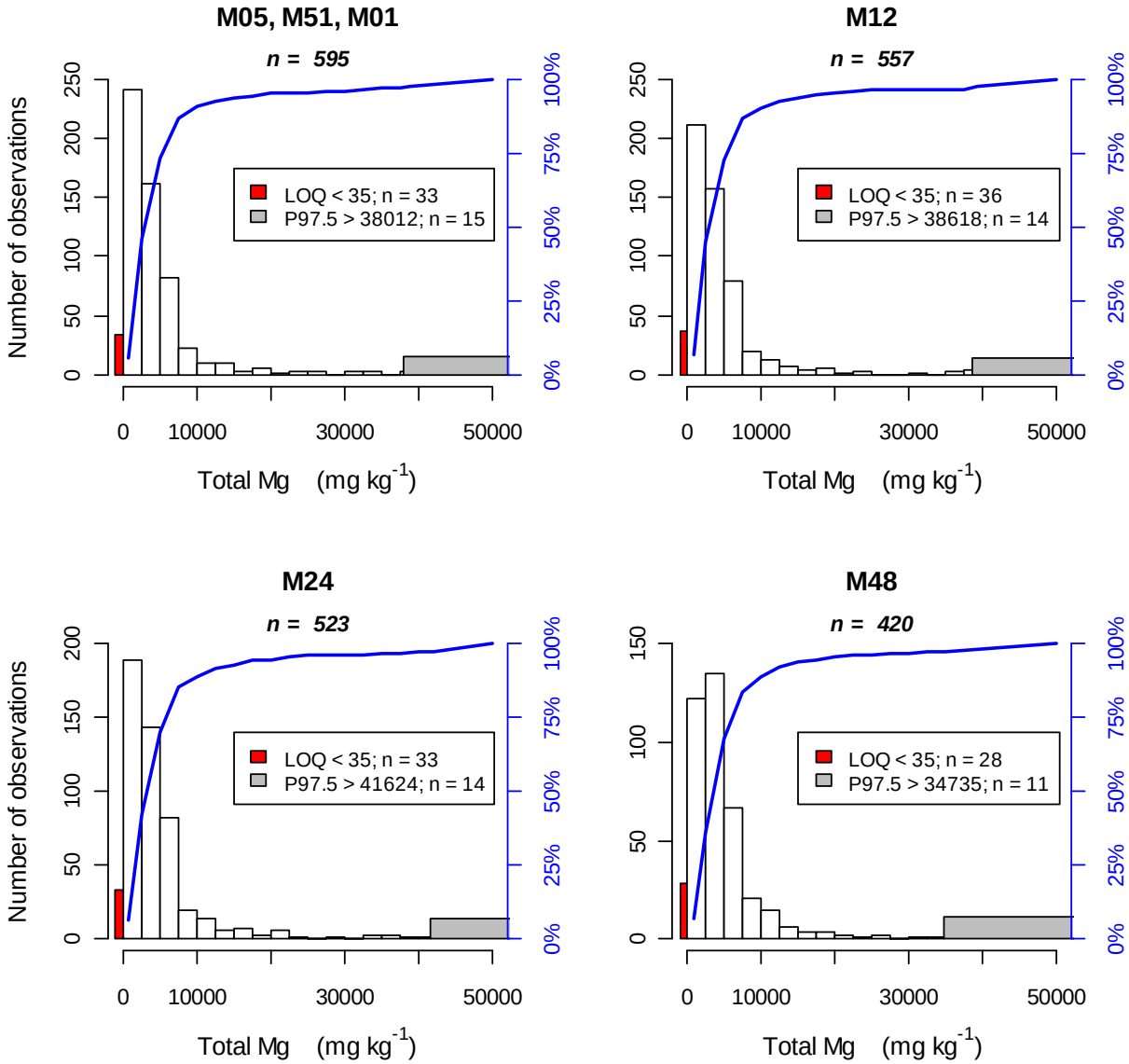


Figure 3.4.164. Absolute and cumulative frequency distribution (in blue) of total magnesium in mineral soil layers of a subset of BioSoil+ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

3.4.11.4 Total Sodium

In the mineral layers of the plot subset, total Na ranges from ~20 to 31800 mg Na kg^{-1}, with median values of all layers comprised within 2814 and 2970 mg Na kg^{-1}. Figure 3.4.165 shows a limited number (< 1%) of left censored observations and less than 2.5 % of the samples holding more than 18569 mg Na kg^{-1}. The unimodal distributions are skewed to the right (skewness between 1.6 and 1.8) and for all layers the modus is between 1000 and 2000 mg Na kg^{-1}. More statistical data are listed in Annex II.

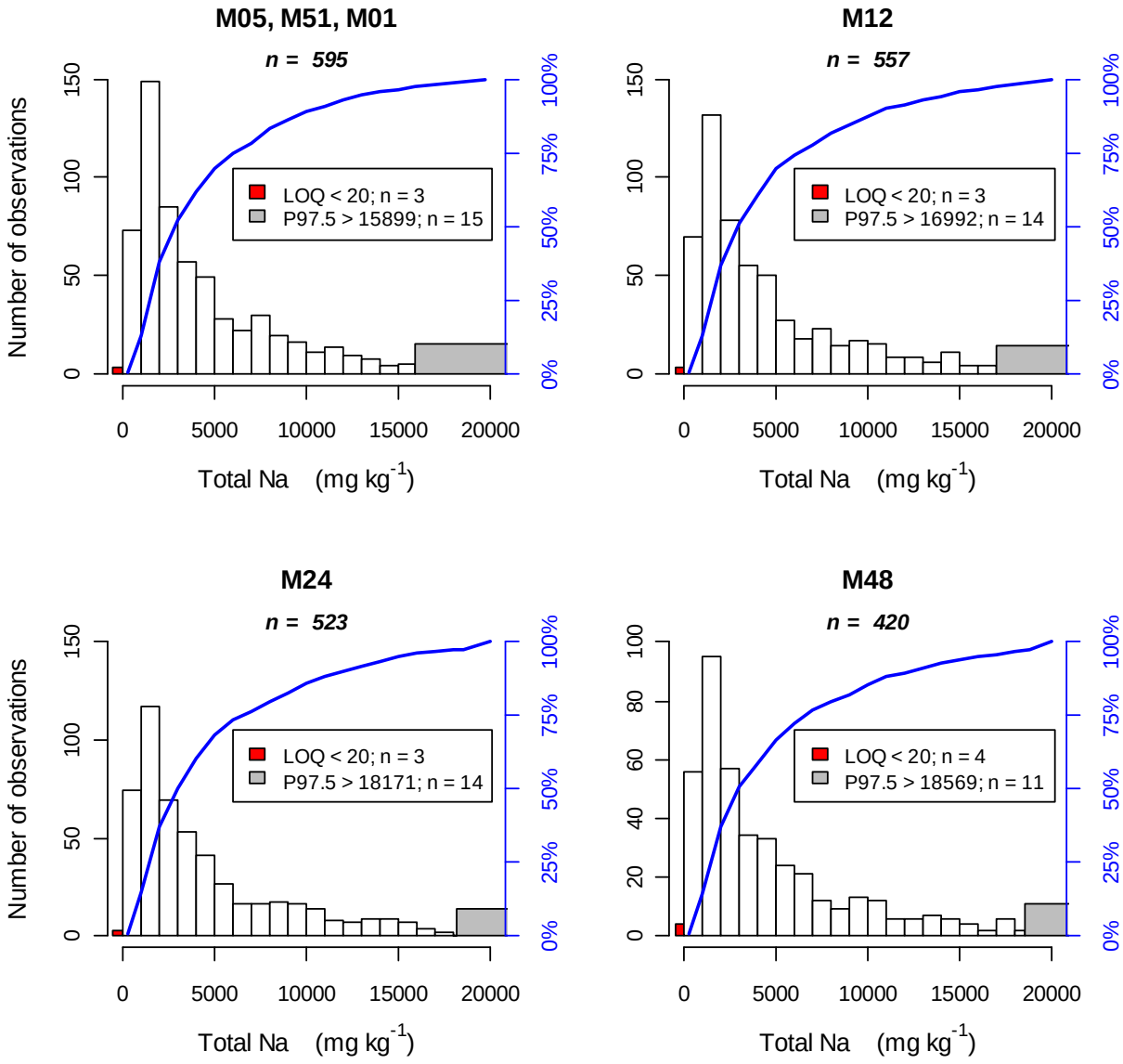


Figure 3.4.165. Absolute and cumulative frequency distribution (in blue) of total sodium in mineral soil layers of a subset of BioSoil+ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

3.4.11.5 Total Aluminium

Aluminium is one of the most abundant metals in the earth's crust. It makes up about 7 to 8 % of the mass (Lutgens and Tarbuck 2000). Total aluminium in mineral forest soil layers ranges from less than 100 to 120000 mg Al kg^{-1}, and is quite evenly distributed between 5000 and 80000 mg Al kg^{-1} (Figure 3.4.166). Median and mean values increase slightly with depth, mainly due the decreasing OM content, containing less Al than soil minerals. The increase of median values with depth is: 43890 < 45100 < 47865 < 53135 mg kg^{-1} similar to the mean values (data in Annex II). Samples containing over 10 % of total aluminium were rarely observed.

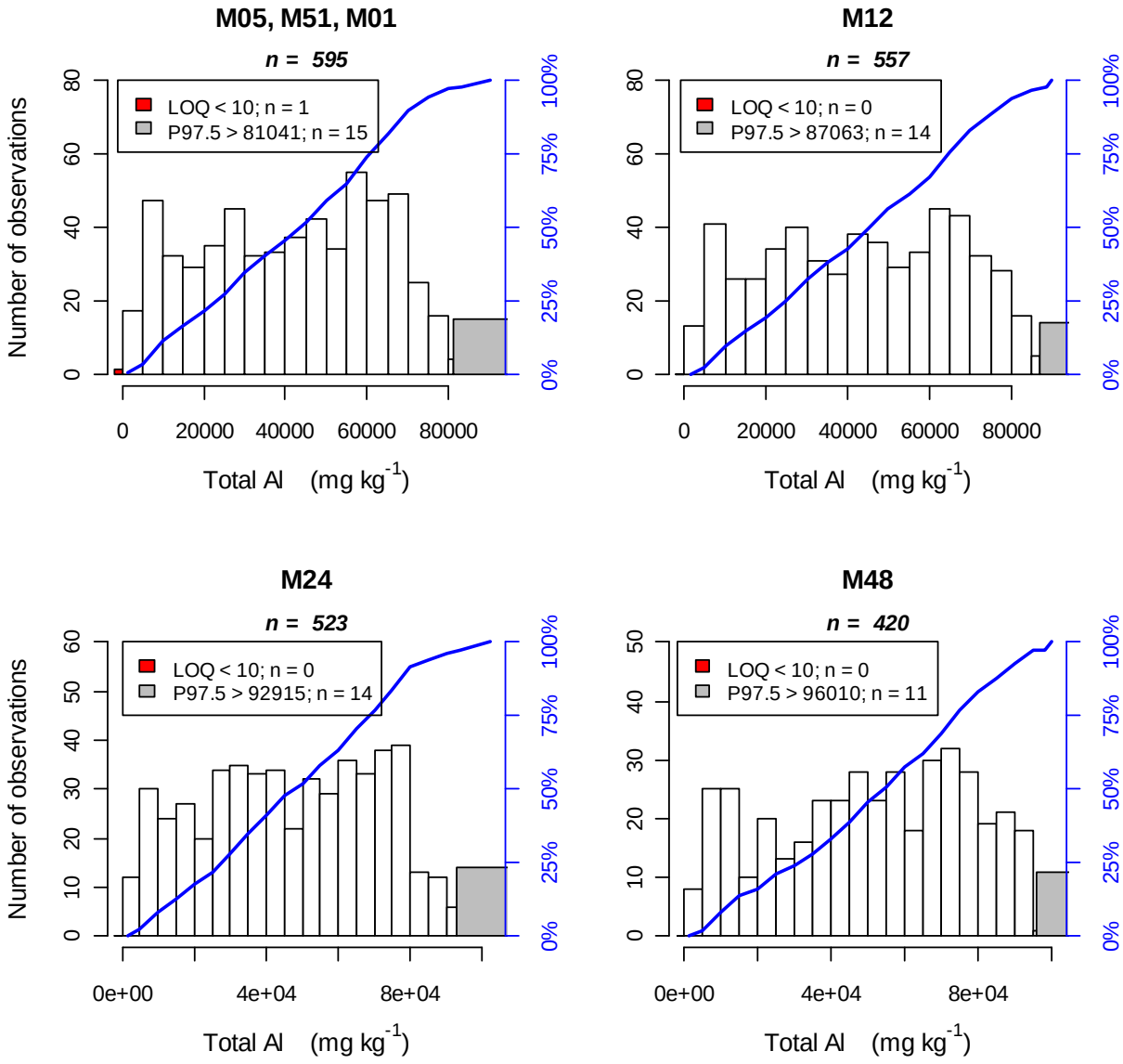


Figure 3.4.166. Absolute and cumulative frequency distribution (in blue) of total aluminium in mineral soil layers of a subset of BioSoil+ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

3.4.11.6 Total Iron

Iron makes up about 5 % by mass of the earths' crust (Lutgens and Tarbuck 2000). The total Fe concentration found in mineral forest soil layers ranges from less than 10 mg kg^{-1} up to 20 % by mass, indicating strong redistribution of iron within the soil profile. Figure 3.4.167 shows the histograms per depth layer, which are quite evenly distributed up to 3 % Fe and then decrease gradually with few observations exceeding 6 % Fe. Median values increase slightly with depth, from 20311 mg kg^{-1} for the upper 10 cm layer to 24384 mg Fe kg^{-1} for the 40-80 cm layer. Mean data and other statistics are given in Annex II.

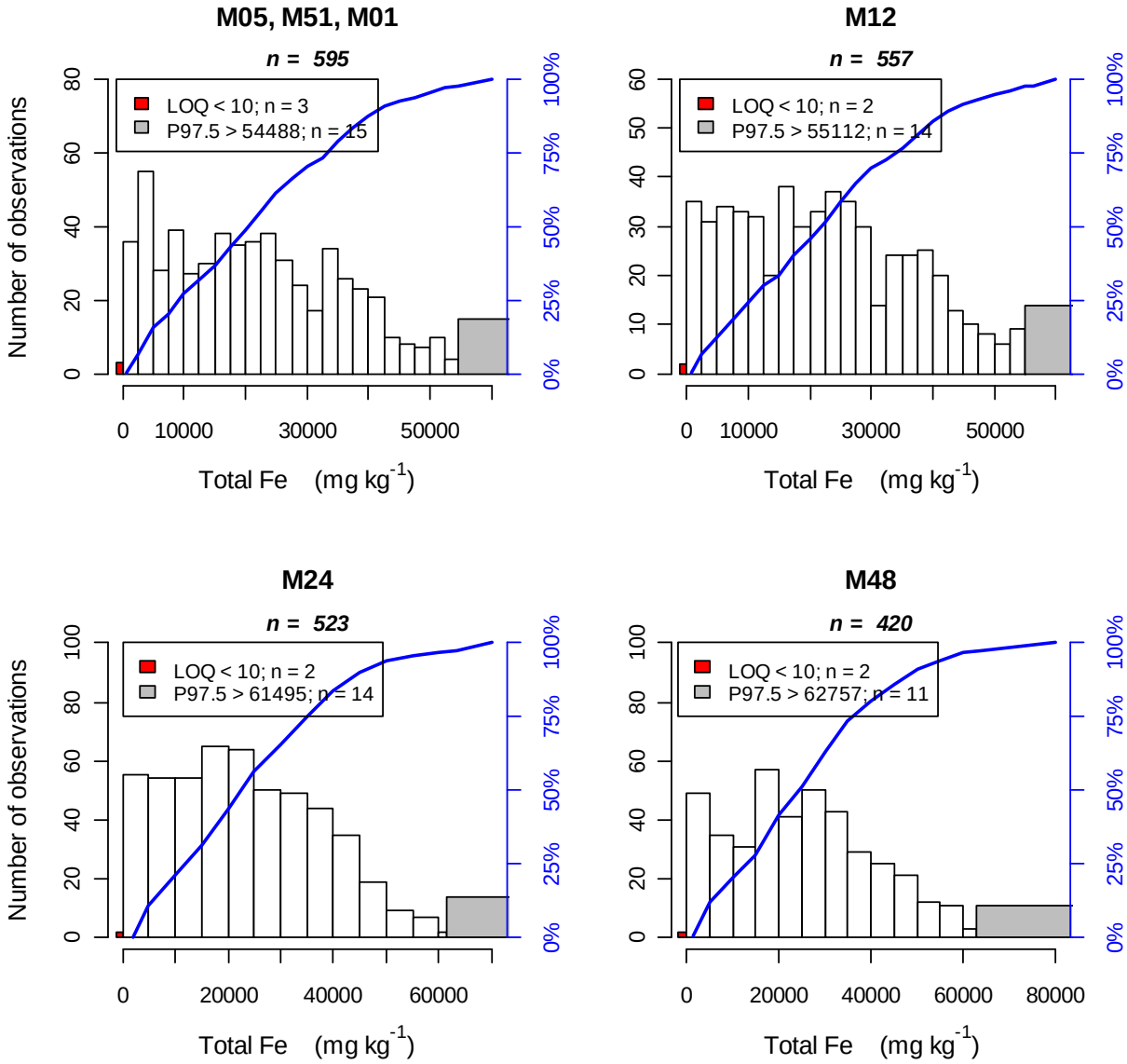


Figure 3.4.167. Absolute and cumulative frequency distribution (in blue) of total iron in mineral soil layers of a subset of BioSoil+ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

3.4.11.7 Total Manganese

The concentration of total Mn is a factor 50 to 100 lower than total Fe and Al in the mineral forest soil layers. Less than 1.7 % of the observations are below the LOQ of 2 mg Mn kg^{-1}, and less than 2.5 % of them exceeds 2000 mg Mn kg^{-1}. Median values of the layers are comprised within 387 and 476 mg Mn kg^{-1}. Figure 3.4.168 indicates that the manganese concentration of most samples is situated in the 0 to 100 mg kg^{-1} class, generally with decreasing observations in the consecutive classes. Other statistical values are summarised in Annex II.

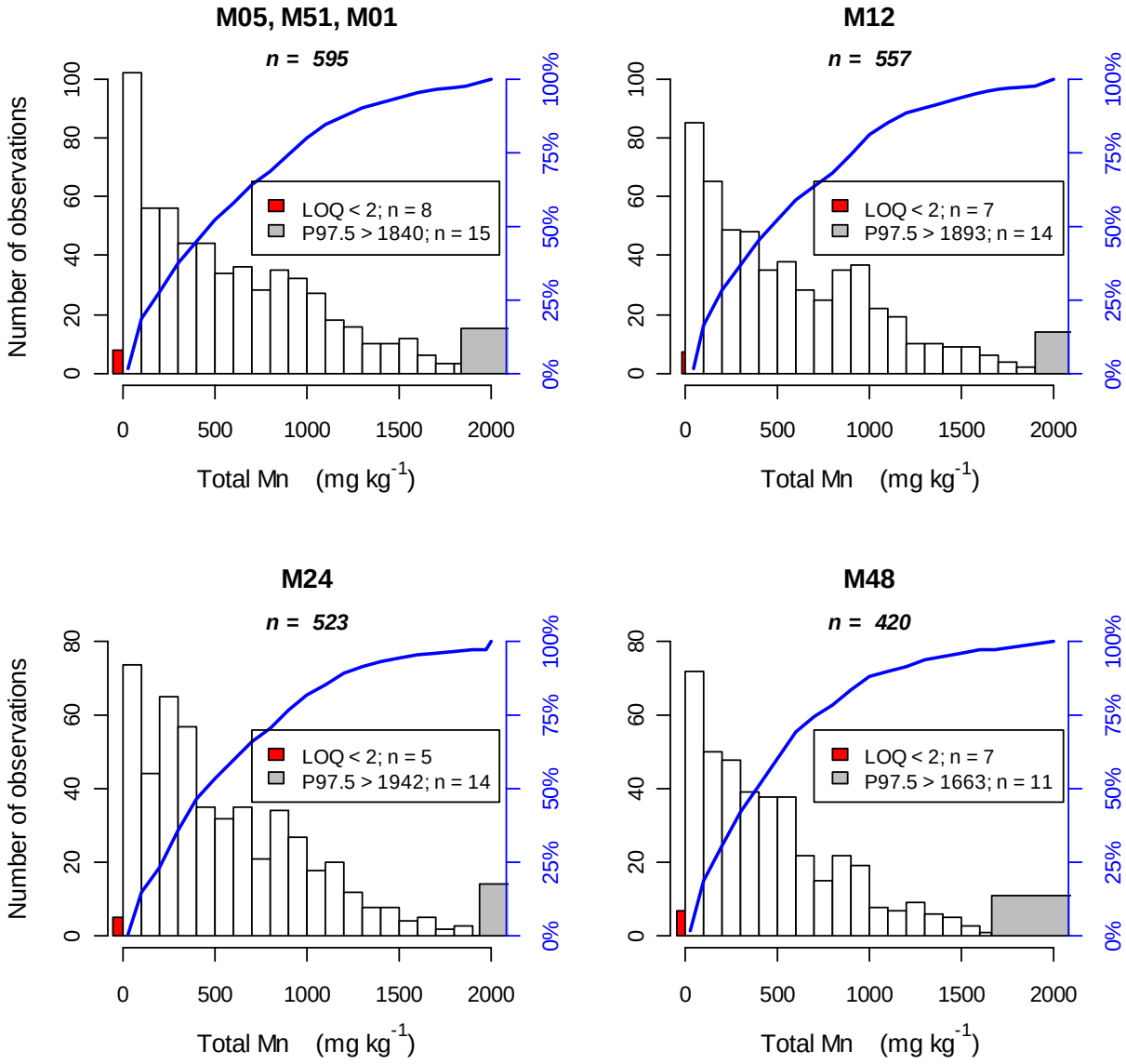


Figure 3.4.168. Absolute and cumulative frequency distribution (in blue) of total manganese in mineral soil layers of a subset of BioSoil+ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

3.4.12 Acid Oxalate Extractable elements

3.4.12.1 Acid Oxalate Extractable Aluminium

Acid Oxalate extractable or so called reactive aluminium was measured both in organic and mineral soil matrices. In the OL and OFH layers, the concentration was generally lower (Figure 3.4.169) than for hydromorphic humus types (H layers) and peat layers (H01 to H48). The acid oxalate extractable Al in peat layers does not differ substantially from those of mineral layers, although the range is smaller.

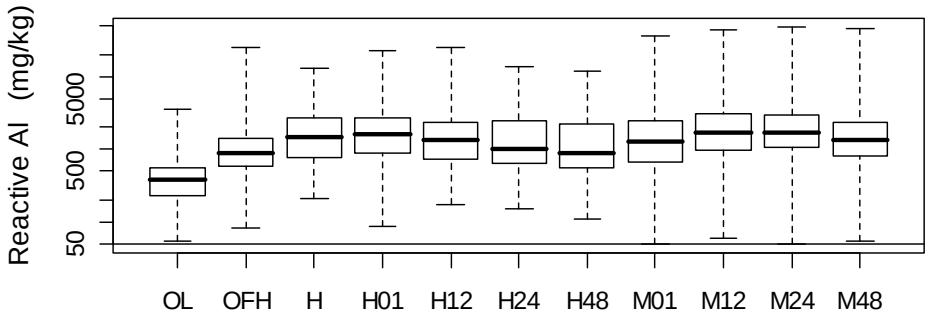


Figure 3.4.169. Box plot of acid oxalate extractable aluminium concentration for all fixed depth layers. The Y-axis is logarithmic. The horizontal line indicates the LOQ at 50 mg kg^{-1}.

Forest Floor

Reactive aluminium in the forest floor layers ranges from less than 50 mg kg^{-1} (LOQ) to maximally ~24000 mg kg^{-1}. Few observations (< 1.5 %) were found below the LOQ and 95 % of all observations range within 91 and 6670 mg kg^{-1} for OL and OFH layers as shown by the distributions in Figure 3.4.170.

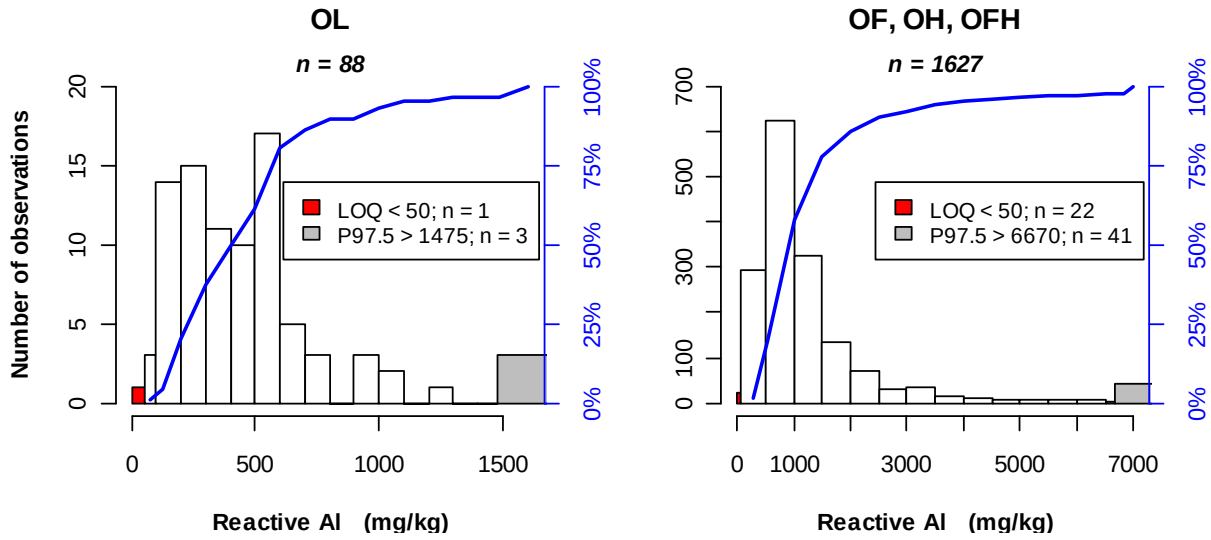


Figure 3.4.170. Absolute and cumulative frequency distribution (in blue) of acid oxalate extractable Al in OL (left) and OF, OH and OFH layers (right) of all BioSoil^{+} plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

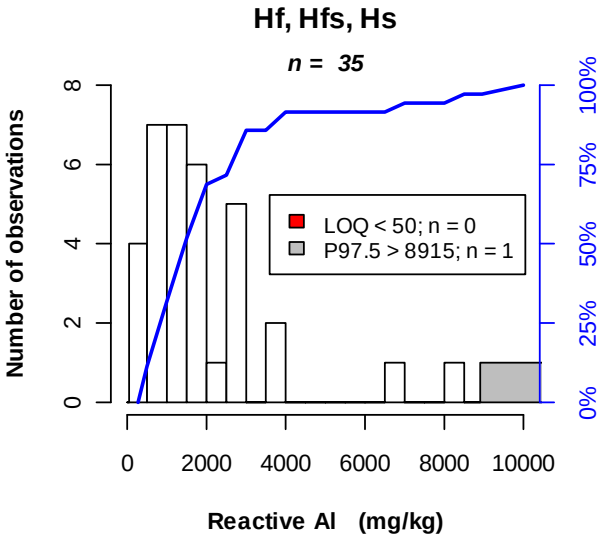


Figure 3.4.171. Absolute and cumulative frequency distribution (in blue) of acid oxalate extractable Al in hydromorphic forest floor layers of all BioSoil^{+} plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

generalise this finding.

Note the limited number of observations in OL layers compared to OFH. The median values are 394 and 872 mg Al kg^{-1} whereas means are 495 and 1414 mg Al kg^{-1} for OL and OFH layers respectively. Most observations are comprised within the 500 - 600 mg Al kg^{-1} class for OL and between 500 - 1000 mg Al kg^{-1} for OFH.

In hydromorphic humus layers the reactive Al concentration is higher than in aerated humus forms (Figure 3.4.171). Most observations (95 %) are comprised within 320 - 8915 mg Al kg^{-1}, mainly in the 500 – 2000 mg kg^{-1} interval. The median value is 1500 mg Al kg^{-1} and the mean 2242 mg kg^{-1}. Few observations exceed 4000 mg kg^{-1}, but the sample number is rather low to

Mineral layers

The concentration range observed for reactive Al in mineral layers is from less than 50 mg Al kg^{-1} (LOQ) up to 47200 mg Al kg^{-1}. Figure 3.4.172 shows clear lognormal distributions with less than 1.2 % left censored observations. The median values range between 1313 and 1723 mg Al kg^{-1} for all depths. Most observations are typically below 2000 mg Al kg^{-1}. All other statistical values are tabularised in Annex II.

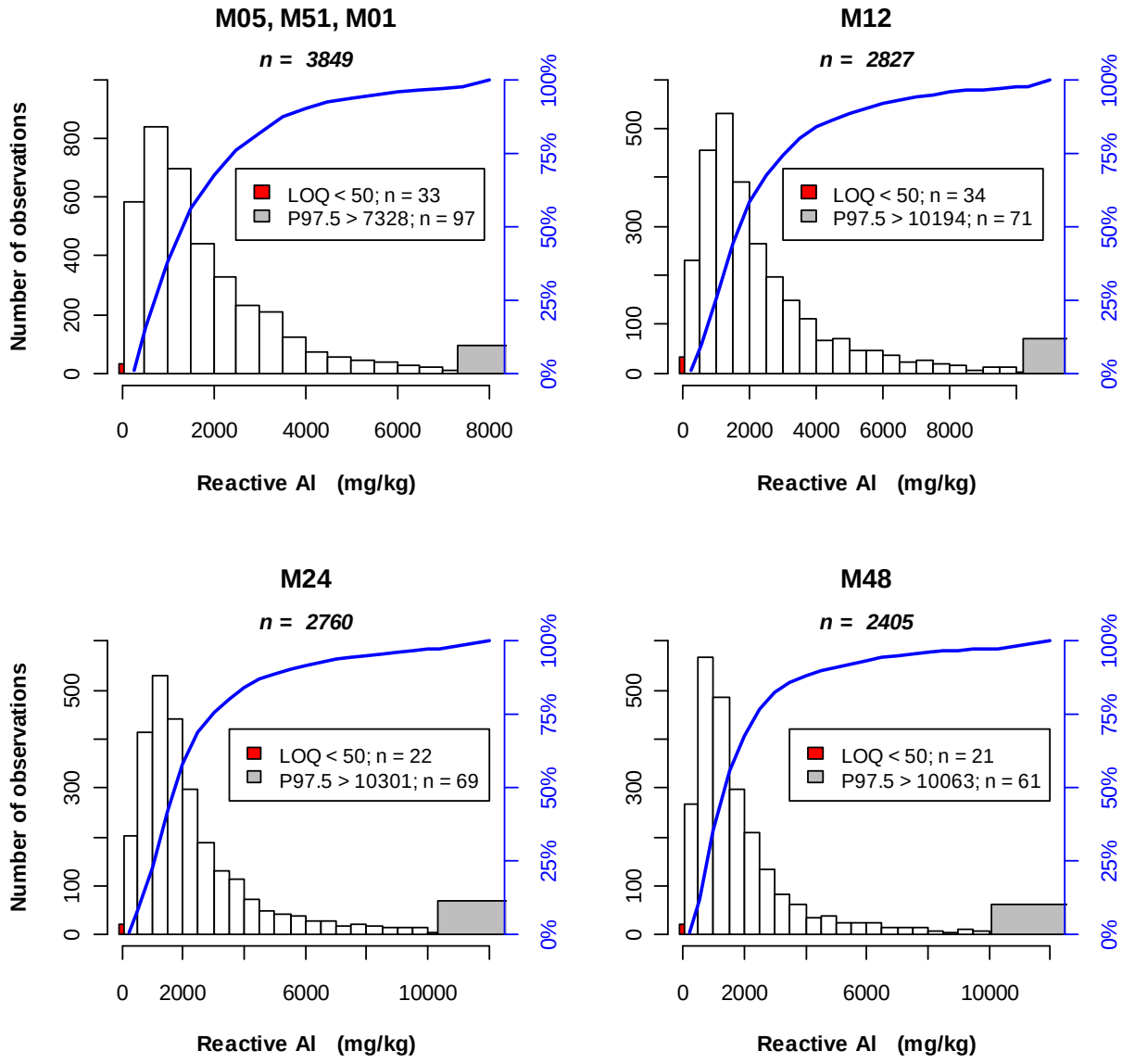


Figure 3.4.172. Absolute and cumulative frequency distribution (in blue) of acid oxalate extractable Al in mineral soil layers of all BioSoil⁺ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

Peat soils

The distribution of reactive Al in peat layers is shown in Figure 3.4.173. No observations are below LOQ (50 mg Al kg^{-1}) and very few exceed 10000 mg Al kg^{-1}. In contrast to mineral layers, the median reactive Al concentration seems to decrease with depth, from 1603 mg Al kg^{-1} in the M01 layer to 901 mg kg^{-1} in the M48 layer. However, there is also a substantial decrease in number of observations so the datasets for computing these medians may be biased. Generally, the reactive Al concentrations of peat soils are comparable with those of mineral layers, predominantly below 2000 mg Al kg^{-1}. The statistical values are listed per layer in Annex II.

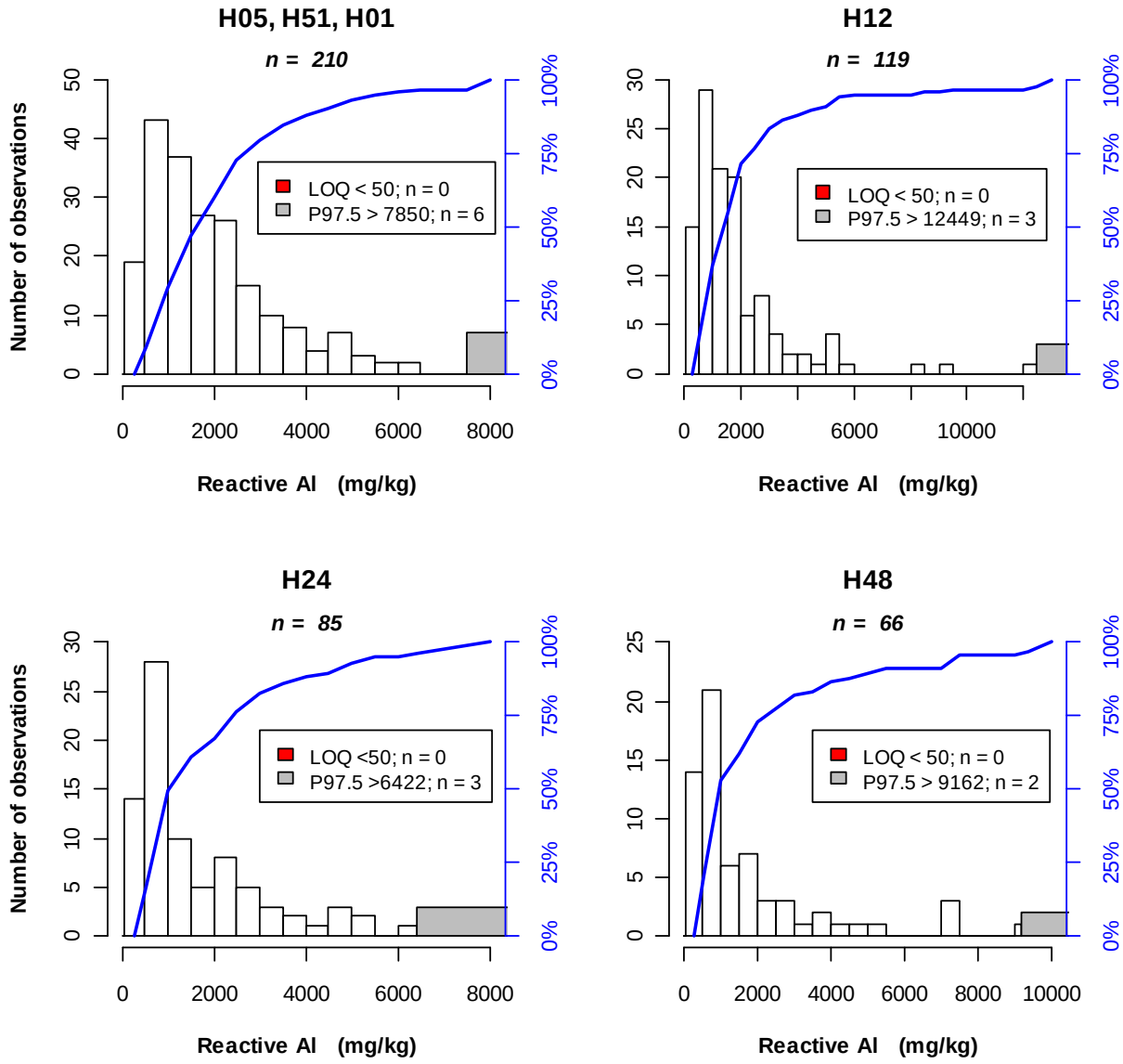


Figure 3.4.173. Absolute and cumulative frequency distribution (in blue) of acid oxalate extractable Al in peat layers of all BioSoil+ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

3.4.12.2 Acid Oxalate Extractable Iron

Acid oxalate extractable or reactive iron is measured both in organic and mineral soil matrices. In the forest floor layers (OL, OFH and H layers), the concentration was generally lower (Figure 3.4.174) than for peat (H01 to H48) and mineral layers (M01 to M48). Peat layers showed the largest ranges, with also higher minimum values compared to the mineral soil layers as indicated by the whiskers of the box plot.

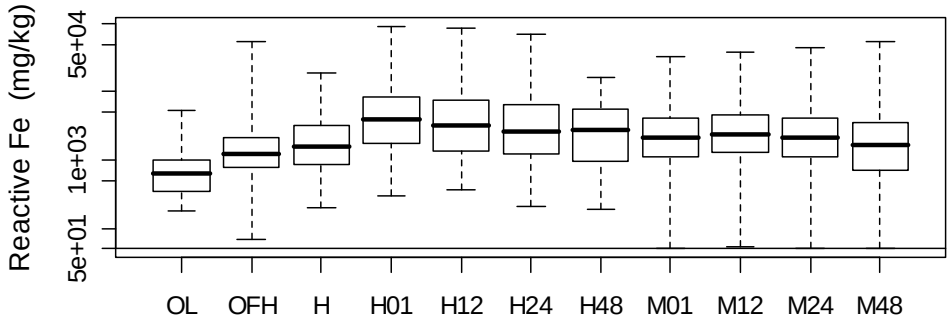


Figure 3.4.174. Box plot of acid oxalate extractable iron concentration for all fixed depth layers. The Y-axis is logarithmic. The horizontal line indicates the LOQ at 50 mg kg^{-1}.

Forest Floor

Reactive iron in the forest floor layers ranges from less than 50 mg kg^{-1} (LOQ) to maximally ~56000 mg kg^{-1} in OFH layers . Few observations (< 1.3 %) were found below the LOQ and 95 % of all observations range within 171 and 9037 mg Fe kg^{-1} for OL and OFH layers as shown by the distribution functions in Figure 3.4.175. Note the limited number of observations in OL layers compared to OFH, which results in a more pronounced lognormal distribution for OFH (skewness = 7.3).

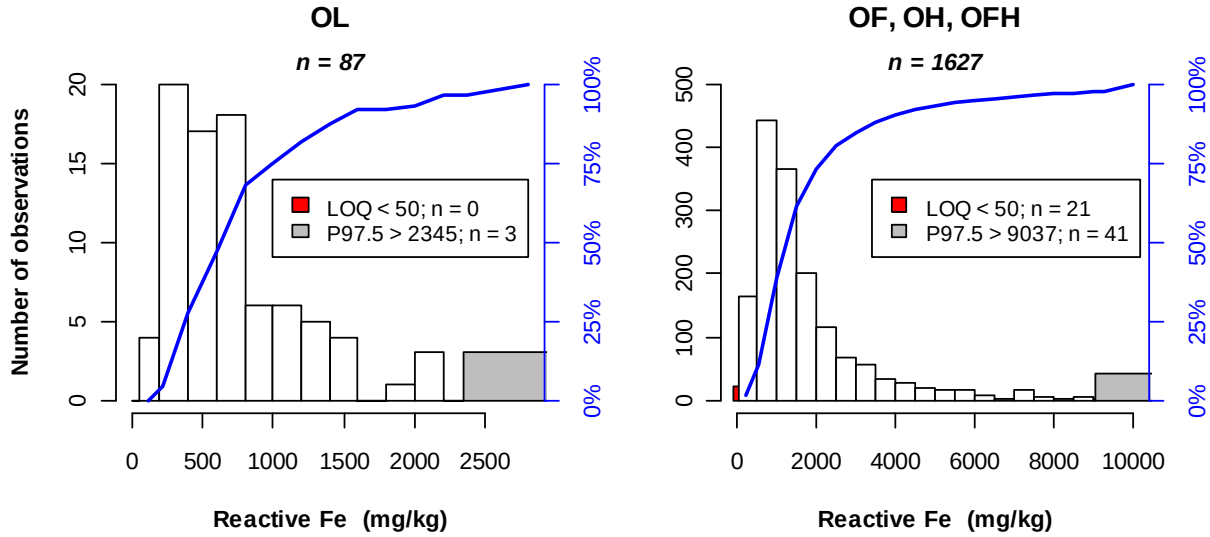


Figure 3.4.175. Absolute and cumulative frequency distribution (in blue) of acid oxalate extractable Fe in OL (left) and OF, OH and OFH layers (right) of all BioSoil^{+} plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

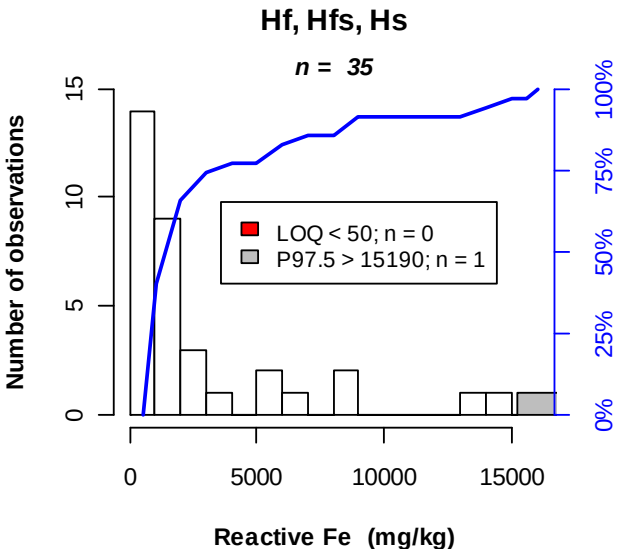


Figure 3.4.176. Absolute and cumulative frequency distribution (in blue) of acid oxalate extractable Fe in hydromorphic forest floor layers of all BioSoil+ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

The median values are 627 and 1207 mg Fe kg^{-1} whereas means are 809 and 2003 mg Fe kg^{-1} for OL and OFH layers, respectively. Most observations are comprised within the 200 - 800 mg Fe kg^{-1} class for OL and between 500 - 1500 mg Fe kg^{-1} for OFH.

In hydromorphic humus layers the reactive Fe concentration is higher than in aerated humus forms (Figure 3.4.176). Most observations (95 %) are comprised within 294 - 15190 mg Fe kg^{-1}, mainly in the 0 – 2000 mg kg^{-1} interval. The median value is 1600 mg Fe kg^{-1} and the mean 3308 mg kg^{-1}.
Few of the limited set of observations exceed 3000 mg kg^{-1}.

Mineral layers

The concentration range observed for reactive Fe in mineral layers is from less than 50 mg Al kg^{-1} (LOQ) up to ~55000 mg Fe kg^{-1}. Figure 3.4.177 shows clear right skewed distributions with less than 1.6 % left censored observations. The median values range between 1628 and 2310 mg Fe kg^{-1} for all depths. Most observations are typically below 2000 mg Fe kg^{-1}. All other statistical values are tabularised in Annex II.

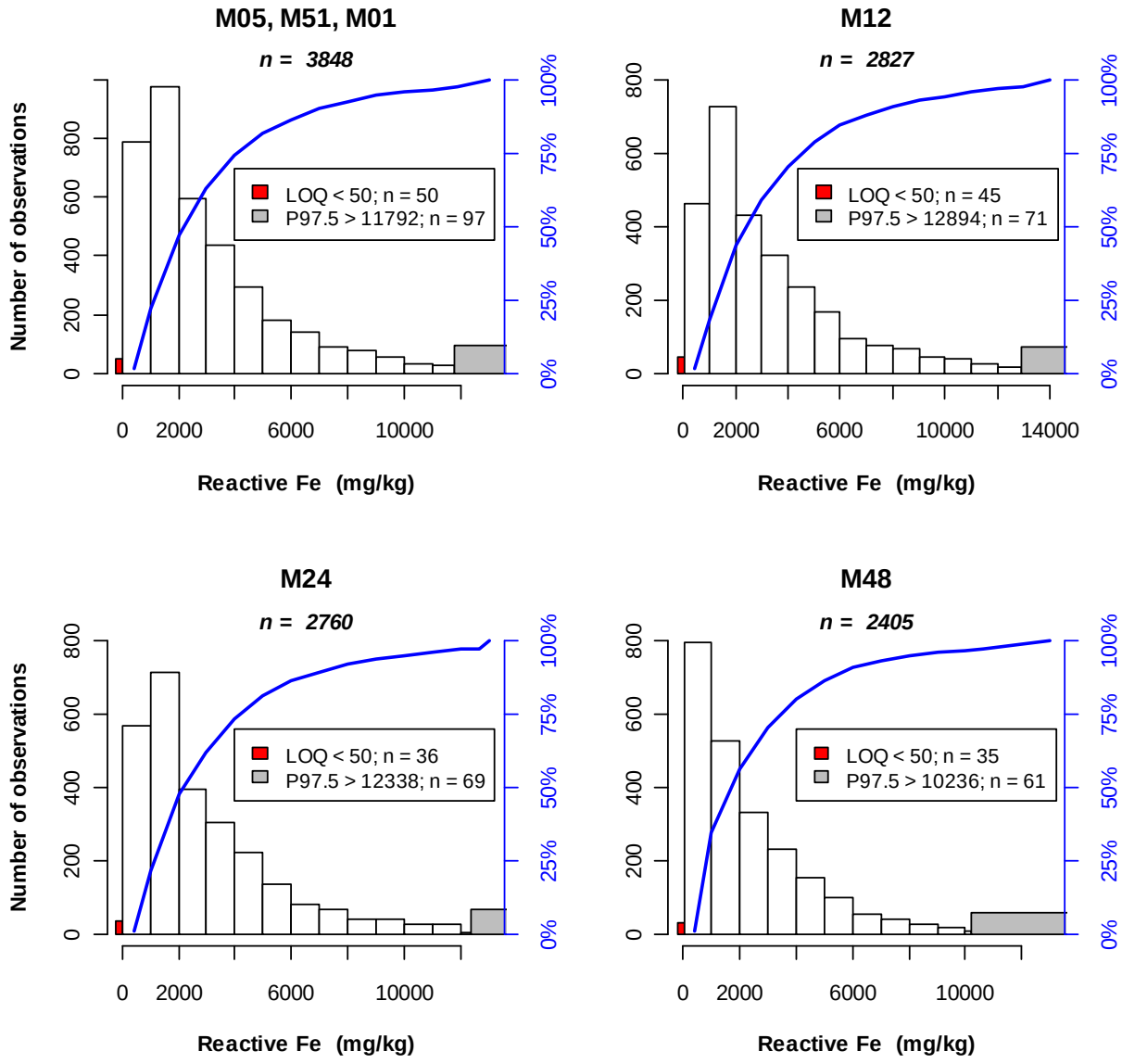


Figure 3.4.177. Absolute and cumulative frequency distribution (in blue) of acid oxalate extractable Fe in mineral soil layers of all BioSoil+ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

Peat soils

The distribution of reactive Fe in peat layers is shown in Figure 3.4.178. No observations are below LOQ (50 mg kg^{-1}) and very few exceed 20000 mg Fe kg^{-1}. The median values (2673 to 3966 mg Fe kg^{-1}) of these peat layers are substantially higher than for mineral layers. Also the 97.5-percentiles are three times as high as in mineral soil. The statistical values per layer are further listed in Annex II.

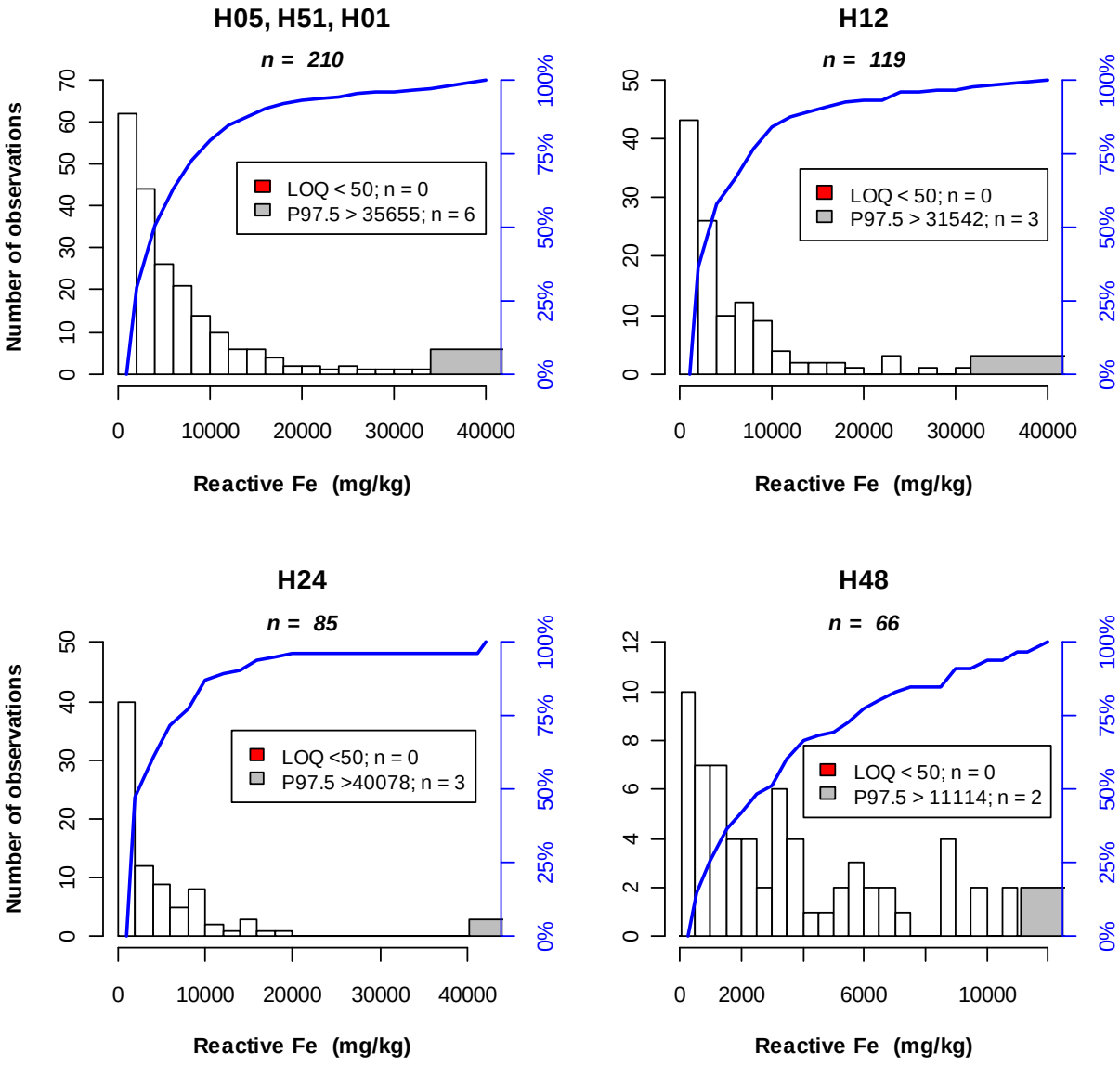


Figure 3.4.178. Absolute and cumulative frequency distribution (in blue) of acid oxalate extractable Fe in peat layers of all BioSoil⁺ plots (Level I and Level II). Red bars indicate observations below LOQ, the grey bars above 97.5 percentile.

3.5 Evaluation of quantification limits and plausible ranges

When applying the revised (Section 2.3.4) limits of quantification, a specific set of parameters showed a high proportion of left censored values (see column Cen% in Annex II). Table 3.5.1 lists those parameters and layers for which over 25 % of all reported observations are below LOQ.

Table 3.5.1. Classified list of parameters and layers showing high proportions of left censored observations

Parameter	Layers
>75 % of left censored observations	
Aqua regia extractable Cd	OFH, H, M01, M12, M24, M48, H01, H12, H24, H48
Exchangeable Fe	OL*
50 - 75 % of left censored observations	
Carbonates	OL*, OFH, H, M24, M48, H01, H12, H24, H48
Aqua regia extractable K	H48
Aqua regia extractable Na	H48
Aqua regia extractable Pb	H48
Aqua regia extractable Cr	H48
Aqua regia extractable Cd	OL
Aqua regia extractable Hg	H01, H12, H24, H48
Free H^+	M12, M24, M48
Exchangeable Na	M12, M24, M48
Exchangeable Fe	M12, M24, M48
Exchangeable Mn	M12, M24, M48, H12, H24
25 - 50 % of left censored observations	
Carbonates	M12, M24
Aqua regia extractable K	H24
Aqua regia extractable Cu	H48
Aqua regia extractable Ni	H48
Aqua regia extractable Cr	H12, H24
Aqua regia extractable Hg	M48
Free H^+	M01
Exchangeable K	M24, M48
Exchangeable Mg	M24
Exchangeable Na	OL*, M01
Exchangeable Al	OL*, H48
Exchangeable Fe	OFH, M01, H48
Exchangeable Mn	H, M01, H01, H48

* Note that for the organic OL layer, nor the exchangeable elements nor carbonates have ever been a requested (neither mandatory or optional) parameter so data have been reported on voluntary basis

Basically, three groups of parameters occur: (i) Aqua regia extractable elements, (ii) Exchangeable elements including free H^+ and (iii) Carbonates. The other parameter groups have a proportion of less than 25 % left censored values, and consequently low levels of these parameters can be quantified reliably with the applied techniques in most forest soils. For the Aqua regia extractable elements listed in Table 3.5.1 most are trace metals, except K. Evidently, they show high occurrences below LOQ when their concentration levels are very low, which is mainly the case in organic layers (e.g. H48). For extractable Cd, the left censored proportion was too high in all layers meaning that the LOQ of 0.5 mg kg^{-1} should be lowered substantially using more accurate instruments if precise measurement of these generally low background levels is required.

Adequate measurement of exchangeable elements is problematic both in organic and mineral layers. It seemed very hard to reliably detect exchangeable Fe in OL and mineral layers for more than half of all samples. The same holds true for exchangeable Na, Fe, Mn and free H^+ in mineral samples. Furthermore, reporting these elements below LOQ causes problems in calculating derived parameters such as cation exchange capacity (CEC) and base saturation, which become also left censored. This may justify the additional measurement of CEC separately.

Finally, measuring carbonates using the calcimeter is also prone to a high proportion of left censored results. This technique seems really not adequate for measuring carbonates in all organic matrices and performs poorly for most mineral soil samples too. We recommend to discard this method and derive Carbonates from other available parameters as extractable/total Ca and Mg.

The same parameter groups are recognised as part of the problem parameters from the last three FSCC soil ring tests, in which most of national labs participated. Aqua regia extracted heavy metals, exchangeable elements and carbonate determinations showed high variability among laboratories in the 4th FSCC ring test (Cools et al. 2006) during the preparation phase of BioSoil. During the BioSoil survey, the 5th ring test revealed that the problem parameters were (1) exchangeable elements, especially Na, Ca, ree H^+, Mg, acidity and Fe, (2) the heavy metals Hg and Cd extracted by aqua regia, Extractable Al and Mg, (3) carbon content in a sample with low organic carbon content and (4) the pH determination of a peat sample (Cools et al. 2007). Groups 1 and 2 are readily found in Table 3.5.1, whereas 3 and 4 were sample related problems. The 6th ringtest after the BioSoil survey reported again some of these parameters: (1) exchangeable elements, especially Na and the acid cations Al, Fe, Mn, free H^+ and acidity, (2) aqua regia extractable elements Na and Cd, (3) the carbonate content in a sample with low $CaCO_3$ content and (4) the determination of the clay content (Cools et al. 2010).

In all, the ring tests consistently and clearly reveal the weakness of the analytical results for specific parameters, especially when samples' concentrations fall in the low level range. It is essential to take this knowledge into consideration when analysing the BioSoil$^+$ database in order to make correct inferences and proper conclusions.

Plausible ranges for soil samples were established in the ICP Forests Working Group on QA /QC in Laboratories and published in part XVI of the ICP Forests manual, Table 3.3.2.1a (König et al. 2010). As indicated in that manual, these plausible ranges are subject to further refinement based on BioSoil$^+$ data. The result is presented in Table 3.5.2.

As indicated in bold, roughly 90 % of Min and Max limits changed. The direction of change is indicated with arrows, showing that some plausible ranges narrowed, other widened while for other parameters the plausible range shifted downwards or upwards. In any case, this process seriously improves the adequacy of the plausible limits for forest soil research at the European level. Hence, this new ranges become a useful tool for database managers, data investigators and modellers.
While the plausible ranges in Table 3.5.2 are applicable at the EU level, countries or regions may benefit from more suitable plausible ranges when developed on a regional basis. We recommend to take into account results from at least 500 regional samples to develop reliable ranges.

Table 3.5.2. Revised plausible ranges for organic and mineral forest soil samples at the European level, based on BioSoil$^+$ data. The 95 % range is determined by the 2.5 to 97.5 percentile interval of all reported observations. Percentiles are based on Regression on Order Statistics (ROS) taking into account left-censored data (< LOQ). The number of decimal places indicates the required precision for reporting. Values in bold are modifications compared to Part XVI on QAQC in laboratories of the ICP Forests Manual (König et al. 2010). The symbol ↑ or ↓ indicate an increase or a decrease compared to the list from part XVI of the ICP Forests manual.

Parameter	Unit	Organic sample*			Mineral soil sample**		
		LOQ	Min	Max	LOQ	Min	Max
Moisture content	%wt	0.1	<0.1	10	0.1	<0.1	10
Particle size: clay	%wt	-	-	-	**0.5**	0.5	**51.3↓**
Particle size: silt	%wt	-	-	-	**0.5**	**1.5↑**	**73.0↓**
Particle size: sand	%wt	-	-	-	**0.5**	**4.0↑**	100
Bulk density[1]	kg m^{-3}	-	50	800	-	**380↑**	1800
pH-$CaCl_2$	-	-	**2.6↑**	**6.9↓**	-	**2.9↑**	**7.7↓**
pH-H_2O	-	-	**3.3↑**	**6.9↓**	-	**3.7↑**	**8.4↓**
$CaCO_3$	g kg^{-1}	3	**0↓**	**360↓**	3	**0↓**	**660↓**
Organic carbon	g kg^{-1}	1.2	**93.0↓**	**590.0↑**	1.2	**0.4↓**	**150.0↓**
Total N	g kg^{-1}	0.5	**4.3↑**	**32.0↑**	0.1	**0.05↓**	**10.0↓**
Free H^+	$cmol_+$ kg^{-1}	**0.1**	**0.10↑**	**17.50↑**	**0.1**	**<0.10↓**	3
Exchangeable acidity	$cmol_+$ kg^{-1}	**0.1**	**0.05↓**	**22.50↑**	**0.1**	**0.05↓**	**11.80↑**
Exchangeable K	$cmol_+$ kg^{-1}	**0.03**	**0.01↓**	**5.30↑**	**0.03**	**0.006↓**	**1.30↓**
Exchangeable Ca	$cmol_+$ kg^{-1}	**0.03**	**0.17↓**	**146.00↑**	**0.03**	**0.005↓**	**47.00↑**
Exchangeable Mg	$cmol_+$ kg^{-1}	**0.03**	0.19	**21.50↑**	**0.03**	**0.002↓**	**7.15↑**
Exchangeable Na	$cmol_+$ kg^{-1}	0.03	**0.005↓**	**2.35↑**	**0.03**	**0.002↓**	**0.45↓**
Exchangeable Al	$cmol_+$ kg^{-1}	**0.02**	**0.002↓**	**16.60↑**	**0.02**	**0.018↓**	**9.00↑**
Exchangeable Fe	$cmol_+$ kg^{-1}	**0.02**	**0.0001↓**	**5.20↑**	**0.02**	**0.0004↓**	**0.70↓**
Exchangeable Mn	$cmol_+$ kg^{-1}	**0.02**	**0.0005↓**	**5.70↓**	**0.02**	**0.001↓**	**0.70↓**
Extractable P	mg kg^{-1}	**35**	**80.0↑**	**2100.0↓**	**35**	**35.0↓**	**1320.0↓**
Extractable K	mg kg^{-1}	**80**	**4.0↓**	**5900.0↑**	**80**	**100.0↑**	**9250.0↓**
Extractable Ca	mg kg^{-1}	**50**	**210.0↑**	**50000.0↓**	50	**20↓**	**140000.0↓**
Extractable Mg	mg kg^{-1}	**35**	**120.0↑**	**7600.0↓**	**35**	**75.0↑**	**30500.0↓**
Extractable S	mg kg^{-1}	**20**	**460.0↑**	**6750.0↓**	**20**	**10.0↓**	**1100.0↓**
Extractable Na	mg kg^{-1}	**20**	**4.0↓**	**540.0↓**	**20**	**12.0↓**	**650.0↓**
Extractable Al	mg kg^{-1}	**10**	**140.0↑**	**26000.0↓**	**10**	**1100.0↑**	**55250.0↑**
Extractable Fe	mg kg^{-1}	**10**	**140.0↑**	**42500.0↓**	**10**	**880.0↑**	**62500.0↓**
Extractable Mn	mg kg^{-1}	**2**	**0.8↓**	**3600.0↓**	**2**	**8.0↑**	**1950.0↓**
Extractable Cu	mg kg^{-1}	**1**	**0.2↓**	**75.0↓**	**1**	**0.3↓**	**55.0↓**
Extractable Pb	mg kg^{-1}	**2.5**	**0.03↓**	**245.0↓**	**2.5**	**1.0↓**	**110.0↓**
Extractable Ni	mg kg^{-1}	**1**	**0.06↓**	**45.0↓**	**1**	**0.5↓**	**80.0↓**
Extractable Cr	mg kg^{-1}	**1**	**0.1↓**	**95.0↓**	**1**	**1.0↓**	**80.0↓**
Extractable Zn	mg kg^{-1}	2	**0.8↓**	**300.0↓**	**2**	**2.5↑**	**165.0↓**
Extractable Cd	mg kg^{-1}	0.5	**<0.01↓**	**2.2↓**	0.5	**<0.01↓**	**2.5↓**
Extractable Hg	mg kg^{-1}	**0.03**	**<0.01↓**	**1.65↓**	**0.03**	**0.02↓**	**2.25↑**
Total K	mg kg^{-1}	**80**	**50.0↓**	**25000.0↑**	**80**	**2000↑**	50000
Total Ca	mg kg^{-1}	**50**	**50.0↑**	**65000.0↑**	**50**	**350.0↑**	**200000.0↓**
Total Mg	mg kg^{-1}	**35**	**100.0↑**	**42000.0↑**	**35**	**180.0↑**	**42000.0↓**
Total Na	mg kg^{-1}	20	<20.0	**15000.0↑**	20	**400.0↑**	**20000.0↑**
Total Al	mg kg^{-1}	**10**	**100.0↑**	50000	**10**	**4000.0↑**	100000
Total Fe	mg kg^{-1}	**10**	**100.0↑**	**25000.0↓**	**10**	**700.0↑**	**65000.0↓**
Total Mn	mg kg^{-1}	**2**	**20.0↑**	**3500.0↓**	**2**	**15.0↑**	**2000.0↓**
Reactive Al	mg kg^{-1}	**50**	**90↑**	**12500↑**	**50**	**170↑**	**10300↑**
Reactive Fe	mg kg^{-1}	**50**	**170↑**	**40000↑**	**50**	**100↑**	**13000↑**

** Organic samples comprise those of OL, OF, OH, OFH, Hf, Hs, Hfs, H05, H51, H01, H12, H24 and H48 layers*
*** Mineral samples comprise those of M01, M12, M24 and M48 layers*
[1] Bulk density was added to the plausible range list

3.6 Multivariate analysis

3.6.1 Introduction

This section describes inherent relationships among measured soil variables. As for the univariate analysis, we discriminate between forest floor, mineral soil and peat layers since the composition and nature of each of these layers reveal different correlations patterns. We do not consider the factor depth in this multivariate analysis when showing and discussing relationships among variables. We focus also on the Level I data only to avoid bias due to the merely averaged data of Level II plots. Since Level I is the far most extensive dataset, relationships found for Level I data will certainly apply for Level II data too.

The analysis is generally conducted in two steps: first an overall probabilistic principal component analysis (PPCA) is performed using all reported soil variables for all samples. Secondly, variables are grouped (e.g. exchangeable elements, macro elements, trace metals) to find the major explaining variables and specific interrelationships among them within each group. For each of these groups we computed non-parametric Spearman correlation matrices using all available data. The applied statistical methods are discussed in Section 2.8.

3.6.2 Forest floor samples

3.6.2.1 Overall analysis

Over 7000 forest floor samples were characterised by thirty variables (Table 3.6.1). Some variables were not analysed systematically which explains that about 33 % of the values are missing making the dataset incomplete. However, because of the large sample number, these NA values could be imputed by probabilistic PCA so that a robust analysis of all variables was still possible.

An initial PPCA revealed 4 extreme outlying samples: one from Poland (plot 53_1440682) with extremely elevated extractable Ca concentration in the OL layer and three plots in Sweden (13_3666, 13_1463 and 13_774) with respectively a very high Zn concentration in OFH, a very high Al concentration in OF and an elevated Zn level in OH. These 4 samples were omitted from the PPCA study, but were still used for correlation analysis since *Spearman* correlation is *not* sensitive to *outliers.* The variables and their loadings for the first five principal components (PC) are given in Table 3.6.1.

These 5 components together explain ~59 % of all variance. All other PCs each accounted for less than 5 % of the total variance. Table 3.6.1 indicates that pH-H_2O and pH-$CaCl_2$ along with extractable Ca and K have the highest positive loadings for the first component (PC1), and their counterparts exchangeable acidity, free H^+ and exchangeable Al and Fe the most negative loadings. Hence, PC1 may be interpreted as an acidity gradient.

Table 3.6.1. The loadings for the first 5 PCs of all Level I forest floor samples

	PC1	PC2	PC3	PC4	PC5
ORGLAY	-0.110	0.275	-0.188	0.454	-0.083
PHCACL2	0.316	-0.020	0.104	0.074	-0.018
PHH2O	0.339	-0.032	0.039	0.106	-0.009
OC	-0.135	-0.458	-0.028	-0.069	-0.081
TON	-0.045	-0.422	-0.253	0.130	0.101
EXCHACID	-0.270	-0.028	-0.219	-0.111	-0.107
EXCHAL	-0.188	0.077	-0.332	-0.012	-0.095
EXCHCA	0.277	-0.154	-0.004	0.145	-0.055
EXCHFE	-0.149	0.016	-0.304	-0.023	-0.105
EXCHK	0.136	-0.253	0.015	-0.259	-0.002
EXCHMG	0.222	-0.211	0.003	0.055	-0.067
EXCHMN	0.023	-0.097	0.056	-0.163	0.454
EXCHNA	0.036	-0.157	-0.062	-0.087	-0.246
FREEH	-0.226	-0.107	-0.045	-0.161	-0.200
EXTRAL	0.248	0.214	-0.287	0.016	-0.028
EXTRCA	0.283	-0.148	0.091	0.199	-0.155
EXTRCD	0.021	-0.023	-0.089	0.232	0.145
EXTRCR	0.165	0.198	-0.194	-0.433	-0.014
EXTRCU	0.048	-0.008	-0.169	-0.052	0.034
EXTRFE	0.170	0.254	-0.335	0.084	0.159
EXTRHG	-0.018	0.058	-0.102	0.067	0.063
EXTRK	0.279	0.002	-0.094	-0.136	-0.057
EXTRMG	0.252	0.026	-0.062	0.145	-0.151
EXTRMN	0.070	-0.046	0.026	-0.037	0.596
EXTRNA	0.205	-0.106	-0.120	-0.124	-0.292
EXTRNI	0.183	0.143	-0.227	-0.410	0.022
EXTRP	0.012	-0.246	-0.325	-0.022	0.249
EXTRPB	-0.007	0.011	-0.168	0.186	0.123
EXTRS	0.021	-0.279	-0.353	0.182	-0.003
EXTRZN	0.034	-0.037	-0.048	0.059	0.097

This information may be also inferred from Figure 3.6.1. This biplot represents both the observations (samples as grey dots) and the variables (soil parameters as red vectors) according to the first and second PC, together accounting for 39 % of the total variation. Projections of scores with the 3rd PC are given in Figure 3.6.2 along with their percentage of explained variance mentioned next to the axis labels.

Carbon, nitrogen, sulphur and phosphorus concentration all contribute most to PC2, which is clearly a trophicity component. The more macronutrients, the lower the organic layer mass which is in line with expectation. Figure 3.6.1 also shows that organic forest floor layer mass is related both to more acid conditions and low nutrient concentrations.

The third PC is mainly determined by extractable Fe, S, Al and P, suggesting that these elements are associated in phosphates and sulphates. PC4 seems to be explained most by its Cr and Ni contributions while PC5 has high negative loadings of both extractable and exchangeable manganese. No biplots were constructed or shown using PCs 4 and 5. The correlations within specific groups of variables are analysed in following chapters.

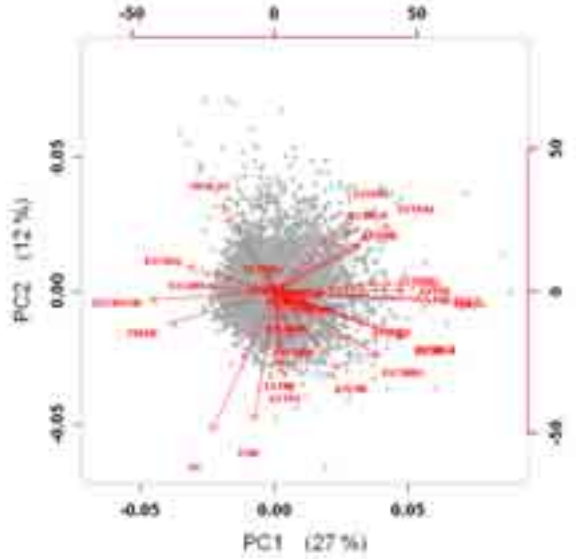


Figure 3.6.1. PPCA biplot of PC1-2 forest floor samples and their variables

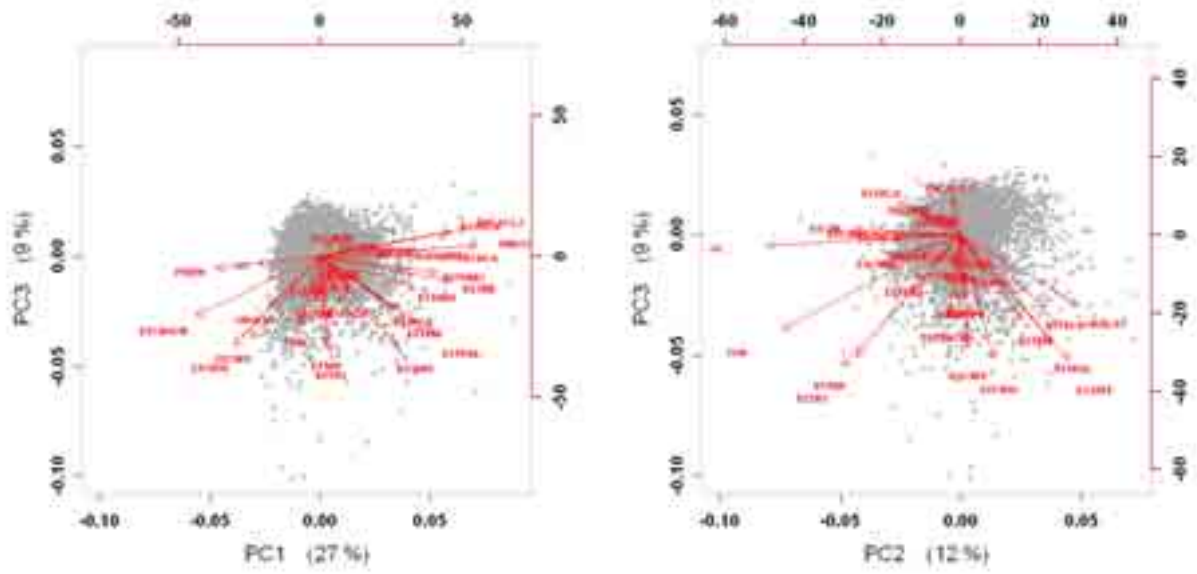


Figure 3.6.2. PPCA biplots of PC1-3 (left) and PC2-3 (right) of forest floor samples and their variables

3.6.2.2 Analysis according to variable groups

Exchangeable elements

Nine variables characterising the exchangeable element pool in forest floors are analysed on 3462 samples according to the multivariate PPCA and bivariate correlation approach. We discarded 3 extreme outliers prior to PPCA, but not for the Spearman correlations. These outliers are an OFH sample from GB plot 6_150 which had an extremely high exchangeable Mg concentration (highest of all EU BioSoil^{+} observations), another OFH sample high in Mg concentration of the Austrian plot 14_174 and a maximum observation value for exchangeable K in the OF of Estonian plot 59_4.

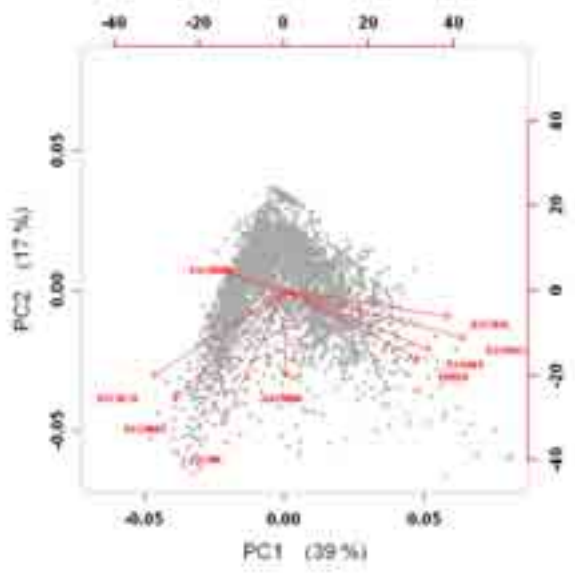


Figure 3.6.3. PCA biplot of forest floor samples with exchangeable elements within PC1-2

About 69 % of the total variation is accounted for by the first three PCs, and 56 % of all variation by the first two (Figure 3.6.3). Exchangeable acidity, its main components (exchangeable Al and Fe) and free H^+ received the highest weight on PC1, while the base cations (exchangeable K, Mg, Na and Ca) show strong negative loadings on PC2. PC3 (not shown) is mainly determined by exchangeable Mn, which apparently provides supplementary information than other acidifying or basic cations on the exchange complex of forest floors. The sample cloud in biplot PC12 has a 'two-legs' shape, one right-'leg' grouping all acidified forest floor samples, and a left leg grouping the FFs rich in base cations. Samples depleted in base cations but also relatively low in exchangeable Fe and Al also occur, and some these have high exchangeable Mn concentrations.

The correlation matrix (Figure 3.6.4) confirms a high correlation among exchangeable acidity, free H^+, exchangeable Al and Fe, but not with Mn.

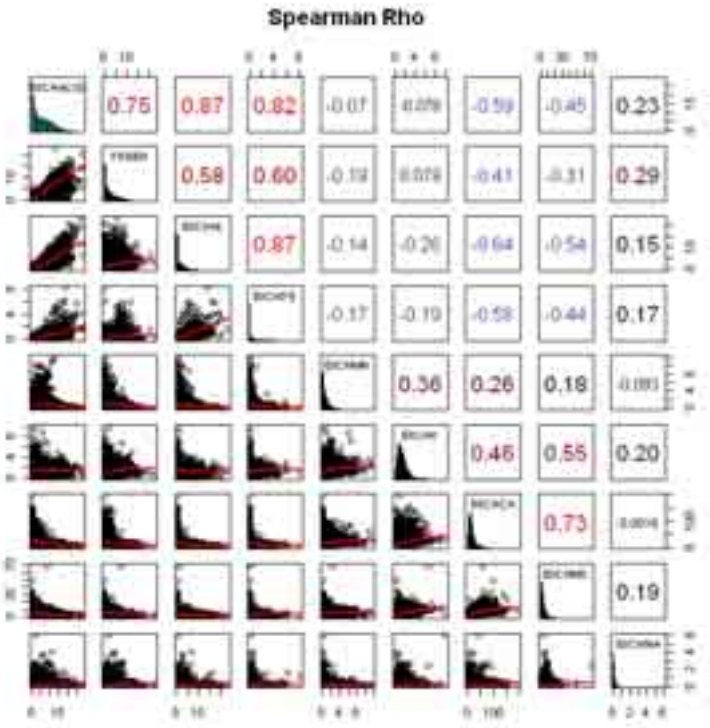


Figure 3.6.4. Correlation matrix scatterplot with LOWESS regression line (in red) for exchangeable elements in forest floors

The latter seems slightly higher and positively correlated with base cations K, Ca and Mg unlike with Na. Best correlated variables are exchangeable acidity, exchangeable Al and Fe at the one hand and exchangeable Ca and Mg at the other. Least or uncorrelated are exchangeable Mn, Ca and Na or between exchangeable K and free H^+ or exchangeable acidity.

Macro elements

Eight variables related to the macro-element pool in forest floors are analysed on 6477 samples by PPCA and Spearman correlation. This group consists of N, OC and the aqua regia extractable elements P, K, Ca, Mg, Na and S. About 14 % of missing values were found for this dataset, which could be imputed by PPCA.

After a first run with PPCA, six samples were obviously outliers distorting the principal component analysis. These were two Finnish samples, one OF layer on plot 11_761 with extreme high K concentration (maximum for BioSoil^{+}) and one OH sample on plot 11_1694 with extreme extractable Mg and Ca levels; two samples from Swedish plots 13_742 and 13_1463 with respectively an extreme S concentration in an Hs layer and elevated Mg concentration in an OF layer; one Polish plot (53_1440682) with an OL layer extremely rich in Ca, Mg, K and S; and finally a German plot in Saarland (412_10509) with also an OL layer with maximum values for extractable Ca, highest for all BioSoil^{+} observations. Results from these six samples were removed prior to PPC analysis, but taken into account for Spearman correlation.

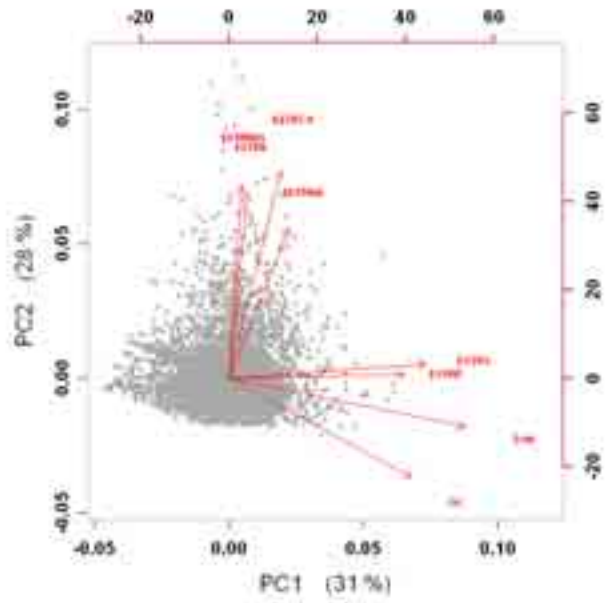


Figure 3.6.5. PCA biplot of forest floor samples with macro-elements within PC1-2

Fifty-nine percent of the total variation is accounted for by the first two PCs (Figure 3.6.5), and 79 % by the first three. Biogene elements as nitrogen, sulphur, carbon and phosphorus contribute most to PC1. The second PC is determined by the base elements (Ca, Mg, K, Na) which are well correlated. The third PC (not shown) has extractable P as its main contributor. So, ordination of forest floors may be effectively done by its N and S concentration (chemical trophicity) along PC1, its base richness along PC2 and its P concentration along PC3. The sample cloud reveals a high density of samples low in N and S and also in base cations.

Figure 3.6.6 shows predominantly positively correlated macronutrients, except for K and OC, Mg and OC or K and N. Best correlated are N and S, and the group K – Ca – Mg in contrast to most other correlations which are relatively low.

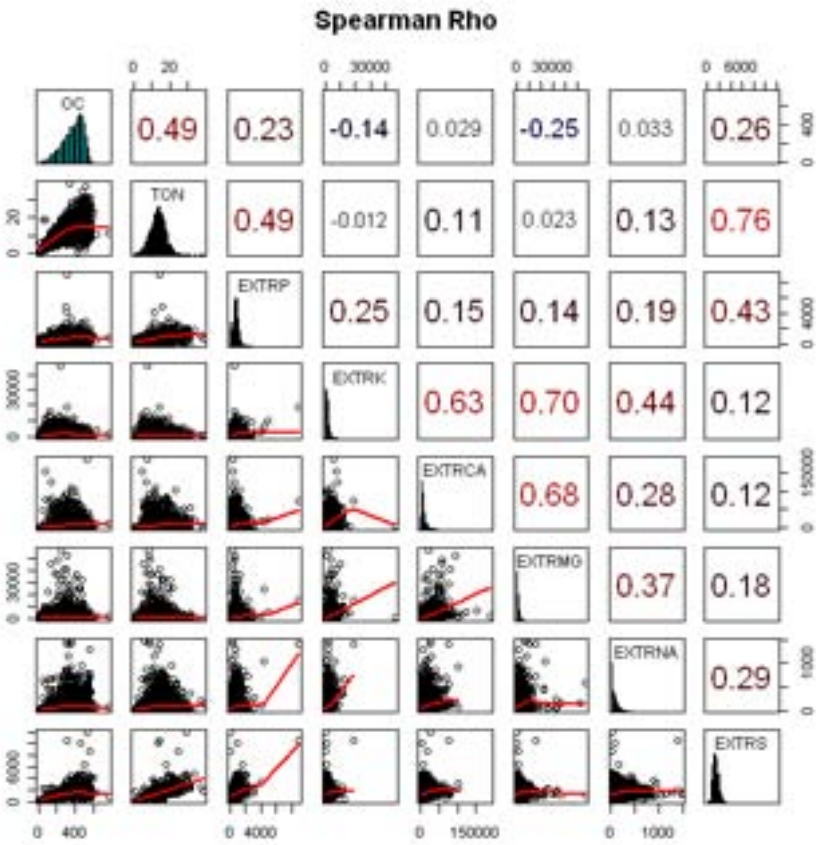


Figure 3.6.6. Matrix correlation scatterplot with LOWESS regression line (in red) for macro-elements in forest floors

Major and trace metals

Major (Al, Fe and Mn) and trace metals (Cd, Zn, Cu, Pb, Ni, Cr and Hg) were determined in 5902 forest floor samples by aqua regia extraction. In total, 9.8 % of all results were reported as missing values, mainly for extractable Hg. These were imputed by PPCA employing the available data. An initial run of this PPCA revealed eight obvious outliers, listed in Table 3.6.2. These observations should be double-checked by the NFCs if they are not erroneous. The eight outliers were removed prior to the final PPCA, unlike for the correlation study.

Table 3.6.2. Forest floor samples with extreme levels of metals according to probabilistic principal component analysis. The max value refers to the general statistics of the respective element in Annex II.

PLOT_ID	LAYER	Observation	BioSoil+ max
13_164	Hfs	Extreme high level of extractable Mn	Yes
13_1223	OF	Extreme high level of extractable Mn	No
13_3666	OFH	Extreme high level of extractable Zn	Yes
53_1440682	OL	Extreme high levels of extractable Al and Fe	Yes
59_102	Hs	Extreme high level of extractable Cu	Yes
60_279	OH	Extreme high level of extractable Pb	Yes
60_2200	OFH	Extreme high level of extractable Cd	Yes
402_1755	OFH	Extreme high level of extractable Pb	No

Without the outliers, about 70 % of all variation is explained by the first three PCs and 61 % by the first two (Figure 3.6.7). The biplot immediately shows two pairs of strongly correlated variables:

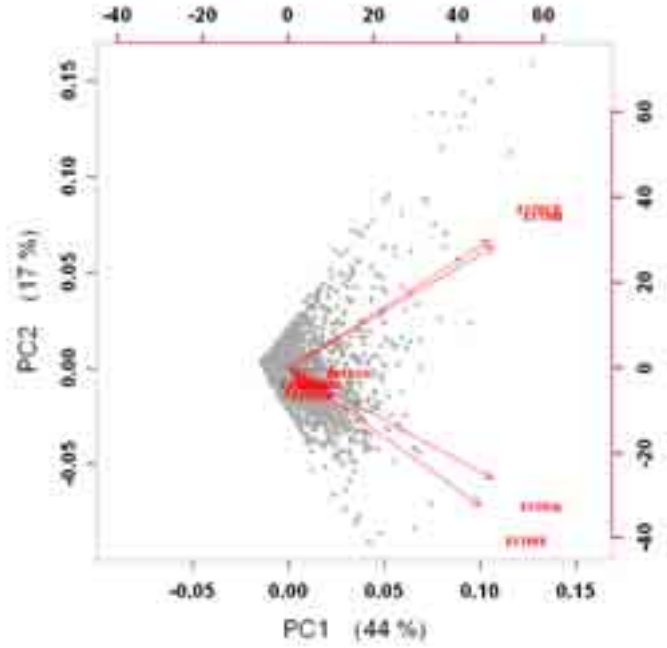


Figure 3.6.7. PCA biplot (PC12) of major and trace metals in forest floor samples

extractable Cr – Ni and extractable Al – Fe, which are tearing the sample cloud apart. Their strong covariation is confirmed in the Spearman correlation matrix (Figure 3.6.8). Another observation is that nearly all metals are positively correlated with each other.

PC1 is determined by all four of the dominant metals (Cr, Ni, Al and Fe) with almost equal loadings whereas PC2 discriminates between Cr and Ni at the positive end and Al and Fe at the negative end. Independently, PC3 is mainly determined by Zn, Pb and Mn concentrations. In general, Hg, Cu and Cd contribute marginally for explaining the variance of forest floor samples.

Figure 3.6.8 lists all Spearman correlations and draws LOWESS regression lines for all paired combinations of metals. Apart from Mn-Hg all correlations are positive. Especially Mn provides a very low correlation with Al, Fe, Pb and Hg. Most others are moderately correlated.

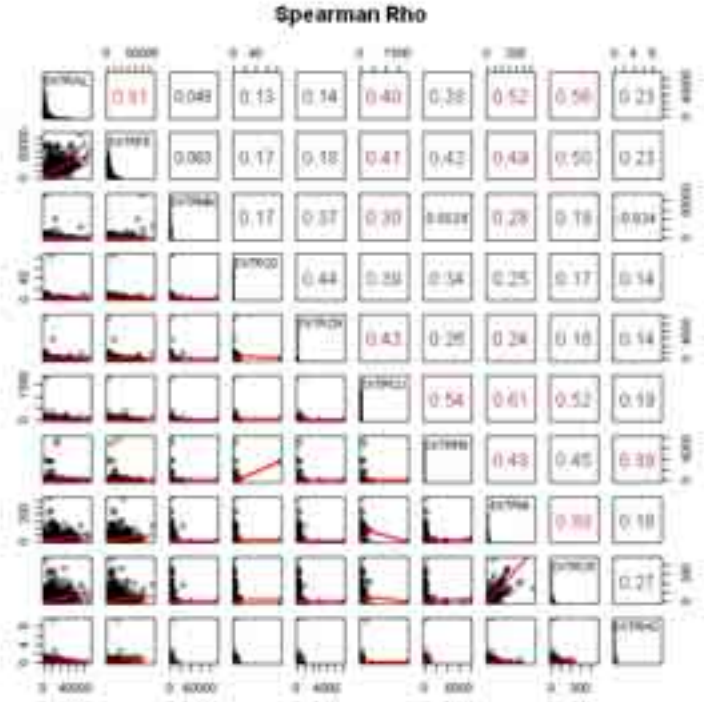


Figure 3.6.8. Matrix correlation scatterplot with LOWESS regression line (red) for major and trace metals in forest floor samples

3.6.3 Mineral soil samples

3.6.3.1 Overall analysis

Forty-five soil variables of 17680 soil samples were explored using PPCA. Three outlying samples all from the same plot (11_1596) were discarded from the PCA analysis. Their extremely high Pb and Zn concentrations (in all layers) distorted the analysis. The variables and their loadings for the first five principal components are given in Table 3.6.3. These 5 components together explain 65 % of all variance. All other PCs each accounted for less than 4 % of the variance.

Figure 3.6.9 represents a biplot of the data with the observations and the variables according to the first and second PCs, together accounting for 45 % of the total variation. Projections of scores with the 2nd and 3rd PC are given in Figure 3.6.10 along with their percentage of explained variance.

The first component is mainly determined by soil texture with fine textured soils (high clay and silt fraction) at the positive side (right) and sand at the negative side. Almost all extractable and exchangeable elements correlate with this clay and silt content, predominantly due to their exchange capacity and mineralogical composition. Negative (linear) contributions to PC1 are observed for bulk density mainly and free H^+, though negligible. This suggests that sandy samples have slightly higher BD than clay soils. So, PC1 is mainly a textural axis but associated with all nutrients inherently combined with it.

Table 3.6.3. The loadings for the first 5 PCs of all Level I mineral soil samples

	PC1	PC2	PC3	PC4	PC5
CLAY	0.224	-0.065	-0.063	0.270	-0.249
SILT	0.184	0.046	-0.269	0.085	-0.351
SAND	-0.232	-0.001	0.216	-0.185	0.360
BD	-0.127	-0.222	-0.056	0.195	0.003
BDEST	-0.187	-0.232	-0.094	0.239	0.048
CFMASS	0.049	0.082	-0.181	-0.365	-0.161
CFVOL	0.110	0.029	-0.177	-0.292	0.097
PHCACL2	0.159	-0.323	0.095	-0.131	-0.089
PHH2O	0.165	-0.333	0.102	-0.100	-0.061
OC	0.188	0.193	0.340	-0.103	-0.161
TON	0.214	0.142	0.325	-0.077	-0.116
CARBONATES	0.011	-0.089	0.019	-0.157	-0.126
EXCHACID	0.009	0.375	0.053	0.190	-0.049
EXCHAL	0.021	0.370	-0.047	0.128	-0.054
EXCHCA	0.208	-0.177	0.261	-0.055	-0.153
EXCHFE	0.019	0.276	0.128	0.026	-0.114
EXCHK	0.148	-0.052	0.289	0.191	0.185
EXCHMG	0.177	-0.122	0.183	-0.006	-0.099
EXCHMN	0.073	0.104	0.000	0.281	-0.039
EXCHNA	0.111	-0.048	0.191	0.101	0.352
FREEH	-0.005	0.141	0.328	0.212	0.070
EXTRAL	0.240	-0.021	-0.109	0.071	0.040
EXTRCD	0.104	0.018	-0.011	-0.113	0.082
EXTRCR	0.190	-0.032	-0.094	0.136	0.201
EXTRCU	0.161	-0.031	-0.058	0.125	0.236
EXTRFE	0.226	0.054	-0.188	0.045	0.119
EXTRHG	0.057	0.073	-0.069	-0.050	0.048
EXTRK	0.187	-0.121	-0.044	0.105	-0.038
EXTRMG	0.143	-0.116	0.015	-0.156	-0.027
EXTRMN	0.174	-0.029	-0.135	0.107	0.074
EXTRNA	0.136	-0.055	0.053	-0.040	0.257
EXTRNI	0.176	-0.056	-0.101	0.134	0.215
EXTRP	0.190	0.063	0.013	-0.127	0.089
EXTRPB	0.017	-0.023	-0.009	0.130	-0.129
EXTRS	0.170	0.120	0.186	-0.103	-0.027
EXTRZN	0.162	-0.045	-0.053	0.129	-0.072
REACAL	0.124	0.133	-0.148	-0.260	0.161
REACFE	0.163	0.204	-0.137	-0.080	0.102
TOTAL	0.158	0.055	-0.094	-0.004	0.104
TOTCA	0.052	-0.125	0.065	-0.099	-0.085
TOTFE	0.179	-0.003	-0.081	0.025	0.066
TOTK	0.056	0.085	-0.065	-0.027	0.117
TOTMG	0.111	-0.063	-0.001	-0.061	0.051
TOTMN	0.138	-0.019	-0.080	0.046	0.050
TOTNA	0.034	0.101	-0.061	-0.056	0.126

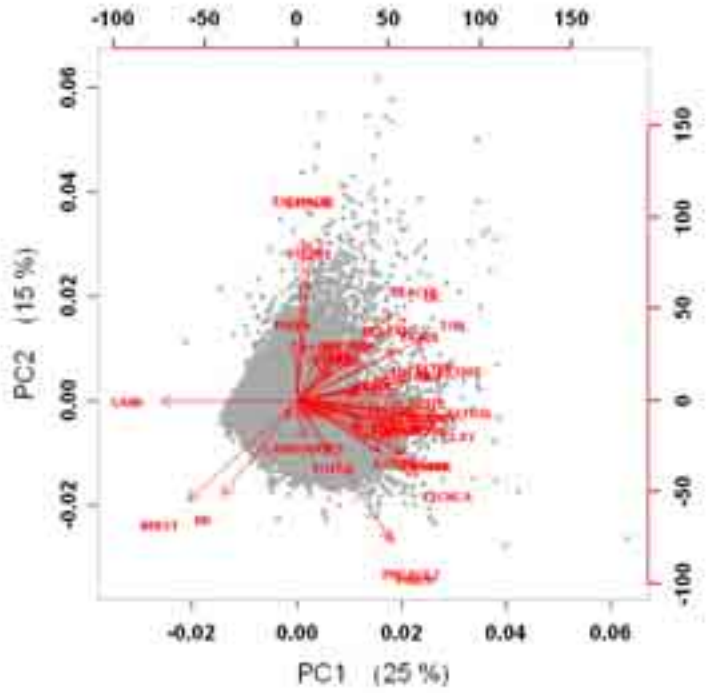


Figure 3.6.9. PPCA biplot of PC1-2 of mineral soil samples and their variables

This explains the high contribution of total nitrogen, phosphorus, calcium, potassium, iron, etc. to this PC1. Consequently, chemically 'poor' soil samples are found at the left side, 'rich' samples to the right.

Highest positive loadings for PC2 are related with soil acidity (exchangeable acidity, Al, Fe and free H^+) and as negative contributions soil reaction (both potential and actual pH), base cations and carbonates. This component may be understood as an acidity gradient, with samples in the upper half of the plot as the most acidified.

Thus, the PC1-2 plot discriminates fine textured acidified soil samples (upper right section) mostly associated with high N, S, reactive Fe and Al, and Mn concentrations from samples high in Ca, Mg and consequently pH (Figure 3.6.9).

The third component (PC3) is predominantly determined by organic matter (OC and TON) and free H^+ along its positive side (Figure 3.6.10). Organic rich samples are scattered towards the upper right corner of both plots.

So most of the samples' variation in multidimensional space is accounted for by (1) their textural and trophic properties, (2) their soil reaction and (3) their organic carbon content. Most informative variables in this respect are clay fraction, exchangeable acidity (or exchangeable Al) and organic carbon. All other variables are correlated with these to some extent. From the overlapping arrows in the plots it is clear that some variables are redundant for explaining variability: pH-H_2O and $CaCl_2$, estimated and measured BD, EXCHACID and EXCHFE, and that some variables are expected to be predicted well by others. For instance, BD and OC are negatively correlated, so this inverse relationship can be used for the development of pedo-transfer functions.

No biplots are given showing PCs 4 or 5. However, from Table 3.6.3. it may be inferred that coarse fragments content (both mass and volume) contribute most to PC4, which might discriminate stony samples and extractable and exchangeable Na are closely related to PC5, which might discriminate samples taken near the seaside from the rest.

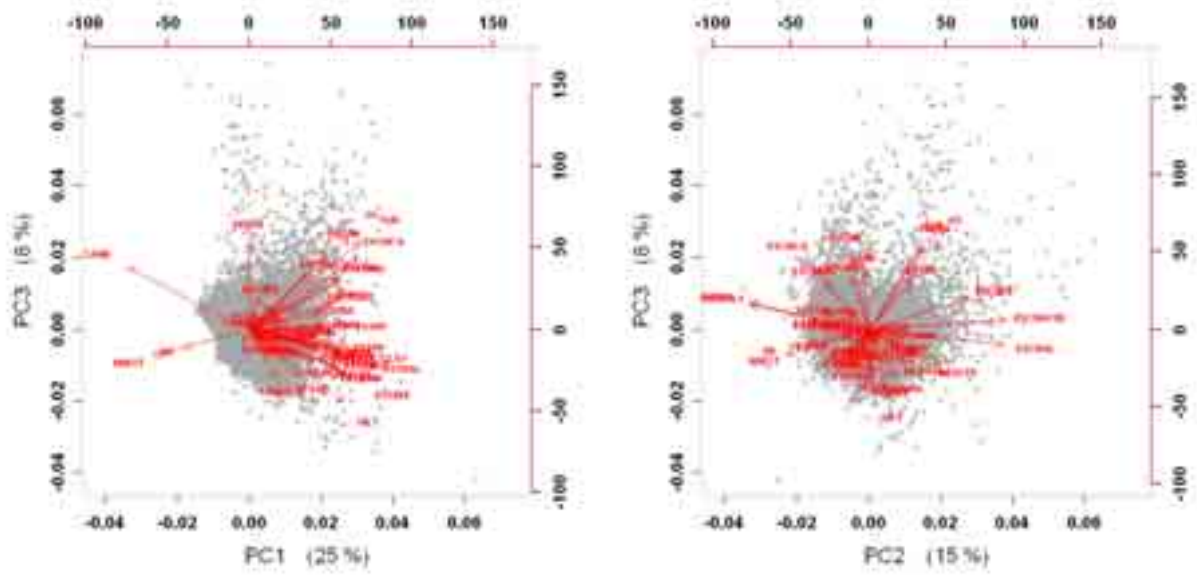


Figure 3.6.10. PCA biplots of PC1-3 (left) and PC2-3 (right) of 22 most reported soil variables of BioSoil+ in mineral soil samples

3.6.3.2 Analysis according to variable groups

Physical parameters

Soil physical variables as texture fractions, bulk density and coarse fragment content are analysed separately. For the PPCA 17375 soil samples could be used, while only 1024 samples had complete data (no missing values) for all 7 variables.

Due to the limited number of variables, 68 % of all variation is already explained by the first two components: 48 % by the first PC and 20 % by the second. Texture variables received clearly the highest weight on PC1, coarse fragments content (mainly CF by volume) on PC2 while PC3 accounts most for bulk density. Next to the PC1-2 projection (Figure 3.6.11), a correlation scatterplot matrix is given (Figure 3.6.12). From both figures it is clear that measured and estimated BD are closely correlated, evidenced by a high Spearman correlation coefficient. A slightly weaker correlation is found for coarse fragments content by mass and volume. Both relationships are further discussed in Volume II of this report.

Conversely, BD seemed poorly correlated with either one soil texture fraction (Rho < 0.2) although BD increases with sand fractions higher than roughly 70 % or silt fractions below ~30 % .

Coarse fragments are also poorly correlated with soil texture (apparently CF by mass more than CF by volume) and weakly negatively correlated with bulk density. So fine earth bulk density decreases with increasing CF content, which is in line with other work (Volume II).

In all, it may be concluded that all three components (texture, BD and CF) provide complementary information on physical soil condition and thus all three remain quite essential to determine.

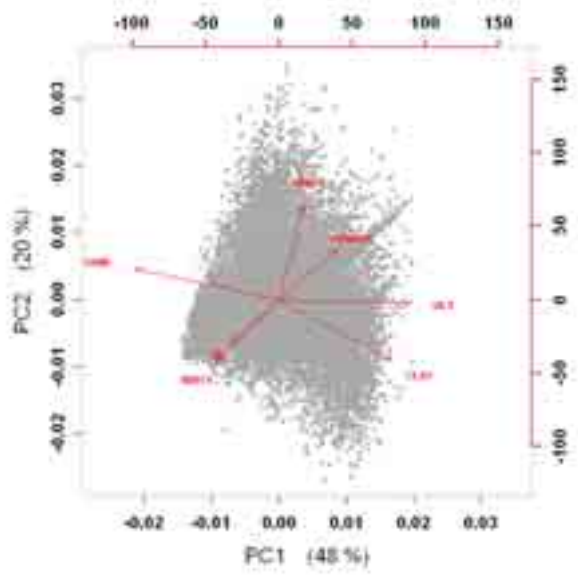


Figure 3.6.11. PCA biplot (PC12) of seven reported physical soil parameters in mineral soil samples

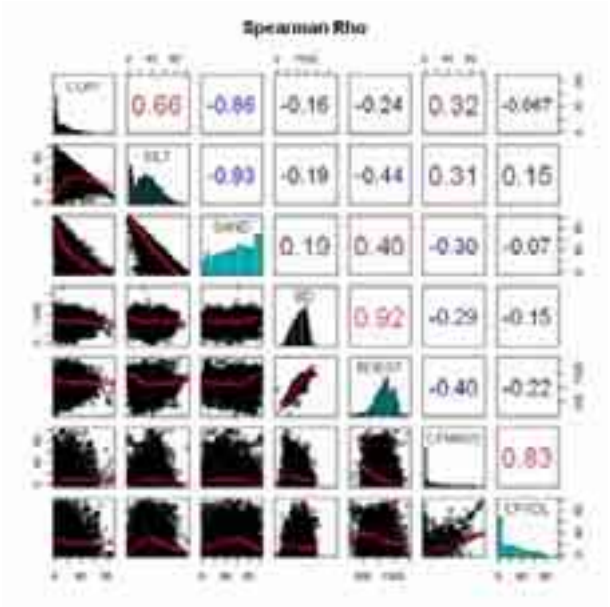


Figure 3.6.12. Matrix correlation scatterplot with lowess regression line (red) for physical soil parameters in mineral soil samples

Exchangeable elements

Nine variables related to the exchangeable element pool are analysed on 15633 samples according to the multivariate PPCA and bivariate approach. Sixty-seven percent of the total variation is accounted for by the first three PCs, and over half of all variation by the first two (Figure 3.6.13).

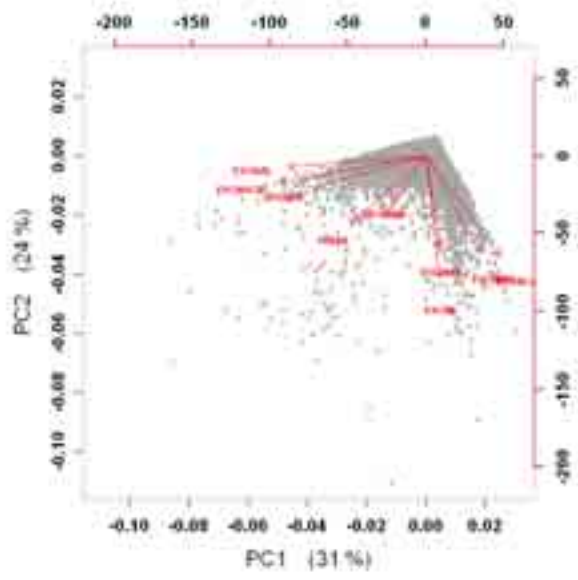


Figure 3.6.13. PCA biplot of mineral soil samples with exchangeable elements within PC1-2

Exchangeable acidity and its main components (exchangeable Al and Fe) received the highest negative weight on PC1, while the base cations (exchangeable K, Ca, Mg and Na) strongly determine PC2. PC3 (not shown) is mainly determined by exchangeable Mn, which apparently provides other information than exchangeable Fe and Al in soils.

The correlation matrix (Figure 3.6.14) reveals a much higher correlation between exchangeable acidity and exchangeable Al than with exchangeable Fe and even less with exchangeable Mn. So, only EXCHAL may be a reliable proxy for exchangeable acidity. As indicated in both PCA and correlation matrix the base cations are reasonably well correlated to each other, least with Na. In contrast, acidifying and base cations are mutually exclusive on the soil exchange complex and correlate negatively which is in line with expectation.

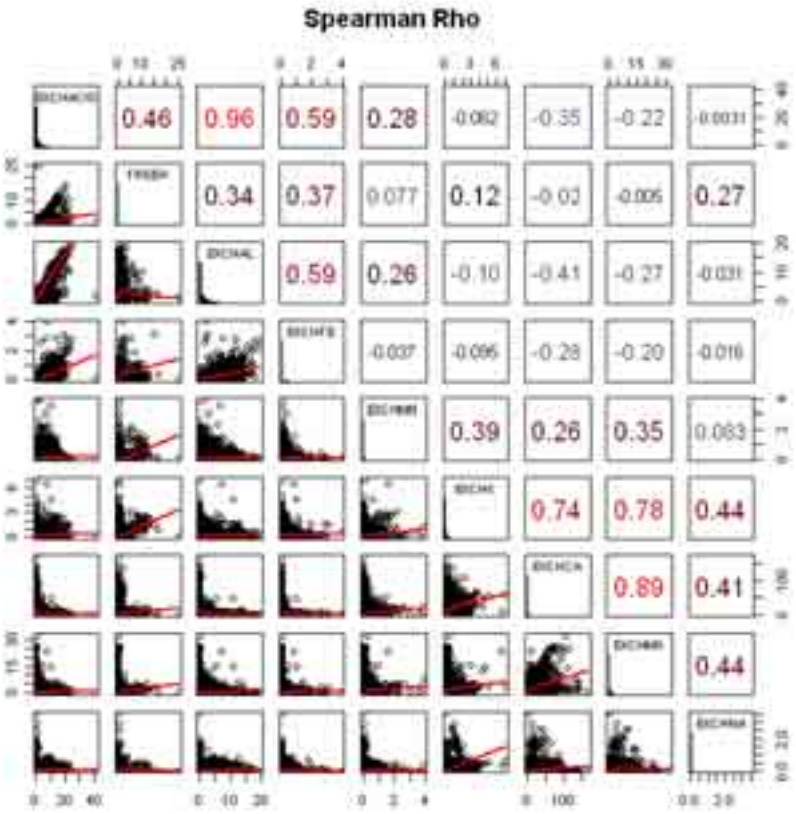


Figure 3.6.14. Matrix correlation scatterplot with LOWESS regression line (in red) for exchange parameters in mineral soil samples

This is not the case for exchangeable Mn that seems to correlate positively with base cations. EXCHMN is related to fine-textured soils which generally have more base cations on their complex than poor sandy soils, which may partially explain this correlation. Another strange finding is the slight positive correlation between free H^+ and both the monovalent cations Na and K, while there is no correlation with the bivalent cations.

Total elements

For only 1962 samples out of 17888 mineral samples 7 total elements were determined, so the relationships are based on a restricted dataset (see data availability for the origin of the samples). The first three components explain 77 % of all variation, with the contribution of the first three PCs being 39, 23 and 15 % of all variance. The projection of PC1-2 is shown in Figure 3.6.15.

All elements seem to be positively correlated, some of them very poorly like calcium and potassium or sodium and calcium, others quite strongly like total Al, Fe and Mg. Figure 3.6.16 shows the bivariate patterns in the dataset. Total aluminium contributes most to the first component , while total Ca and Mg contribute more to PC2 and PC3. The components are further difficult to interpret.

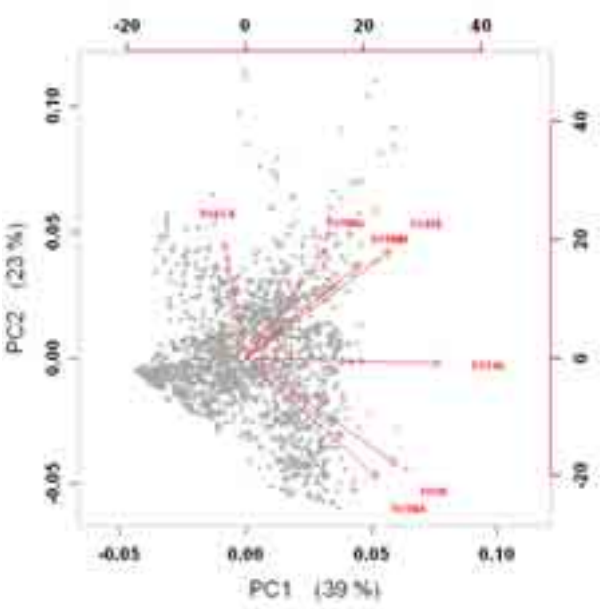


Figure 3.6.15. PCA biplot (PC12) of seven total elements in mineral soil samples

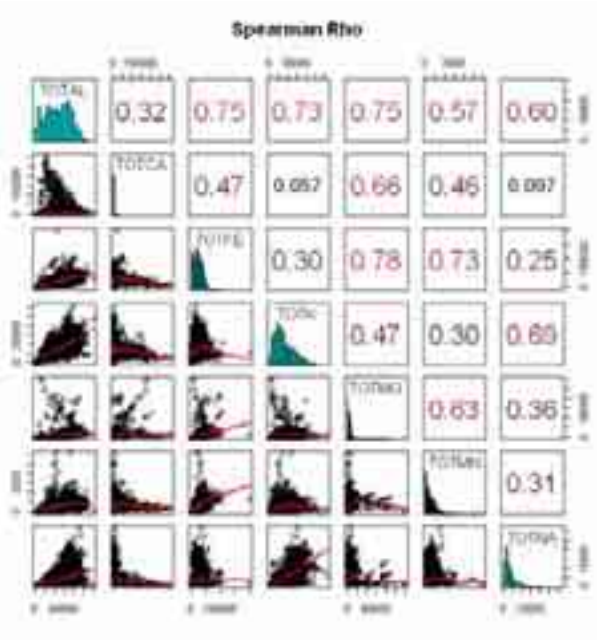


Figure 3.6.16. Matrix correlation scatterplot with LOWESS regression line (red) for total elements in mineral soil samples

Macro elements

Eight variables related to the macro-element pool in soil are analysed on 16884 samples by PPCA and Spearman correlation. Here, apart from N and OC, aqua regia extractable elements (semi-total concentrations) are considered instead of real total concentrations of these elements. Sixty-five percent of the total variation is accounted for by the first two PCs (Figure 3.6.17), and 76% by the first three. Biogene elements as nitrogen, carbon, sulphur and phosphor contribute most to PC1. From these, total N, C and S correlate best with each other and least with P (Figure 3.6.18). The second PC is determined by the base elements (Ca, Mg, K, Na) which are well correlated. The third PC (not shown) has extractable K as its main contributor. So, based on total elements mineral soil samples may be effectively ordinated using just OC and extractable Ca concentration. Figure 3.6.18 shows that all macro-elements are positively correlated with each other. However, except for C and N, the scatterplots do not reveal clear linear patterns, so that other factors (soil type, sampling) depth are needed to explain these scattered data.

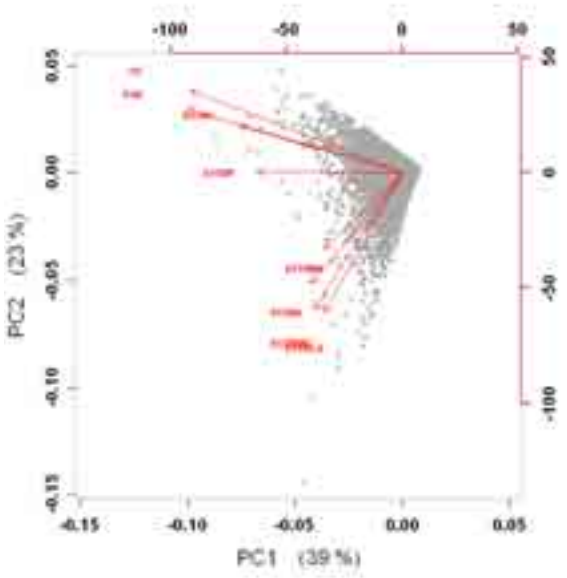


Figure 3.6.17. PCA biplot of mineral soil samples with macro-elements within PC1-2

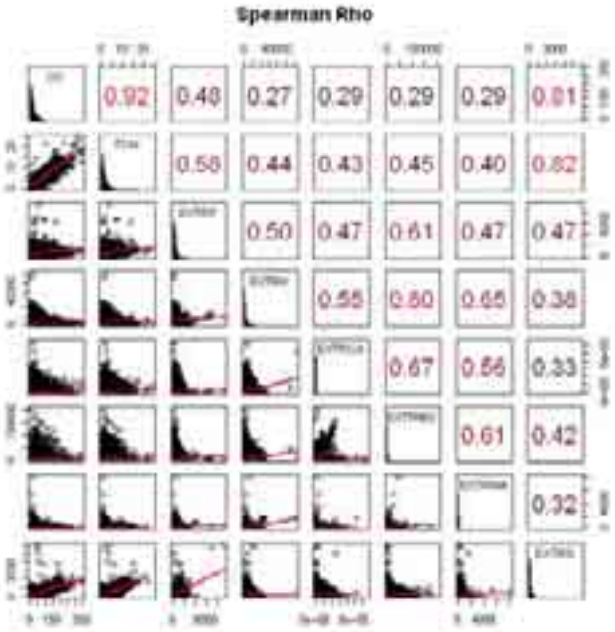


Figure 3.6.18. Matrix correlation scatterplot with lowess regression line (in red) for macro-elements in mineral soil samples

Major metals

Major metals were determined in 13215 samples and their relationships investigated. About 80 % of all variation is explained by the first 2 orthogonal components. PC1 is mainly determined by extractable Fe and Al, which are highly correlated (Figure 3.6.19). Extractable Mn contributes most to PC2 while reactive Fe and Al contribute most to PC3. Hence Mn is least correlated with reactive Al (Figure 3.6.20).

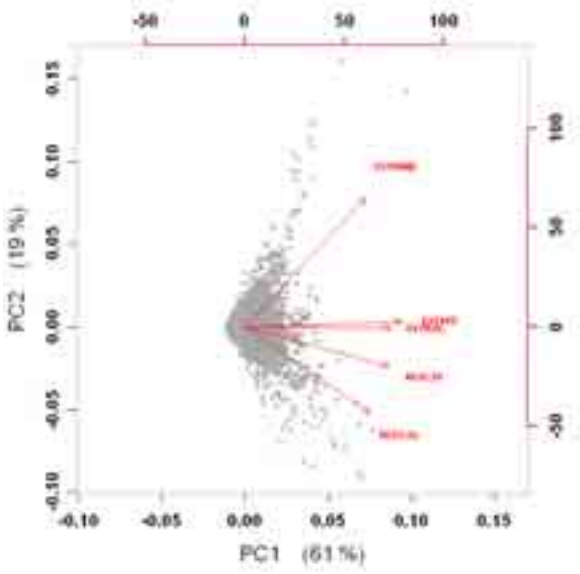


Figure 3.6.19. PCA biplot (PC12) of five major metals in mineral soil samples

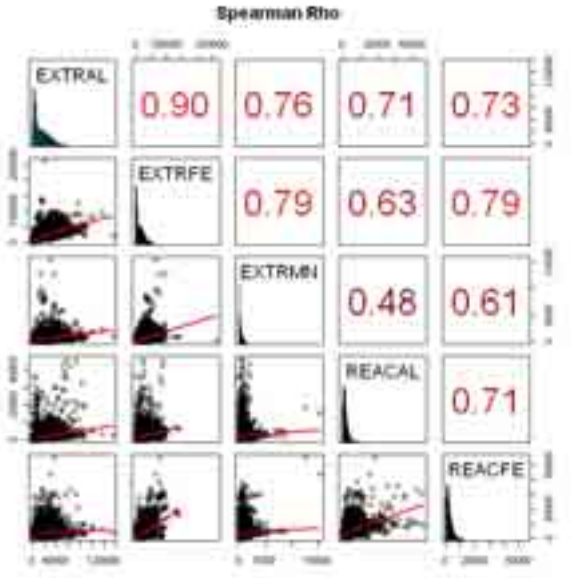


Figure 3.6.20. Matrix correlation scatterplot with LOWESS regression line (red) for major metals in mineral soil samples

Trace metals

In 10045 samples, seven trace metals were analysed. A first run of PPCA revealed 6 outlying samples. Three of them originated from plot 11_1596 with extremely high Pb* and Zn* levels, as already noticed in the overall analysis, high Pb and extremely high Cd* concentrations were found in the M05 layer of plot 60_2200, high Cu*, Ni and Cr* levels in M01 on plot 66_9, and high Ni and Cr levels in the M01 layer on plot 1_2118. A high level means at least greater than the $P_{97.5}$ value in the Tables of Annex II whereas an asterisk-flagged metal indicates the maximum reported value for that element of all analyses.

For the further PPCA these six samples were omitted, and the biplot in Figure 3.6.21 was produced. Again, some outlying samples are found originating from Italy (5_2002, 5_443, 5_305), Cyprus (66_8), France (1_2126), Germany (410_352), Slovenia (60_2553), Slovakia (54_87) and Sweden (13_746 and 13_1326). It shows that most countries have metal contaminated forest soils with elevated trace metal concentrations in one or more layers. An in depth evaluation of the trace metals concentrations is given in Volume II of this report.

About 84 % of all variation is explained by the first 3 orthogonal components, and 71 % by PC1-2. PC1 is mainly determined by the metals Ni, Cr, Cu and Zn, whereas Cd and Hg are the main contributors to the second PC. Extractable Cu is the most important contributor to the third PC. Note that Pb does not contribute to the first two PCs (Figure 3.6.21), neither to the PC3-5. Consequently Pb in mineral soils has little discriminating power among samples.

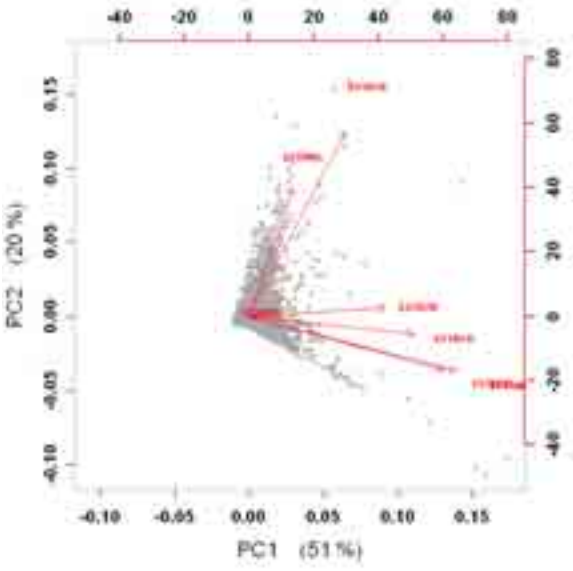


Figure 3.6.21. PCA biplot (PC12) of seven trace metals in mineral soil samples

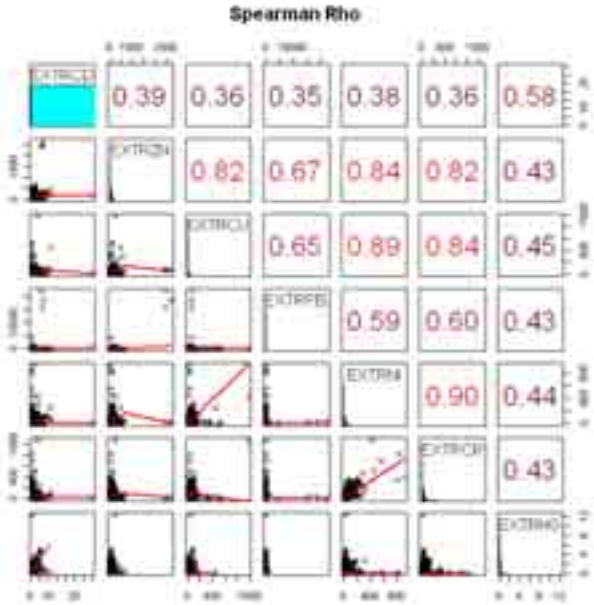


Figure 3.6.22. Matrix correlation scatterplot with lowess regression line (red) for trace metals in mineral soil samples

Some trace metals are highly correlated, like Ni and Cr. The Spearman correlation coefficients in Figure 3.6.22 indicate that if some trace metals are present in elevated levels, their correlated metals are likely to have elevated levels too. This is the case for the group Cr, Ni, Zn and Cu on the one hand and Cd and Hg on the other. However, care should be taken for the latter group since many observations are below LOQ for both of these elements.

3.6.4 Peat samples

3.6.4.1 Overall analysis

During BioSoil, 928 peat samples were reported and 878 of them hold data on all or a subset of the 31 variables listed in Table 3.6.4. Note that the list of 31 variables does not contain the variables BD (measured nor estimated), organic layer mass and carbonates since these were only reported for less than 20 % of the samples. The amount of missing data (NA values) for the 31 variables is ~15 % and these can be easily imputed by PPCA.

Table 3.6.4. The loadings for the first 5 PCs of all Level I peat samples

Variable	PC1	PC2	PC3	PC4	PC5
PHCACL2	-0.330	0.127	-0.089	0.022	-0.006
PHH2O	-0.320	0.130	-0.089	0.000	-0.001
OC	0.227	0.178	0.184	0.290	0.128
TON	-0.124	0.078	0.156	0.466	0.203
EXCHACID	0.291	-0.196	0.066	0.059	-0.116
EXCHAL	0.132	-0.319	0.075	0.124	-0.171
EXCHCA	-0.264	0.220	-0.028	0.057	-0.016
EXCHFE	0.142	-0.211	0.109	0.267	0.013
EXCHK	0.118	-0.081	0.204	-0.026	0.117
EXCHMG	-0.071	0.176	0.324	0.014	-0.302
EXCHMN	-0.014	-0.091	0.152	0.120	0.119
EXCHNA	0.024	0.082	0.311	-0.077	0.397
FREEH	0.270	0.006	0.027	-0.031	-0.023
EXTRAL	-0.189	-0.326	0.002	-0.146	-0.117
EXTRCA	-0.261	0.210	-0.066	0.062	0.023
EXTRCD	-0.116	-0.233	0.030	-0.260	0.278
EXTRCR	-0.191	-0.150	0.213	-0.091	-0.142
EXTRCU	-0.146	-0.149	0.223	0.017	-0.088
EXTRFE	-0.212	-0.222	-0.085	0.208	0.006
EXTRHG	-0.125	-0.098	-0.081	0.087	-0.030
EXTRK	-0.163	-0.229	0.219	-0.262	-0.012
EXTRMG	-0.237	0.093	0.182	-0.199	-0.114
EXTRMN	-0.064	-0.069	-0.322	0.058	-0.034
EXTRNA	-0.028	0.033	0.368	-0.088	0.350
EXTRNI	-0.182	-0.141	0.261	-0.039	-0.060
EXTRP	-0.144	-0.285	0.031	0.307	0.042
EXTRPB	-0.005	-0.095	-0.241	-0.059	0.427
EXTRS	-0.186	0.054	0.085	0.240	0.217
EXTRZN	0.002	-0.170	-0.217	-0.234	0.357
REACAL	-0.017	-0.289	-0.009	0.022	-0.038
REACFE	-0.157	-0.207	-0.142	0.315	0.029

The first 5 components explain 24, 12, 8, 8 and 6 % respectively or 58 % of the total variance together. The variables and their loadings for the first five principal components are given in Table 3.6.4.

Figure 3.6.23 represents a biplot of the first 2 principal components. Projections of scores with the 2nd and 3rd PC are given in Figure 3.6.24 along with their percentage of explained variance.

The first component is mainly determined by acidity related variables: pH-$CaCl_2$, pH-H_2O (overlapping in Figure 3.6.23), exchangeable and extractable Ca and extractable Mg contribute positively and exchangeable acidity and free H^+ negatively. There loadings are shown in Table 3.6.4.

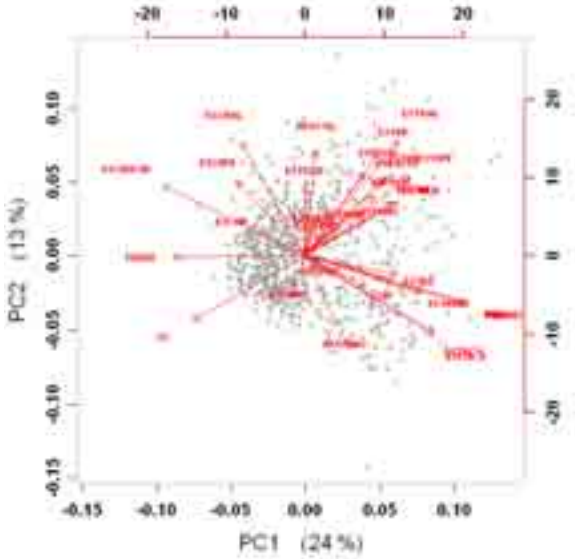


Figure 3.6.23. Overall PPCA biplot of peat samples with their variables

The strongest contributors to PC2 are Aluminium fractions (exchangeable, extractable and reactive Al). PC3 seems most determined by exchangeable and extractable Na at the negative side and extractable Mn at the opposite side (see Figure 3.6.24). The loadings for the 4th PC are predominantly nitrogen, reactive and exchangeable Fe and extractable P. Extractable Zn and exchangeable and extractable Na contribute most to the 5th PC, but this only explains 6 % of the variance. In all, the most important chemical variables for explaining variation in peat samples are pH, extractable or exchangeable aluminium, sodium and nitrogen.

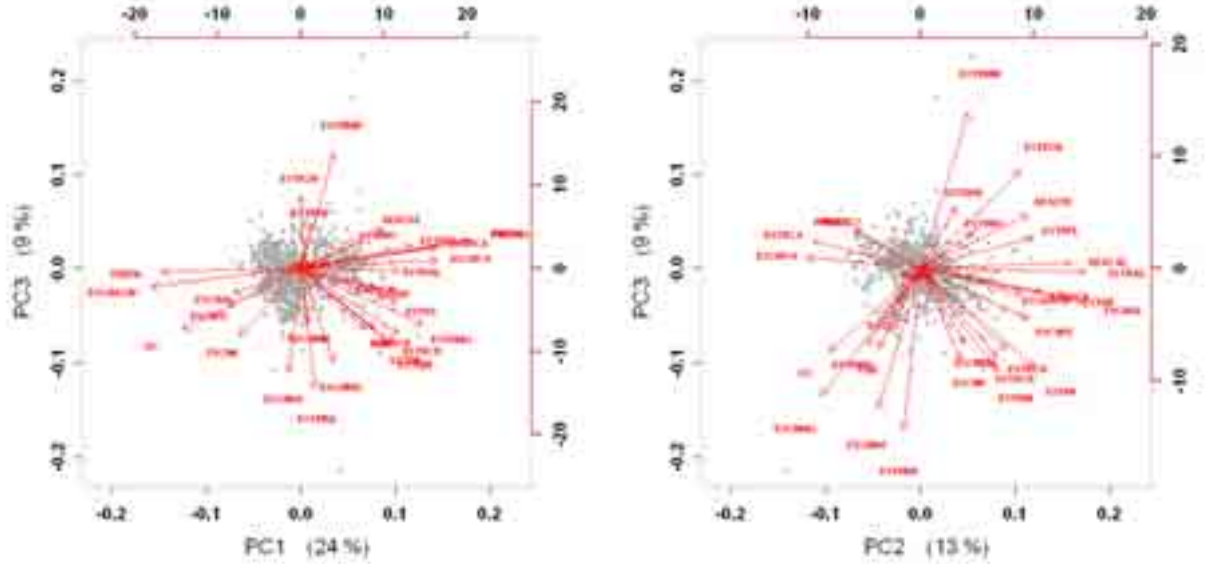


Figure 3.6.24. PCA biplots of PC1-3 (left) and PC2-3 (right) of 31 chemical variables of peat samples

3.6.4.2 Analysis according to variable groups

Exchangeable elements

Nine exchangeable elements were reported for exactly 756 peat samples, holding less than 1 % of missing data which were imputed by PPCA. The first three components explain 63 % of all variation while the first two exactly 50 %. The biplot in Figure 3.6.25 shows that exchangeable acidity, free H^+, exchangeable Fe and Al are important contributors to PC1, whereas exchangeable K and Mn have high loadings for PC2. Exchangeable Na does not contribute to PC1 nor PC2, but has highest contribution to PC3. In PC1-2 exchangeable Al is opposite to exchangeable Ca and Mg, which is also evidenced by high negative correlations in Figure 3.6.26. Except for Mn, it was found that exchangeable acidity, free H^+, Al and Fe are better correlated among each other than are the base cations.

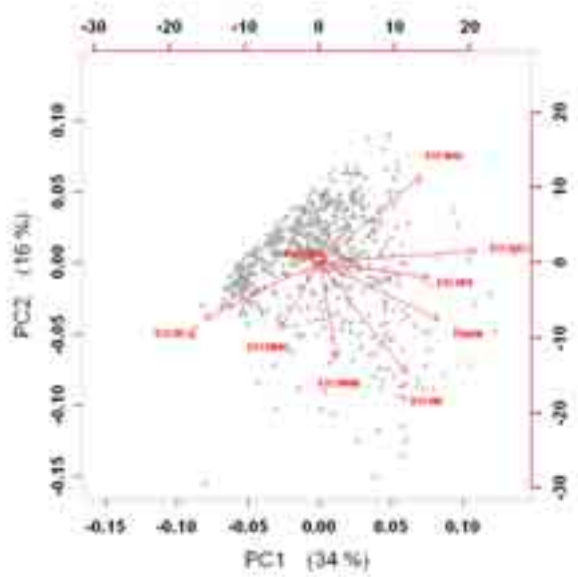


Figure 3.6.25. PCA biplot (PC12) of peat samples with exchangeable elements as vectors

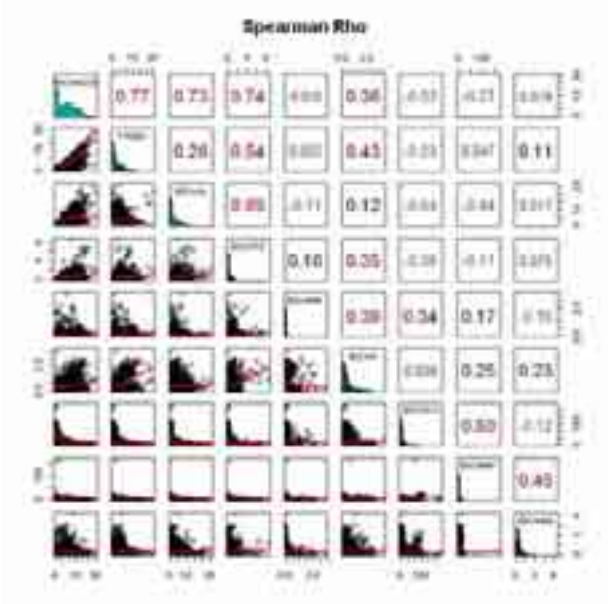


Figure 3.6.26. Matrix correlation scatterplot with LOWESS regression line (red) for exchangeable elements in peat samples

Macro elements

Eight variables related to the macro-element pool in peat layers are analysed on 877 samples by PPCA and Spearman correlation. About 7 % of all reported values were missing. Here, apart from N and OC, aqua regia extractable elements (semi-total concentrations) are considered instead of real total concentrations of these elements which were scarcely reported for peat layers. About 52 % of the total variation is accounted for by the first two PCs (Figure 3.6.27), and 65 % by the first three.

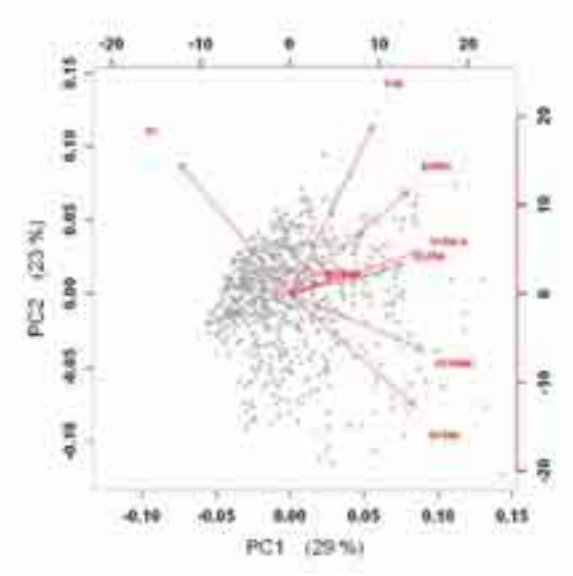


Figure 3.6.27. PCA biplot of peat samples with macro-elements according to 1st and 2nd PC

The principal loadings for the first PC are provided by extractable Mg, K, Ca, P, and S whereas merely TON and OC for PC2. The main contributor for PC3 is phosphorus while sodium for PC4.

When looking at bivariate correlations, Figure 3.6.28 learns that total N and S have the highest correlation while the others are mostly weakly correlated, even C and N. The negative correlation between C and potassium is also clear from the PCA biplot, but rather difficult to explain.

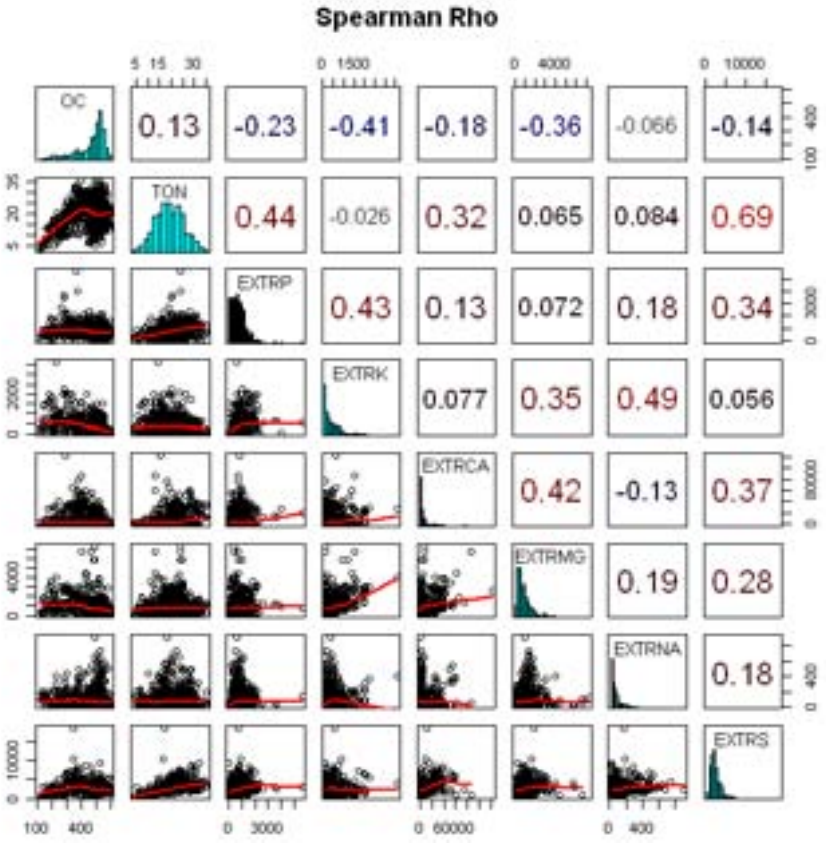


Figure 3.6.28. Matrix correlation scatterplot with LOWESS regression line (in red) for macro-elements in peat layers

Major metals

Five major metals were determined in 844 peat samples and their relationships were investigated. About 22 % missing values are present in the data matrix but be could be handled by PPCA. An initial PPCA revealed eight outlying samples originating from 5 plots: extremely high Mn concentration in Swedish plots 13_584 and 13_799* (all depths) and high reactive Al in H01 layer on plot 13_645*, extremely high reactive/extractable Al in H12 layer of UK plot 6_103* and high reactive/extractable Fe in H01 layer of the Lithuanian 56_830* plot. An asterisk next to the plots indicate that the maximum observed level (see Annex II) was found on these plots. For the PPCA, these eight outliers were not considered.

About 89 % of all variation is explained by the first 2 orthogonal components, and 96 % by the first three. PC1 is mainly determined by extractable Fe and Al and reactive Fe. Reactive and extractable Al contribute most to PC2 (Figure 3.8.29). Along PC3 reactive and extractable Al are at both ends enabling to discriminate the samples and helps in explaining about 7 % of the variance.

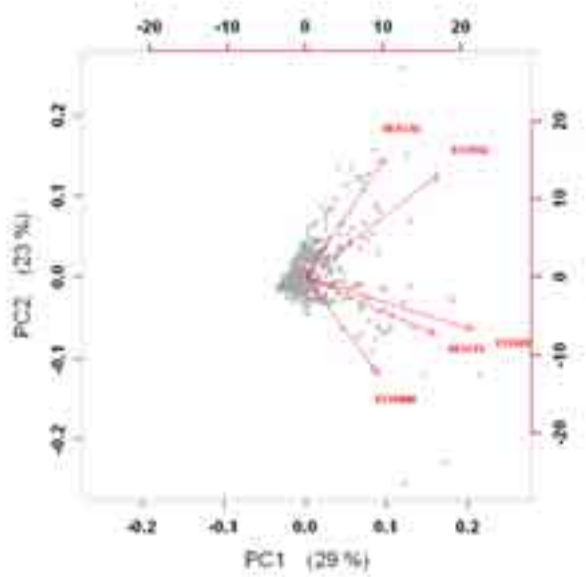


Figure 3.6.29. PCA biplot (PC12) of five major metals in peat samples

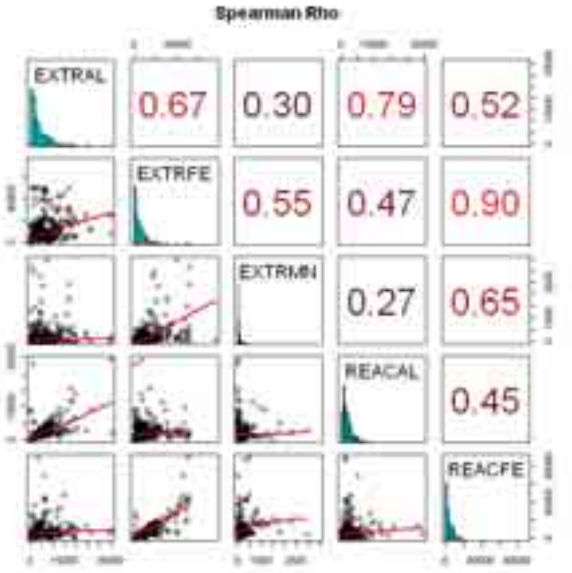


Figure 3.6.30. Matrix correlation scatterplot with LOWESS regression line (red) for major metals in peat samples

The correlation matrix in Figure 3.6.30 shows high correlation between extractable and reactive Fe and somewhat less for Al. All metals are positively correlated.

Trace metals

Seven trace metals were analysed in 784 samples of peat layers. About 12 % of all values were reported as missing values, which were imputed by PPCA. The first 3 components explain 72 % of all variation and the first 2 PCs account for 56 %. Figure 3.6.31 illustrates well that Ni, Cr and Cu contribute mainly to the first component and Zn and Cd to the second. Lead explains almost all variance of PC3 (~15 %). The other metals are of minor importance for ordination of the samples.

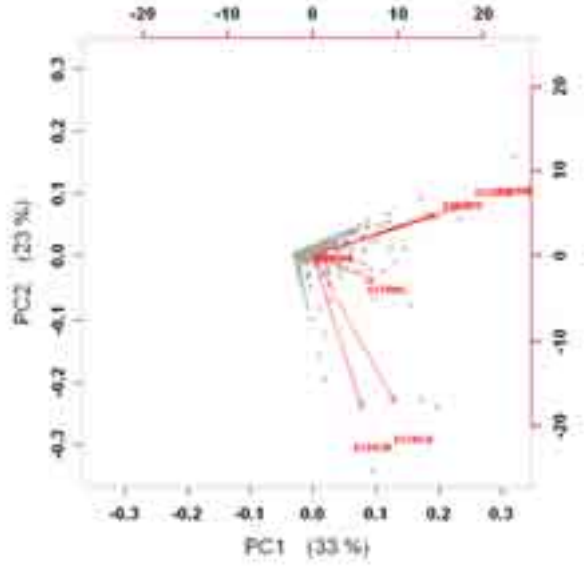


Figure 3.6.31. PCA biplot (PC12) of seven trace metals in peat samples

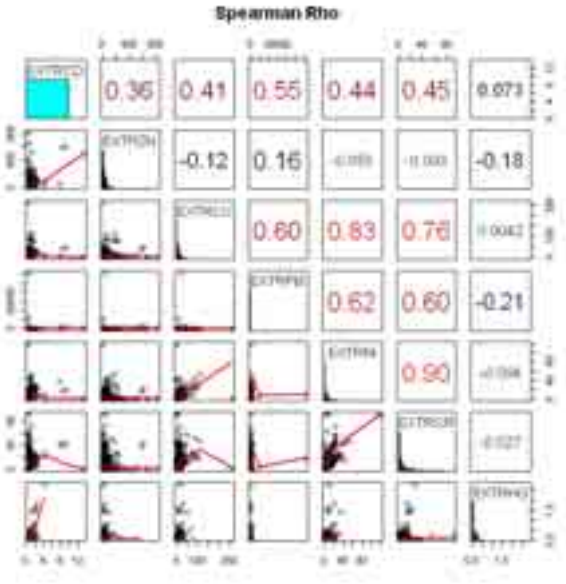


Figure 3.6.32. Matrix correlation scatterplot with LOWESS regression line (red) for trace metals in peat samples

The correlation matrix in Figure 3.6.31 again shows which trace metals are often correlated in peat layers: the group of Cu, Ni, Cr and Pb on the one hand and Cd and Zn. Mercury, mostly present in very low amounts, correlates weakly with other metals.

3.6.5 Conclusions

The multivariate approach revealed the internal structure of the BioSoil^{+} SOM data by identifying the most important gradients (components) and displaying the variables in biplots so that their informative value and their covariance is visualised and better understood. The covariance patterns and the magnitude in variance explaining power of the variables differed for each soil compartment. Table 3.6.5 attempts to make a synthesis of the most informative variables which can explain a maximal amount of variance in the SOM dataset.

Table 3.6.5. Top ten major variance explaining variables in forest floor, mineral soil and peat layers

Forest Floor	Mineral soil	Peat
pH-$CaCl_2$ (or pH-H_2O)	Clay (Soil Texture)	pH-$CaCl_2$ (or pH-H_2O)
Exchangeable Ca (or Extractable Ca)	Total N	Exchangeable acidity
Exchangeable acidity	Exchangeable Ca	Exchangeable Ca (or Extractable Ca)
Organic C	Organic C	Organic C
Total N	Bulk Density	Extractable Mg (or Exchangeable Mg)
Organic layer mass	Exchangeable acidity (or Al)	Extractable Fe
Extractable S	pH-$CaCl_2$ (or pH-H_2O)	Exchangeable Al (or Extractable Al)
Extractable P	Exchangeable Fe	Extractable Mn
Extractable Fe	Exchangeable K	Extractable Na
Extractable Al	Free H^{+}	Extractable K

For ordination of forest floor samples, predominantly pH, organic layer mass and (semi) total concentrations (C, N, S, P, Ca, Al and Fe) are already adequate for explaining most of the variance. Determination of exchangeable elements and/or exchangeable acidity is rather redundant and not

worth the extra cost. Conversely, exchangeable elements, including exchangeable acidity and free H^+ seem quite important for explaining the variance in mineral soil samples in addition to textural fractions (mainly clay fraction), bulk density, C, N and pH. Total elements and aqua regia extractable elements provide supplementary information, but these are not explaining most of the variation among mineral samples. In peat samples, apart from OC and pH, a combination of exchangeable and extractable elements explain most of the variance. However, for the cations Al, Ca and Mg extractable concentrations are good proxies for exchangeable ones.

For the characterisation and classification of samples the above mentioned selection of variables is recommended. Obviously, other variables may be much more informative when studying soil condition (e.g. contamination level), processes (e.g. weathering) or fluxes (e.g. N-cycle).

4 Conclusions

Volume I of this second European Forest Soil Condition report is presented here as Life$^+$ FutMon report 'S-Soil-11Soil' and is the major evaluation product of Action C1-Soil-3(FL) "*Quality, expertise and evaluations within soil surveys*". It is clearly related to the other end products of this action: the quality assurance and control activities for soil analysis, the further update of the soil manual for harmonised procedures in forest soil monitoring and the organisation of expert meetings to discuss and evaluate the findings of the pan-European BioSoil$^+$ database. This first volume synthesises all available data and is mainly descriptive. The second volume evaluates carbon and nutrient stocks, acidification and contamination levels, forest soil classification across Europe and compares with the first European forest soil condition survey.

The BioSoil$^+$ database is substantially larger than the BioSoil database evaluated by Hiederer et al. (2011) through the inclusion of 524 Level I plots from Poland, an additional 331 Level I plots of Spain and 27 Serbian plots. Conversely, 4 Hungarian Level II plots present are missing. In total the BioSoil$^+$ database contains of 4928 Level I and 127 Level II plots.

About 44 % of the number of Level I plots assessed during the first forest soil condition survey in the 1990s were revisited during the BioSoil survey (2326 plots). The overlap of the Level I crown condition assessment plots and BioSoil$^+$ is about 80 %, which is an improvement compared to the first soil survey (~70 %). Though, only a limited set of 127 permanent Level II plots were investigated during BioSoil. For about 75 % of them historical soil data are available enabling assessment of temporal changes.

A substantial improvement compared to the first survey is the profile and horizon description according to internationally agreed guidelines, both for humus types and mineral soils, in order to classify them according to reference classification systems. Next to the extension of the list of chemical parameters, much more attention is paid to the proper determination of soil physical properties such as particle size distribution, coarse fragments and fine earth bulk density. However, new problems aroused in stony soils which need further fine-tuning in the manual.

As was permitted, some countries reused existing profile descriptions and associated analytical data. Overall profile information was collected in the period 1987 - 2008 for Level I plots and during 1994 - 2008 for Level II. Although officially the survey period of BioSoil started in 2006 and lasted till 2008, some countries took fixed depth samples at earlier dates (2003 onwards). Roughly fixed depth sampling on Level I was conducted between 2004 - 2008 while 2006 - 2009 for Level II. The period for laboratory analysis was generally shifted 1 - 2 years later.

Compared to the plots surveyed during the first survey, the Level I BioSoil$^+$ plot coverage has been extended to the east, west and south, but not to the north. The Level II plots reassessed in BioSoil$^+$ cover only partially those stored from the first inventory. Their extent is much less to the south and to the west.

In BioSoil$^+$ plots are more evenly distributed longitudinally than during the first survey. Also there are northern plots surveyed than in the first survey but more Level I plots between 48° and 55° N, mainly due to a greater plot density in Poland. The number of plots in the south remained quite constant. The BioSoil$^+$ Level II latitudinal and longitudinal distribution pattern is different from Level I and should not be considered 'representative' for European forest soils, since it largely under represents northern and southern European plots. Likewise, the BioSoil$^+$ Level II subset

under represents plots with elevation between 150 and 1500 m AMSL compared to Level I. Therefore, for spatial analysis at EU scale, it is recommended to integrate the Level II subset into the Level I set.

The BioSoil$^+$ data was complemented with additional information derived from existing databases and GIS coverages, not only for checking and validating the BioSoil$^+$ data, but also for stratifying specific soil characteristics and to investigate their correlation with ecological and anthropogenic factors. This way, BioSoil$^+$ data can be related with previous forest soil surveys and other ICP-Forests databases, with the European soil database, forest cover map and Corine Land Cover, with Biogeographical and Ecoregions and with Natura 2000 areas. Through the overlay with the WORLDCLIM geodatabase, basic climatological data could be retrieved for each BioSoil$^+$ plot in order to link soil characteristics with climate.

Fifty percent of the BioSoil$^+$ Level I plots have a mean annual temperature between 5.1 and 9.8 °C, a mean minimum temperature between -9.0 and -1.3 °C and a maximum temperature between 20.5 and 24.1 °C. Medians for all plots are 7.4 °C, -5.4 °C and 21.9 °C, respectively. Fifty percent of the plots receive between 586 and 816 mm annual precipitation, whereas the total range is comprised within 306 - 1953 mm.

BioSoil$^+$ Level I plots are mostly located in the Biogeographical regions Boreal and Continental and in the Ecoregions Fennoscandia, Central plains and Ibero-Macaronesian. The Level II plot subset seems highly represented in the Fenno-Scandian shield and overrepresented in the Atlantic Biogeographic region or the Western plains (Ecoregion) .

BioSoil surveyors judged the water supply of nearly 80 % of the plots to be sufficient. Excessive water supply was limited to ~5 % of the plots, while insufficient on a number of Mediterranean, Boreal and Continental plots.

More than 50 % of the BioSoil$^+$ Level I plots are dominated by only two coniferous tree species, Pinus sylvestris and Picea abies. The third most important tree species is Fagus sylvatica. In all, conifers are much more present on BioSoil$^+$ plots compared to broadleaves (64 % vs 36 %). When considering stand type, 36 % of the plots are coniferous, 34 % mixed and 29 % broadleaved. The nearly equal importance of coniferous and mixed stands on Level I might be biased as Sweden reported all its 794 plots being mixed. Compared to Level I, the percentage of mixed stands on Level II is much smaller. Since forest type classification is missing on 59 % of the BioSoil$^+$ plots, this is considered an important data gap.

The Corine land cover information puts a relatively large portion of the plots in agricultural land (11 %). This might be due to generalisation (scale), imprecise coordinates or misclassification of remote sensing data. All plots are forest plots as this requirement was a the basis of the plot selection.

Approximately one fifth of the Level I and ~44 % of Level II BioSoil$^+$ plots are located within a Natura 2000 site, mainly combined Birds and Habitats Directive sites and Habitats directive sites. In the selection of the Level II plots, Natura 2000 areas are over represented compared to Level I.

The three most dominant parent material groups are unconsolidated glacial deposits/glacial drift, unconsolidated deposits and igneous rocks. This material seems to have a high impact on a large number of soil parameters, as may be deducted from the maps. When analysing the reported soil

parent materials, it became apparent that some countries reported the geological formation in stead of the soil parent material.

For the first time humus forms of all plots were classified according to an European classification system. Hydromorphic semi-terrestrial forms were reported for 9 % of the BioSoil$^+$ plots. Of the terrestrial forms, Mor types occur on 32 %, Moder on 28 % and Mull types on 22 % of all plots. However, distributions clearly differ by biogeographical region.

A high pedodiversity of forest soils is found across European forests. Of the 32 major reference soil groups described at world scale, 26 have been described in BioSoil$^+$. The dominant Reference Soil Groups are Cambisols, followed by Regosols and Oodzols. Together with Arenosols, Leptosols, Luvisols, Histosols, Gleysols, Umbrisols, Stagnosols, Phaeozems and Alisols they make up 95 % of the profiles. Anthropogenic influence of soil profiles seems unimportant in BioSoil$^+$ and is only determining 0.3 % of the profiles. At least one qualifier was available for 92 % of the profiles and at least 2 qualifiers for 51 % of the profiles. The most frequently applied qualifier was *Haplic*. The second most frequent set of qualifiers refers to the base saturation status. A third set of qualifiers refers to the stoniness.

The type of water table was mostly not observable during the survey and/or not reported. Also, only on less than 30 % of the profiles, the highest and lowest groundwater level was recorded. Thus, assessment of the site hydrology during a soil survey remains difficult.

The level of detail for soil horizon description varied considerably amongst countries. This was obvious from the number of described horizons and the total profile depth. While some countries described the soil horizons till a depth of more than 150 cm, others rather reported rather shallow soil profiles. Also the information stored for each described horizon remains very limited.

Concerning the sampling of the fixed depth, problems were met in sampling of peat layers. Especially peat layers overlying mineral soil layers or underlying thick semi-terrestrial forest floor layers generated much confusion and created problems for horizon designation and harmonised sampling.

The list of mandatory soil analyses was much more extended during the BioSoil project compared to the recommendations made in the soil manual of ICP Forests. The data availability in the BioSoil$^+$ database shows that BioSoil requirements have been too ambitious as most countries were unable to report results for all required analyses, layers and parameters. For almost all parameters, the data availability in the BioSoil$^+$ database gradually decreases with depth.
Some general trends could be observed concerning the availability of the data reported to BioSoil$^+$:

i) For none of the analytical parameters a full coverage for all layers and all plots could be obtained.
ii) Mandatory parameters have a better coverage than optional parameters. Parameters that were already mandatory in the ICP Forests soil manual are better covered that the parameters that were set mandatory exclusively for the BioSoil survey. Various organisational, financial and scientific reasons might explain this. For example, the scientific sense of analysing acid ammonium oxalate extractable Fe and Al in the organic layer was questioned by a number of forest soil experts.
iii) When a country did not manage to analyse and/or report all mandatory information, several approaches (or a combination of them) were observed:
    a. Only the **mandatory** parameters were analysed but not the optional;
    b. All mandatory analyses were conducted but **on a limited number of plots**;

c. The **number of depth layers** was reduced. In that case, usually the deeper layers (below 20 cm) were left unsampled or unanalysed. It is often unclear if shallow sampling is due to physical constraints (bedrock, high stoniness, elevated water table) or other reasons (logistic, financial, time constraints, ongoing national surveys).
d. The rules outlined in the ICP Forests manual (2006) were followed which were less demanding than the BioSoil specifications, resulting in both a **reduction** of **mandatory parameters** and **mandatory layers** (for example no sampling of the OL layer).

The first forest soil condition report (Vanmechelen et al. 1997) raised concern on the unavailability, for many plots, of parameters that are important for studying soil changes induced by atmospheric deposition such as exchangeable cations in the organic layer. Yet, data on individual exchangeable cations are now available for 73 % of the sampled OFH forest floor layers and on about 80 % of the peat samples.

Since the list of individual limit of quantification (LOQ) values for each lab were not available for this report, a revised list of median LOQ values for each variable is developed. Differences between LOQ values for organic and mineral matrices seemed negligible. For both matrices one standard LOQ value is determined for each parameter. For total nitrogen, however, specific LOQ values for each matrix are maintained. Observations below LOQ were not disregarded when analysing the BioSoil$^+$ database, but considered as left censored data and handled with dedicated statistical tools. Hence, these observations are fully taken on board for further inference and interpretation.

The newly assembled BioSoil$^+$ database was subject to a completion process and a profound data validation by FSCC. The latter consisted of compliance, conformity and uniformity checks based on the long FSCC experience with the applied methods and lab proficiency on the one hand, and feedback from the national forest soil experts and NFCs on the other. This way, numerous corrections were made.

In the BioSoil$^+$ database, field names were recoded or added in order (i) to harmonise with the first forest soil condition database, (ii) to guarantee unique plot IDs and (iii) to shorten the field names for easy handling in statistical environments.

Reliability classes were attributed to the reported reference soil groups based on all available information. For about 62 % of all profiles, the RSG seemed correct, for 31 % the RSG could be correct but this was not entirely verifiable and for 7 % of the profiles the RSG was incorrect, contradicting or lacking. A great number of soil types were recoded in new fields to conform with the classification rules of World Reference Base update 2007.

The reference forest (soil) area considered in this report is 135 Mha covered by BioSoil countries and 163 Mha for the total European forest area, hereby excluding forests of the Russian Federation. Hence the coverage of BioSoil$^+$ is estimated at 82 % of the total European forest area.

The dominant soil texture in European forest is Sandy Loam which is mainly found in Finland and Central and Southern Europe. A sandy region, consisting of eolian sands, stretches from Flanders, over Germany to Poland. South of this region the loess belt is formed which is dominated by soil textures such as Sandy Loam, Loam and Silt Loam. These textures determine the local soil properties to a great extent.

A wealth of original forest floor data was gathered at the pan-European scale. The median dry mass of the OFH layer is about 3 kg m^{-2} which is 5 times higher than the median dry mass of the

litter layer (OL) and 4 times less than the median dry mass of hydromorphic forest floors. A median OL layers is just 0.6 cm thick whereas an OFH layer 3 cm. While less than 10 % of the well aerated forest floors are thicker than 10 cm, this is exactly the median thickness of hydromorphic forest floors. These forest floor characteristics are a prerequisite for calculating stocks.

The median measured bulk density of the mineral forest soil is 1015 kg m^{-3} in the topsoil and increases with depth to 1354 kg m^{-3} in the 40 – 80 cm layer. The median bulk density of the peat soils is 117 kg m^{-3} in the topsoil increasing to 158 kg m^{-3} in the 40 – 80 cm layer.

For all depth layers, by far most samples show coarse fragments in the class 0 - 5 % by mass while the number of samples gradually decreases for higher classes.

Soil reaction, measured both as pH-$CaCl_2$ (potential pH) and pH-H_2O (actual pH), is determined in forest floor, mineral soil and peat layers. The peat layers are clearly most acid (median pH-$CaCl_2$ between 3.2 and 3.4). In the mineral layers, median pH increases with depth (pH-$CaCl_2$ from 4.0 in 0 – 10 cm layer till 4.5 in 40 – 80 cm layer) whereas it decreases in the forest floor profile (from 4.7 in OL to 3.7 in OFH layer). Most calcareous soils are located in the Mediterranean countries although some small calcareous areas are found in the Baltic States and England as well. Analysis of carbonates in organic samples seemed to be very difficult, both in forest floors and peats.

The organic carbon and nitrogen concentrations were extensively measured in forest floors, mineral soil and peat layers. In the organic layers, we find typical organic carbon concentrations around ~500 g kg^{-1} and nitrogen concentrations ~10 – 40 g kg^{-1}. The mineral soil carbon concentrations vary roughly between 0 and 150 g kg^{-1} and nitrogen between 0 and 10 g kg^{-1}. These concentrations decrease exponentially with depth.

Concerning the exchangeable elements, free H^+ in mineral soils proved rather difficult to measure. Instead, exchangeable acidity values were more informative. Exchangeable Na was difficult to measure in the mineral soil samples. Exchangeable Fe proved to be difficult to be analysed in OL layers and the in mineral subsoil layers. Large difficulties were involved with the determination of exchangeable Mn in mineral and peat soil samples.

Sixteen elements were measured by aqua regia extraction, in forest floor, mineral soil and peat samples. A first group comprise the macro nutrients P, K, Ca, Mg and S. A second group are macro elements present in high amounts (Al, Fe, Mn and Na) of which Fe and Mn are considered as micro nutrients for trees. A third group are the trace metals Cu, Pb, Ni, Cr, Zn, Cd and Hg. The distributions of the concentrations for all these elements are clearly documented and discussed for each soil compartment, resulting in an important chemical reference base for forest soils.
In Volume II, the group of the macro nutrients is discussed when evaluating the nutrient stocks in forest soils and the group of the trace metals is investigated in the chapter on contamination of forest soils by heavy metals.

Iron was found to be the most dominant aqua regia extractable element in all types of forest soil samples (including forest floor, mineral soils and peat soils). In mineral soils and forest floor layers, Al occurs in nearly comparable concentrations though the concentration of Al becomes relatively less important in peat soils. In these peats, Fe is present in the highest concentrations but it is followed by Ca and S while Al is only the 4th in row.

The concentrations of aqua regia extractable elements – including trace metals - are generally lower in peat soils compared to mineral soils, except for three macro nutrients: P, Ca and S. For

most elements the concentrations within peat soil generally decrease with depth except for Mg, Zn and Hg.

The determination of Al and Fe in acid ammonium oxalate extract are estimates for reactive Al and Fe. In peat layers nearly the same Fe concentration levels are measured as by the aqua regia extract. In mineral soil acid ammonium oxalate only extracts one sixth of the Fe amount extracted by aqua regia and in forest floors about one fourth.

Based on the univariate descriptive statistics, updates of the plausible ranges of all continuous soil variables were developed, separately for organic samples and mineral soil samples, as a useful tool for analysis and modelling of forest soil characteristics at the EU scale.

Multivariate analyses showed that for the forest floor samples, predominantly pH, organic layer mass and (semi) total concentrations (C, N, S, P, Ca, Al and Fe) are already adequate for explaining most of the variance. Determination of exchangeable elements seemed rather redundant. Conversely, these exchangeable elements were quite important for explaining the variance in the mineral soil samples in addition to textural fractions (mainly clay fractions), bulk density, C, N and pH. Total elements and aqua regia extractable elements provide supplementary information, but these are definitely not explaining most of the variation among mineral samples. In peat samples, apart from OC and pH, a combination of exchangeable and extractable elements explain most of the samples' variance. However, for the cations Al, Ca and Mg extractable concentrations are good proxies for the exchangeable ones.

In summary, the BioSoil demonstration project proved that a harmonised European forest soil survey within the time span of three years is possible. However a number of essential preconditions were in favour of this demonstration project. The BioSoil survey could rely not only on the validated soil manual of ICP Forests, but also on the existing ICP Forests network at the European level. Moreover, in several countries the BioSoil survey was efficiently combined with an already ongoing national forest soil survey such as in Austria, Germany and Sweden.

The assembling of national BioSoil datasets into BioSoil^{+} and its thorough validation and analysis during FutMon led to an updated European forest soil database. With the help of national soil experts, numerous corrections and additions have been made to BioSoil data resulting in BioSoil^{+}. Forest soils are now well characterised, but the EU picture still contains blank areas and needs further completion. Hence, BioSoil^{+} data should be further completed for specific countries, variables and depths, especially at the intensive monitoring plots on Level II.

BioSoil^{+} sets a reference for further forest ecosystem monitoring endeavours and is a sound basis for EU reporting (e.g. MCPFE). Further scientific exploration of this database and links with other forest components will at least take a decade. Integration of the current BioSoil^{+} database with previous/other pan-European forest soil databases is essential. To monitor changes in overall forest soil condition, conducting a EU wide survey each 10 - 15 years is highly recommended. Strict implementation of harmonised methods outlined in the updated ICP forests manual is crucial to detect real temporal changes and to ensure transnational comparison.
In addition to the BioSoil data reported by the national focal centres, the results of the 10 – 15 % subset of samples analysed by the central laboratory were not released and claimed protected and consequently not available to the FSCC for evaluation within FutMon. Integration of this dataset in BioSoil^{+} and combined with the results of interlaboratory comparisons could have generated substantial added value.

5 Recommendations

These recommendations include suggestions for further improvements to the existing quality strategy for European forest soil condition surveys, based on the experience of the BioSoil evaluation. First a set of specific recommendations are listed and some general ones at the end.

Field assessments

To check whether plots of the two forest soil inventories on the ICP Forests Level I 16 x 16 km grid are coinciding or not, two criteria are recommended: (i) identical plotIDs and (ii) not exceeding a inter-distance of 2 km. Doing so, a (Type I) error of less than 5 % is expected.
Plot coordinates in WGS84 should be reported as +/-DDMMSS in sexagesimal units (base 60). This requirement should be explicitly added to the manual to avoid base 100 units in the future.

Better guidelines are needed for i) the assessment of effective soil profile depth, ii) reporting stoniness in forest soils as volume percentage of coarse fragments, unlike mass percentage, iii) the assessment of total bulk density in addition to fine earth bulk density and iv) the reporting of the parent material codes. The difference between parent material and geological formation needs to be clarified.

The sampling of peat soils need to be better harmonised. First of all, a clear definition of peat soils is required. The minimum thickness of peat to apply the peatland sampling scheme should be clear and the occurrence of a second 0 cm reference line has to be avoided. The list of mandatory/optional parameters of peat layers should be unambiguous. We recommend that a small expert working group elaborates on a final peatland sampling scheme which can accommodate all special cases of peat containing forest soils.

A data gap which could relatively easy being filled in is the information on stand type (mixed, broadleaf, coniferous) and on forest type, especially for Finland and Sweden.

Laboratory analysis

When reporting low values, each analysis result should be associated with a laboratory-specific limit of quantification, not limit of detection (LOD). The LOQ should be reported together with the analytical data and information on the analytical methods in a separate quality data file (and not in a text document). This proves to be the only way to store and retrieve this essential information in the database along with the actual analytical data.

In the BioSoil survey, all ICP Forests optional and mandatory soil parameters on Level I were made mandatory without profound discussion. Conversely, the original list has been thoroughly discussed by the Expert Panel on Soil and Soil Solution during several expert panel meetings over the past 15 years. In case of future surveys, FSCC strongly recommends to follow the Expert Panel's recommendations and the last updated soil manual when fixing parameters and layers.

More specifically, this means that the exchangeable elements in the OL layer should not be analysed as variability proves to be too large. Further the analysis of the BioSoil^{+} data show that it is not useful to measure exchangeable Na in the mineral soil and exchangeable Fe and Mn in the subsoil (layers 20 – 40 and 40 – 80 cm). During BioSoil a major effort was made to measure all

exchangeable elements, though smart analyses are recommended in the future. Further, the determination of carbonates in peat layers generally does not provide useful information and should not be repeated in future surveys.

The concentrations of some trace metals (e.g. Cd, Hg) or some exchangeable elements are predominantly below LOQ. The Expert Panel should decide whether it is scientifically relevant that laboratories lower their LOQ by using more adequate analytical instruments or methods. Also, some laboratories reported in the interlaboratory comparisons unacceptable high LOQ values for some parameters. Therefore we recommend to set a clear LOQ range which is required for each parameter.

Database

The BioSoil$^+$ database could already be substantially improved by solving a great deal of inconsistencies and problems found during the elaboration of this report and it can be further improved in the future. This should be a joint task of the Forest Soil Expert Panel and FSCC for the coming years. Updated versions of the database should get a specific version number and release date. A logbook should be kept to document the updates.

The databases of the first European forest soil condition survey and the second (BioSoil$^+$) should be integrated. This process would be beneficial for (i) completing the European forest soil database since both databases complement each other, (ii) harmonising de facto all data fields and units, (iii) facilitating assessments of temporal change in forest soils and (iv) documenting better the change in methodology over time. FSCC has most experience to perform this task.

Forest soil characteristics and plot aggregated soil data (e.g. average topsoil base saturation, 1-m SOC stock) should be derived from BioSoil$^+$ and stored in a separated 'derived' dataset along with proper metadata (methods documented). This data could be useful for analysis by non soil scientists.

Countries that were participating in the BioSoil survey are invited to critically check the findings of this report, especially when related to their national data, and report all discrepancies and errors to the FSCC.

The BioSoil$^+$ information is a sound basis to perform an a-priori selection of plots for specific experimental designs in soil related forest ecosystem studies. Likewise, selection of a subset of BioSoil$^+$ data may be useful for a posteriori analysis or verification of model outcomes.

General recommendations

The BioSoil demonstration project has proven that a harmonised European forest soil survey is feasible within a 3 years period. However, at least another three year is required for adequate data validation and a robust analysis, evaluation and synthesis of the soil data.

The analysis, evaluation and synthesis of the data should be performed by experts in forest soils, highly acquainted with the methodology (manual) and capabilities of the involved laboratories.

National experts that participated in the survey should be involved in the data validation and evaluation process to a maximum extent.

Prior to conducting a next EU wide soil survey, a transparent and binding agreement dealing with data ownership and database availability should be established between all actors. It is crucial that the scientific community is granted full access to the validated data after a predefined period.

In BioSoil the optional parameters became all mandatory which is costly and often not resulting in much added value to the database as may be concluded from this report. In a next survey it is recommended to stick to the mandatory parameters only and strongly stimulate the countries to assess this set as completely as possible.

Experience and gained insights of the BioSoil^{+} data evaluation should be disseminated as widely as possible, by publication in peer-reviewed papers, feed back in working groups (IUSS World Reference Base, European Humus Research group), in international conferences and during EU COST actions.

Currently the BioSoil^{+} database lacks the analytical information of the 10 – 15 % of BioSoil samples and historical samples of the first forest soil inventory analysed by the central laboratory and stored at the BioSoil database at the JRC. FSCC invites countries to ask for this information to allow further in-depth evaluations.

The Expert Panel on Soil and Soil solution should make proper amendments and corrections to the ICP Forests Soil Manual based on the lessons learned from the FutMon evaluation of the BioSoil demonstration project.

List of abbreviations

Abbreviation	Unit	Description
ρ_b	m^{-3}	Dry bulk density
AMSL	m	Above mean sea level (for altitude or elevation)
BCa		Bias corrected and accelerated (for $CI_{95\%}$ determined by bootstrapping)
BD	kg m^{-3}	Bulk density
BRT		Boosted Regression Trees (Statistical technique)
BS	%	Base saturation
CEC	$cmol_+$ kg^{-1}	Cation exchange capacity
Cen		Censored data (when left censored, data below LOQ)
CF		Coarse fragments
$CI_{95\%}$		Confidence interval at the P = 0.05 level (95% confidence)
CLRTAP		Convention on Long-Range Transboundary Air Pollution
DM		Dry mass (~DW: dry weight)
DTM		Digital Terrain Model
EC		European Commission
EEA		European Environmental Agency
EFI		European Forest Institute
ETRS89		European Terrestrial Reference System (1989)
EUSIS		European Soil Information System
FFCs	t ha^{-1}	Forest floor carbon stock
FSCC		Forest Soil Co-ordinating Centre
FSCDB		Forest Soil Condition Database (data of 1st Forest Soil Survey)
GPS		Global positioning system
HGWL		Mean highest groundwater level
ICP Forests		International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests
IFN		Inventaire Forestier National
INRA		Institut national de la recherche agronomique
ISO		International Organization for Standardization
JRC		Joint Research Centre (European Commission)
Kurt		Kurtosis of a distribution
LAEA		Lambert Azimuth Equal Area Coordinate Reference System
LGWL		Mean lowest groundwater level
LCL		Lower confidence limit of a confidence interval
LOD		Limit of detection
LOQ		Limit of quantification
MAP	mm	Mean Annual Precipitation
MAT	°C	Mean Annual Temperature
Max		Maximum value of a dataset
Min		Minimum value of a dataset
NA		Not available (indicates a missing value)
NFC		National Focal Centre of ICP Forests
NNDs		Nearest Neighbour Distances
OC	g kg^{-1}	Organic carbon
ORGLAY	kg m^{-2}	Organic layer dry mass
PC		Principal component
PCA		Principal component analysis
PCC		Programme Coordinating Centre of ICP Forests
PCCDB		ICP Forests databases available at PCC Hamburg
PFH		Profile horizon dataset of BioSoil+ database
PLS		Plot dataset of BioSoil+ database
PPCA		Probabilistic Principal component analysis
PRF		Profile dataset of BioSoil+ database

Abbreviation	Unit	Description
P_x		Percentile x value (e.g. $P_{97.5}$ = 97.5 percentile)
RFA		reference forest area
RSG		Reference Soil Group (World Reference Base)
SD		Standard deviation
SGDBE		Soil geographical database of Eurasia (Geodataset)
Skew		Skewness of a distribution
SMU		Soil mapping unit (field from SGDBE)
SOM		Soil organic matter or Dataset of fixed depth analyses of BioSoil^{+}
STU		Soil typological unit (field from SGDBE)
TMAX	°C	Maximum temperature of warmest month
TMIN	°C	Minimum temperature of coldest month
TON	g kg^{-1}	Total organic nitrogen
UCL		Upper confidence limit of a confidence interval
UN/ECE		United Nations Economic Commission for Europe
WGS84		World Geodetic System datum 1984; coordinate system
WRB		World Reference Base for Soil resources

References

Blakemore L.C., Searle P.L. and Daly B.K. 1987. Methods for chemical analysis of soils. N.Z. Soil Bureau Sci. Rep. 80. Soil Bureau, Lower Hutt.

Clarke N., Clegg S., Guan X. and Gobran G.R. 1996. Principal component analysis as a useful method in the study of soil chemical processes. Skogforsk 47, 30 pp.

Clarke N., Cools N., Derome J., Derome K., De Vos B., Fürst A., König N., Kowalska A., Mosello R., Tartari G.A., Ulrich E. 2009. FutMon QA/QC Guide for Laboratory Work (1st version). ICP Forests Working Group on QA/QC in Laboratories. [http://www.futmon.org/futmon-field-protocols]

Clarke N., Cools N., Derome J., Derome K., De Vos B., Fürst A., König N., Kowalska A., Mosello R., Tartari G.A, Ulrich E. 2008. ICP Forests Working Group on QA/QC in Laboratories. Quality Assurance and Control in Laboratories. A review of possible quality checks and other forms of assistance. [http://www.icp-forests.org/DocsQualLab/QualCheckMay2008.pdf]

Cools N. and De Vos B., 2010. Sampling and Analysis of Soil. Manual Part X, 208 pp. 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://icp-forests.net/page/icp-forests-manual]

Cools N., Verschelde P., Quataert P., Mikkelsen J. and De Vos B. 2006. Quality Assurance and Quality Control in Forest Soil Analysis: 4th FSCC Interlaboratory Comparison. NBO.R.2006.6. Forest Soil Coordinating Centre, Research Institute for Nature and Forest, Geraardsbergen, Belgium. 66 pp. + annexes (on CD-Rom). [http://fscc.inbo.be]

Cools N., Mikkelsen J.H. and De Vos B. 2007. Quality Assurance and Quality Control in Forest Soil Analysis: 5th FSCC Interlaboratory Comparison. INBO.R.2007.46. Forest Soil Coordinating Centre, Research Institute for Nature and Forest, Geraardsbergen, Belgium, 63 pp. + annexes (partly on CD Rom). [http://fscc.inbo.be]

Cools N. and De Vos B. 2008. The FSCC soil reference material. Supporting study of the EU Forest Focus BioSoil demonstration project. INBO.IR.2008.49. Research Institute for Nature and Forest, Brussels.

Cools N. and Mencke E. 2008. EC/UNECE ICP Forests 1st Meeting of the heads of the laboratories, 9 - 10 June 2008, Hamburg. Germany. Zendingsverslag (in English). INBO.Zv.2008.33, Research Institute for Nature an Forests (INBO), Geraardsbergen. Belgium.

Cools N. and De Vos B. 2010. 6th FSCC Interlaboratory Comparison 2009. INBO.R.2010.4. Research Institute for Nature and Forest, Brussels. 52 pp. + annexes (partly on CD Rom). [http://fscc.inbo.be]

Currie L. A. 1999. Detection and quantification limits: origins and historical overview. Analytica Chimica Acta 391:127-134.

de Haas, 2010. SamSamWater Climate Tool. [http://www.samsamwater.com/climate/]

De Vos B., Vandecasteele B., Deckers S., Muys B. 2005. Capability of loss-on-ignition as a predictor of total organic carbon in non-calcareous forest soils. Comm. Soil Sci Plant Anal.36: 2899-2921.

De Vos B. 2008. Tolerable limits for interlaboratory forest soil ringtests. F4B Biosoil supporting study. INBO.IR.2008.43. Research Institute for Nature and Forest, Brussels.

EEA. 2004. Ecoregions for rivers and lakes. [http://www.eea.europa.eu/data-and-maps/data/ecoregions-for-rivers-and-lakes]

EEA. 2006. The indicative Map of European Biogeographical Regions: Methodology and development. European Topic Centre On Biological Diversity, Paris, 13 pp.

EEA. 2007. European forest types. Categories and types for sustainable forest management reporting and policy. 2nd edition. European Environment Agency, Copenhagen 111 pp.

Efron B. and Tibshirani R. J. 1993. An introduction to the bootstrap, CRC Press, Boca Raton.

Expert Panel on Soil and FSCC (Forest Soil Co-ordinating Centre). 2003. Baert, G., Cools, N., Delanote, V., De Vos, B., Groenmans, R., Langouche, D., Roskams, P., Scheldeman, X., Vanmechelen, L., Van Ranst, E. Upgrade of the 4th Edition of the ICP Forests' Manual on methods and criteria for harmonised sampling, assessment, monitoring and analysis of the effects of air pollution on forests, Part IIIa. 114 pp.

FAO, IIASA, ISRIC, ISS-CAS, JRC. 2008. Harmonized World Soil Database (version 1.0). FAO, Rome, Italy and IIASA, Laxenburg, Austria.

FAO, ISRIC and ISSS. 1998. World Reference Base for Soil Resources. World Soil Resources Report 84, Rome, 88 pp. [http://www.fao.org/docrep/W8594E/W8594E00.htm]

FAO. 1990. Guidelines for soil description. 3rd Edition (Revised). Soil Resources, Management and Conservation Service, Land and Water Development Division, FAO, Rome.

FAO. 2006. Guidelines for soil profile description and classification. Fourth edition. FAO, Rome. [ftp://ftp.fao.org/agl/agll/docs/guidel_soil_descr.pdf]

FAO-UNESCO. 1974. FAO-UNESCO Soil Map of the World: Vol. 1, Legend. UNESCO, Paris.

FAO-UNESCO-ISRIC. 1988. Soil Map of the World. Revised Legend. Reprinted with corrections. World Soil Resources Report N° 60. FAO, Rome.

FAO-UNESCO-ISRIC. 1990. FAO-UNESCO Soil Map of the World: Revised Legend. World Soil Resources Report 60. Rome. 119 pp. Reprinted 1990.

FOREST EUROPE, UNECE and FAO. 2011. State of Europe's Forests 2011. Status and Trends in Sustainable Forest Management in Europe. Ministerial Conference on the Protection of Forests in Europe, Oslo, Norway.

FSCC (Forest Soil Co-Ordinating Centre). 2006. Manual IIIa: Sampling and Analysis of Soil. In: ICP Forests, 2006: Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests. UNECE ICP Forests Programme Co-ordinating Centre, Hamburg. 26 pp. + annexes [http://www.icp-forests.org/Manual.htm].

Hamblin W. K. and Christiansen E.H. 1998. Earth's dynamic systems. Eighth edition. Prentice-Hall, New Jersey. 740 pp.

Helsel D. and Lee L. 2006. Analysis of environmental data with nondetects. Statistical methods for censored environmental data. ASA workshop. 30 pp.

Helsel D. 2005. Nondetects and data analysis: Statistics for censored environmental data. John Wiley and Sons, New York. 268 pp.

Hiederer R. and Durrant T. 2010. Evaluation of the BioSoil Demonstration Project. Preliminary Data Analysis. JRC Scientific and Technical reports. EUR 23578 EN. Publication Office of the European Union. 126 pp.

Hiederer R., Michéli E. and Durrant T. 2011. Evaluation of the BioSoil Demonstration Project. Soil Data Analysis. JRC Scientific and Technical reports. EUR 24729 EN. Publication Office of the European Union. 155 pp.

Hijmans R.J., Cameron S.E., Parra J.L., Jones P.G. and Jarvis A. 2005. Very high resolution interpolated climate surfaces for global land areas. Int. J. Climatol. 25:1965-1978.

ISO. 1995. ISO 10694. Soil Quality – Determination of organic and total carbon after dry combustion (elementary analysis). International Organization for Standardization. Geneva, Switzerland. 7 pp. [www.iso.ch]

ISO. 1993. ISO 11272. Soil Quality – Determination of dry bulk density. International Organization for Standardization. Geneva, Switzerland. 10 pp. [www.iso.ch]

ISO. 1993. ISO 11465. Soil Quality – Determination of dry matter and water content on a mass basis – Gravimetric method. International Organization for Standardization. Geneva, Switzerland. 3 pp. [www.iso.ch]

ISO. 1994. ISO 10390. Soil Quality – Determination of pH. International Organization for Standardization. Geneva, Switzerland. 5 pp. [www.iso.ch]

ISO. 1994. ISO 10693. Soil Quality – Determination of carbonate content - Volumetric method. International Organization for Standardization. Geneva, Switzerland. 7 pp. [www.iso.ch]

ISO. 1994. ISO 11254. Soil Quality – Determination of exchangeable acidity in barium chloride extracts. International Organization for Standardization. Geneva, Switzerland. 5 pp. [www.iso.ch]

ISO. 1994. ISO 11260. Soil Quality – Determination of effective cation exchange capacity and base saturation level using barium chloride solution. International Organization for Standardization. Geneva, Switzerland. 10 pp. [www.iso.ch]

ISO. 1994. ISO 11464. Soil Quality – Pretreatment of samples for physico-chemical analysis. International Organization for Standardization. Geneva, Switzerland. 9 pp. [www.iso.ch]

ISO. 1994. ISO 5725-2 Accuracy (trueness and precision) of measurement methods and results – part 2: Basic method for determination of repeatability and reproducibility of a standard measurement method'. 42 pp. [www.iso.ch]

ISO. 1995. ISO 11261. Soil Quality – Determination of total nitrogen – Modified Kjeldahl method. International Organization for Standardization. Geneva, Switzerland. 4 pp. [www.iso.ch]

ISO. 1995. ISO 11466. Soil Quality – Extraction of trace elements soluble in *aqua regia*. International Organization for Standardization. Geneva, Switzerland. 6 pp. [www.iso.ch]

ISO. 1998. ISO 11277. Soil Quality – Determination of particle size distribution in mineral soil material – Method by sieving and sedimentation. International Organization for Standardization. Geneva, Switzerland. 30 pp. [www.iso.ch]

ISO. 1998. ISO 13878. Soil Quality – Determination of total nitrogen content by dry combustion ("elemental analysis"). International Organization for Standardization. Geneva, Switzerland. 5 pp. [www.iso.ch]

ISO. 2001. ISO 14869-1. Soil Quality – Dissolution for the determination of total element content - Part 1: Dissolution with hydrofluoric and perchloric acids. International Organization for Standardization. Geneva, Switzerland. 5 pp. (available at www.iso.ch)

ISRIC and FAO. 2002. Procedures for soil analysis. Sixth ed. ISRIC Technical Paper N° 9. L.P. Van Reeuwijk (ed). Wageningen, The Netherlands.
[http://www.isric.org/Isric/Webdocs/Docs/ISRIC_TechPap09_2002.pdf]

ISSS Working Group RB. 1998. World Reference Base for Soil Resources: Introduction (J.A. Deckers, F.O. Nachergaele and O.C. Spaargaren, Eds.). First Edition. International Society of Soil Science (ISSS), International Soil Reference and Information Centre (ISRIC) and Food and Agriculture Organization of the United Nations (FAO). Acco. Leuven. 165 pp.

IUSS Working Group WRB. 2006. World Reference Base for Soil Resources 2006. World Soil Resources Reports No. 103, FAO, Rome.
[http://www.fao.org/ag/Agl/agll/wrb/doc/wrb2006final.pdf]

IUSS Working Group WRB. 2007. World Reference Base for Soil Resources 2006, first update 2007. World Soil Resources Reports No. 103, FAO, Rome.
[http://www.fao.org/ag/agl/agll/wrb/doc/wrb2007_corr.pdf]

JRC. 2001. Soil geographical database of Eurasia at scale 1:1,000,000 VERSION 4 beta, 25/09/2001. EU Joint Research Centre, Ispra.
[http://eusoils.jrc.ec.europa.eu/ESDB_Archive/ESDBv2/popup/sg_meta.htm]

Kempeneers P., Sedano F., Seebach L. and San-Miguel-Ayanz, J. 2010. Data fusion of High and Medium Resolution Remote Sensing images applied to forest type mapping. Joint Research Centre, Ispra, Italy. [http://forest.jrc.ec.europa.eu/]

König N., Kowalska A., Brunialti G., Ferretti M., Clarke N., Cools N., Derome J., Derome K., De Vos B., Fürst A., Jakovljevič T., Marchetto A., Mosello R., O'Dea P., Tartari G.A., Ulrich E. 2010. Quality Assurance and Control in Laboratories. 53 pp. Part XVI. In: Manual on methods and

criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests. UNECE, ICP Forests Programme Co-ordinating Centre, Hamburg. ISBN: 978-3-926301-03-1. [http://www.icp-forests.org/Manual.htm]

Lambert J.J., Daroussin J., Eimberck M., Le Bas C., Jamagne M., King D. and Montanarella L. 2003. Soil Geographical Database for Eurasia and The Mediterranean: Instructions Guide for Elaboration at scale 1:1,000,000, Version 4.0. European Soil Bureau Research Report No.8, EUR 20422 EN, 64 pp. Office for Official Publications of the European Communities, Luxembourg. [http://eusoils.jrc.ec.europa.eu/ESDB_Archive/eusoils_docs/doc_ESBN.html]

Lutgens F. K. and Tarbuck E.J. 2000. Essentials of Geology, 7th Ed., Prentice Hall.

Mikkelsen J., Cools N. and Langohr R. 2006. Guidelines for Forest Soil Profile Description, adapted for optimal field observations within the framework of the EU Forest Focus Demonstration Project. BIOSOIL. Partly based on the 4th edition of the Guidelines for Soil Profile Description and Classification (FAO, 2006).

Moreno R.M., Arias M.L., Peña G.S., Cascon M.R.G. and Bellesta R.J. 1997. La red Europea de seguimiento de daños en los bosques (Nivel I) España, 1987 - 1996. O.A. Parques Nacionales, Ministro de Medio Ambiente. Madrid. 557 pp.

Poesen J. and Lavee H. 1994. Rock fragments in top soils: significance and processes. Catena 33: 1-28.

R Development Core Team. 2008. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Reference Index. Version 2.7.1 (2008-06-23). 2721 pp. [http://www.R-project.org]

Stacklies W., Redestig H., Scholz M., Walther D. and Selbig J. 2007. pcaMethods – a bioconductor package providing PCA methods for incomplete data. Bioinformatics 23: 1164-1167

Stacklies W. and Redestig H. 2010. The pcaMethods package. CAS-MPG Partner Institute for Computational Biology (PICB) and Max Planck Institute for Molecular Plant Physiology, Germany. [http://bioinformatics.mpimp-golm.mpg.de]

Schuck A., Van Brusselen J., Päivinen R., Häme T., Kennedy P. and Folving S. 2002. Compilation of a calibrated European forest map derived from NOAA-AVHRR data. European Forest Institute Internal Report 13, EUR 20546, Joensuu, Finland.

USDA. 2004. Soil Survey Laboratory Methods Manual Soil Survey. Investigations Report No. 42, Version 4.0, November 2004. Edited by Rebecca Burt.

Vanmechelen L. Groenemans R. and Van Ranst E. 1997. Forest Soil Condition in Europe, results of a large-scale soil survey. 1997 Technical Report. EC, UN/ECE, Ministry of the Flemish Community; Brussels, Geneva. 261 pp. [htpp://fscc.inbo.be]

Vervaet H., Massart B., Boeckx P., Van Cleemput O. and Hofman G. 2002. Use of principal component analysis to assess factors controlling net N mineralization in deciduous and coniferous forest soils. Biol Fertil Soils 36:93-101.

WWF. 2001. The Mediterranean forests. A new conservation strategy. WWF, MedPO, Rome.

Zanella A., Englisch M., Jabiol B., Katzensteiner K., de Waal R., Hager H., van Delft B., Graefe U., Brun J.-J., Chersich S., Broll G., Kolb E., Baier R., Baritz R., Langohr R., Cools N., Wresowar M., Milbert G. and Ponge J.F. 2006. Towards a Common Humus Form Classification, A First European Approach: Few Generic Top Soil References as Functional Units. Poster presented at the 18th World Congress of Soil Science, Philadelphia, July 9-15, 2006.

Zanella A., Jabiol B., Ponge J.F., Sartori G., De Waal R., Van Delft B., Graefe U., Cools N., Katzensteiner K., Hager H. and Englisch M. 2011. A European morpho-functional classification of humus forms. Geoderma: 164: 138-145

Annexes

Annex I. BioSoil laboratories

Austria

Franz Mutsch
Unit of Forest Soil
Federal Research and Training Centre for Forests (BFW)
Seckendorff-Gudent-Weg 8
A - 1131 Vienna

Belgium

Gerrit Genouw, Els Mencke
Bodemkundig en Analytisch Labo
Research Institute for Nature and Forest
Gaverstraat 4
B - 9500 Geraardsbergen

Cyprus

Panicos Hadjigeorgiou
Analytical Laboratories Section
Department of Agriculture
Louki Akrita 26
CY - 1411 Nicosia

Czech Republic

Jan Jindra, Iva Tosnerova
Department of Experimental Laboratories
Forestry and Game Management Research Institute
(Výzkumný ústav lesního hospodárství a myslivost)
Jiloviste - Strnady 136
CZ - 156 04 Praha 5 - Zbraslav

Denmark

Preben Frederiksen, Lars Bo Pedersen
Forest & Landscape Denmark
University of Copenhagen
Rolighedsvej 23
DK - 1954 Frederiksberg C

Ole Borggaard
Department of Basic Sciences and Environment
University of Copenhagen
Thorvaldsensvej 40
DK - 1871 Frederiksberg C

Estonia

Tõnu Tõnutare
Laboratory of Soil Science and Agrochemistry Department
Estonia University of Life Sciences Viljandi mnt, Eerika
EE - 50412 Tartu

Mae Uri
Tartu Environmental Research Ltd.
Akadeemia, 4
EE - 51003 Tartu

Finland

Arja Tervahauta
Central Laboratory
Finnish Forest Research Institute
Jokiniemenkuja 1
FIN - 01300 Vantaa

Kirsti Derome
Rovaniemi Research Station
Finnish Forest Research Institute
Etelavanta 55; P.O. Box 16
FIN - 96301 Rovaniemi

France

Henri Ciesielski, Annie Guerin
Laboratoire d'Analyses des Sols
INRA d'Arras
Rue de Cambrai 273
FR - 62000 Arras

Germany

Gabriele Trefz-Malcher
Abt. Bodenkunde
Forstliche Versuchs- und Forshungsanstalt Baden-Württemberg
Wonnhaldestr., 4
D - 79100 Freiburg

Frank Gutwasser
Ökologisches Zentrallabor
Hochschule für nachhaltige Entwicklung Eberswalde (University of Applied Sciences)
Friedrich - Ebert - Str. 28
D - 16225 Eberswalde

Joachim Block
FAWF – Trippstadt
Forschunganstalt für Waldökologie und Forstwirtschaft Rheinland-Pfalz
Hauptstr. 16
D - 67705 Trippstadt

Frank Symossek
Labor Standortserkundung / Bodenmonitoring
Staatsbetrieb Sachsenforst Geschäftsleitung
Bonnewitzer Str.34
D - 01796 Pirna - OT Graupa

Guenter Kiessling
Abteilung Untersuchungswezen
Thüringer Landesanstalt für Landwirtschaft (TLL Jena)
Naumburger Str. 98
D - 07743 Jena

K.D. Fetzer, Katja Drescher-Larres
Landesamt für Umwelt- und Arbeitsschutz
Sachbereich Geologie und Boden
Don Bosco Straße 1
D - 66119 Saarbrücken

Nils König
Nordwestdeutsche Forstliche Versuchsanstalt
Northwest German Forest Research Station
Grätzelstrasse 2
D - 37079 Göttingen

Rolf Ellinghaus
Landesbetrieb Hessisches Landeslabor
Abt.VI - Landwirtschaftliches Untersuchungswesen
Am Versuchsfeld 13
D - 34128 Kassel-Harleshausen

Uwe Blum
Abteilung 2 - Boden und Klima
Bayerische Landesanstalt für Wald und Forstwirtschaft
Hans-Carl-von-Carlowitz-Platz 1
D - 85354 Freising

Gerhard Milbert
Fachbereich Methodenentwicklung und Produktkontrolle
Geologischer Dienst Nordrhein-Westfalen
De-Greiff-Straße, 195
D - 47803 Krefeld

Uwe Klingenberg
LUFA Rostock
Landwirtschaftliche Untersuchungs- und Forschungsanstalt
Graf-Lippe-Str. 1
D - 18059 Rostock

Klaus Wies
Landwirtschaftliche Untersuchungs- und Forschungsanstalt Speyer
Obere Langgasse 40
D - 67346 Speyer

Matthias Hauenstein
LGB Mainz
Landesamt für Geologie und Bergbau
Emy-Roeder-Str. 5
D – 55129 Mainz

Greece

Panagiotis Michopoulos
Laboratory of Forest Land and Biogeochemistry
Forest Research Institute of Athens
Terma Alkmanos, Ilissia
GR - 11528 Athens

Hungary

András Bidló
Institute of Site Survey
Faculty of Forestry, West-Hungarian University
Bajcsy-Zs. u. 4
H - 9400 Sopron

Gábor Páncél
Ecological Laboratory
Forest Research Institute
Várkerület 30/a
H - 9600 Sárvár

Ireland

Philip O'Dea
Coillte Laboratories
Research & Environment, Coillte Teo.
Church Road
Newtownmountkennedy
IRL - County Wicklow

Italy

Stefano Carnicelli, Guia Cecchini
Dipartimento di Scienza del Suelo e Nutrizione della Pianta
Università degli Studi di Firenze
Piazzale delle Cascine 15
I – 50144 Firenze

Grazia Masciandaro, Giorgio Poggio
Research Unit of Soil Chemistry
CNR - Institute for Ecosystem Studies
Area della Ricerca
Via Moruzzi 1
I - 56124 Pisa

Simona Vingiani
Laboratory analisi pedologiche
Facoltà di Agraria, Università di Napoli Federico II
Dipartimento di Scienze del Suelo, della Pianta e dell'Ambiente (DISSPA)
Via Università 100
I – 80055 Portici (NA)

Roberto Comolli
Dipartimento di Scienze dell' Ambiente e del Teritorio
Università degli Studi di Milano-Bicocca
Pizza della Scienza 1
I – 20126 Milano

Eleonora Bonifacio, Gloria Falsone
Dipartimento di Valorizzazione e Protezione delle Risorse AgroForstali
Università degli Studi di Torino
Via Leonardo da Vinci 44
I – 10095 Grugliasco

Latvia

Andis Lazdiņš, Arta Bārdule
Laboratory of Forest Environment
Latvia State Forest Research Institute "Silava"
Riga Street 111
LV - 2169 Salaspils

Lithuania

Jadvyga Lubyté
Agrochemical Research Centre
Lithuanian Institute of Agriculture
Savanoriu Avenue 287
LT - 50127 Kaunas

Poland

Józef Wójcik
Laboratory of Forest Environment Chemistry
Department of Forest Habitat Science - Forest Research Institute
Sekocin Stary, ul. Braci Lesnej 3
PL - 05-090 Raszyn

Portugal

Lídia Farropas
Laboratório Químico Agrícola Rebelo da Silva
National Research Institute for Biological Resources (INRB)
Tapada de Ajuda, Apartado 3228
P - 1301-903 Lisboa

João Coutinho
Laboratório de Solos e de Plantas
Universidade de Trás-os-Montes e Alto Douro
Qta de Prados, Apart. 1013
P - 5001-801 Vila Real

Republic of Serbia

Zoran Miletic
Institute of Forestry
Pedology Laboratory
Kneza Višeslava 3
11030 Belgrade

Slovak Republic

Anna Stanciková
Central Forestry Laboratory (CLL)
National Forest Centre (NLC)
T.G. Masaryka 22
SK - 962 92 Zvolen

Slovenia

Daniel Zlindra
Laboratory for Forest Ecology
Slovenian Forestry Institute
Vecna pot 2
SI – 1000 Ljubljana

Spain

José Manuel Grau, Ana de la Cruz
INIA-Laboratorio de Ecosistemas Forestales
INIA - CIFOR - Dpto. Ecología y Genética Forestal
Carretera Coruña km 7.5
E - 28040 Madrid

Sweden

Gunilla Bergvall, Lars Lundin
Soil chemical laboratory, Department of Soil and Environment
Sveriges Lantbruksuniversitet (SLU), Swedish University of Agricultural Sciences
Johan Brauners vag 1, Ultuna// P.O.Box 7001
S - 75007 Uppsala

United Kingdom

François Bochereau
Environmental Research Laboratory
Forest Research
Alice Holt Lodge, Wrecclesham
UK - GU104LH Farnham, Surrey

Annex II. Tables general statistics

Clay content (%)

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	$MeanCI_{95\%}$		Skew	Kurt
												LCL	UCL		
M01	5628	110	2.0	<0.5	0.7	2.9	10.2	19.9	45.5	85.4	13.4	13.1	13.7	1.37	4.97
M12	4121	79	1.9	<0.5	0.7	3.0	10.4	19.9	45.5	84.2	13.6	13.2	14.0	1.40	5.23
M24	3532	100	2.8	<0.5	0.6	2.5	9.2	19.4	46.7	87.5	13.1	12.6	13.5	1.46	5.29
M48	3178	184	5.8	<0.5	0.5	2.1	8.6	20.7	51.3	85.8	13.7	13.2	14.2	1.49	5.20

Silt content (%)

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	$MeanCI_{95\%}$		Skew	Kurt
												LCL	UCL		
M01	5628	17	0.3	<0.5	2.0	14.1	29.7	45.1	73.0	93.9	31.0	30.5	31.5	0.40	2.40
M12	4121	25	0.6	<0.5	2.0	16.9	31.3	45.3	72.8	96.2	32.1	31.5	32.7	0.32	2.45
M24	3532	35	1.0	<0.5	1.6	14.2	29.2	43.9	70.8	100.0	30.1	29.5	30.8	0.39	2.54
M48	3178	57	1.8	<0.5	1.1	11.6	26.2	40.5	71.5	100.0	27.7	27.0	28.4	0.52	2.71

Sand content (%)

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	$MeanCI_{95\%}$		Skew	Kurt
												LCL	UCL		
M01	5628	5	0.08	<0.5	4.1	31.8	58.2	81.6	96.5	100.0	55.6	54.8	56.3	-0.23	1.83
M12	4121	1	0.02	0.5	4.0	31.8	56.5	78.0	96.8	99.8	54.3	53.5	55.2	-0.17	1.91
M24	3532	2	0.06	<0.5	4.2	34.6	59.7	81.1	97.7	99.9	56.8	55.9	57.8	-0.26	1.94
M48	3178	3	0.09	<0.5	4.3	35.8	61.8	84.1	98.6	100.0	58.6	57.6	59.6	-0.31	1.95

Organic layer mass (kg m^{-2})

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	$MeanCI_{95\%}$		Skew	Kurt
												LCL	UCL		
OL	2676	7	0.26	0	0.07	0.32	0.62	1.02	2.78	95.3	0.83	0.75	0.90	41.7	2000
OFH	4547	70	1.54	0	0.17	1.23	2.99	5.81	21.1	135	5.08	4.82	5.34	7.08	71.7
H	167	0	0.00	0.42	1.03	7.94	12.7	18.3	43.9	88.7	15.3	13.4	17.1	2.72	14.6
H01	146	0	0.00	0.93	1.61	6.59	9.46	14.6	50.4	94.2	14.0	11.8	16.2	2.57	11.8
H12	117	0	0.00	0.93	1.37	6.63	13.0	17.0	38.9	77.0	13.4	11.4	15.3	2.79	15.2
H24	113	0	0.00	1.86	2.74	11.4	23.5	34.4	63.0	128	25.1	21.8	28.4	2.11	11.8
H48	51	0	0.00	1.38	2.39	8.30	15.3	31.0	89.3	102	23.4	17.0	29.7	1.69	5.56

Organic layer thickness (cm)

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	$MeanCI_{95\%}$		Skew	Kurt
												LCL	UCL		
OL	2420	0	0	0.00	0.07	0.32	0.62	1.02	2.78	30	1.74	1.67	1.82	5.77	61.3
OFH	4323	0	0	0.00	0.17	1.23	2.99	5.81	21.1	64	4.26	4.11	4.41	3.80	26.6
H	167	0	0	1.00	1.00	7.00	10.0	11.0	38.0	40	11.8	10.4	13.2	1.70	5.02

Measured bulk density (kg m^{-3})

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	$MeanCI_{95\%}$		Skew	Kurt
												LCL	UCL		
M01	3753	0	0	99	385	776	1015	1251	1561	2847	1007	997	1017	-0.08	2.64
M12	2504	0	0	88	506	927	1180	1385	1645	1965	1140	1128	1153	-0.39	2.57
M24	1558	0	0	90	462	969	1248	1433	1651	1908	1180	1164	1196	-0.65	2.80
M48	1049	0	0	103	583	1106	1354	1527	1728	2508	1286	1267	1306	-0.71	3.31
H01	116	0	0	41	45	94	151	283	781	1030	217	183	251	2.20	8.80
H12	56	0	0	58	71	111	158	239	707	1203	219	168	271	2.97	13.5
H24	39	0	0	64	74	102	147	214	829	1158	216	147	285	2.87	11.3
H48	21	0	0	64	66	80	117	150	783	1250	181	72.3	289	3.81	16.6

Estimated bulk density (kg m^{-3})

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	$MeanCI_{95\%}$		Skew	Kurt
												LCL	UCL		
M01	2956	0	0	103	399	880	1052	1273	1531	1629	1056	1045	1066	-0.36	2.88
M12	2485	0	0	120	567	972	1143	1327	1574	1808	1136	1126	1147	-0.42	3.19
M24	2283	0	0	141	625	1084	1245	1437	1621	1904	1229	1219	1240	-0.70	3.69
M48	2141	0	0	134	739	1202	1301	1498	1701	1965	1316	1306	1326	-0.75	4.93
H01	26	0	0	96	107	188	250	438	758	819	319	247	391	1.07	3.49
H12	16	0	0	89	103	187	213	269	757	860	275	179	371	1.97	6.19
H24	11	0	0	84	90.5	149	186	247	753	860	257	127	388	2.06	6.22
H48	12	0	0	79	88.1	131	159	245	754	860	250	125	375	1.99	6.01

Mass percentage of coarse fragments (% DM)

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	$MeanCI_{95\%}$		Skew	Kurt
												LCL	UCL		
M01	3390	0	0.0	0	0.00	0.20	3.72	18.0	73.2	95.7	14.0	13.3	14.7	1.74	5.02
M12	2309	0	0.0	0	0.00	0.88	7.11	28.2	76.1	100	18.5	17.5	19.4	1.32	3.62
M24	1964	0	0.0	0	0.00	0.51	5.07	18.7	67.2	100	13.1	12.3	13.9	1.89	6.46
M48	1630	0	0.0	0	0.00	0.21	3.99	15.5	61.4	100	11.6	10.7	12.4	2.15	7.90

Volume percentage of coarse fragments (% vol)

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	$MeanCI_{95\%}$		Skew	Kurt
												LCL	UCL		
M01	4438	0	0.0	0	0.00	3.00	16.5	32.8	68.7	99.0	21.2	20.6	21.8	0.92	3.11
M12	3255	0	0.0	0	0.00	5.00	20.1	37.8	70.8	90.0	24.2	23.4	24.9	0.75	2.76
M24	2087	0	0.0	0	0.00	4.43	20.0	42.2	79.0	95.0	26.0	25.0	27.0	0.73	2.53
M48	1589	0	0.0	0	0.00	5.00	30.0	55.0	85.0	95.3	32.5	31.2	33.8	0.39	1.91

pH-$CaCl_2$

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	$MeanCI_{95\%}$		Skew	Kurt
												LCL	UCL		
OL	731	0	0	2.90	3.40	4.20	4.72	5.30	6.90	7.40	4.80	4.74	4.86	0.62	3.39
OFH	4653	0	0	2.31	2.77	3.20	3.72	4.90	6.83	7.46	4.15	4.11	4.18	0.89	2.77
H	161	0	0	2.59	2.61	3.20	3.40	3.83	5.40	5.70	3.57	3.47	3.67	1.28	4.92
M01	6707	0	0	2.49	3.00	3.56	4.00	5.00	7.44	7.80	4.46	4.43	4.50	1.12	3.05
M12	4694	0	0	2.70	3.28	3.90	4.20	4.82	7.52	7.90	4.64	4.61	4.67	1.34	3.66
M24	3708	0	0	2.81	3.51	4.06	4.30	4.90	7.60	8.10	4.71	4.68	4.75	1.53	4.33
M48	3298	0	0	3.15	3.70	4.18	4.49	5.08	7.70	8.10	4.87	4.83	4.91	1.42	3.90
H01	367	0	0	2.40	2.62	2.94	3.20	3.87	6.37	6.87	3.56	3.46	3.66	1.64	5.04
H12	253	0	0	2.40	2.61	2.93	3.30	4.01	6.36	7.10	3.65	3.53	3.78	1.39	4.31
H24	192	0	0	2.50	2.65	3.00	3.40	4.10	6.15	6.87	3.74	3.60	3.88	1.27	3.96
H48	96	0	0	2.60	2.66	3.00	3.43	4.97	6.46	6.84	4.05	3.80	4.29	0.61	2.03

pH-H_2O

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	$MeanCI_{95\%}$		Skew	Kurt
												LCL	UCL		
OL	389	0	0	3.66	3.96	4.60	5.10	5.50	6.43	7.20	5.08	5.02	5.15	0.24	2.91
OFH	3535	0	0	3.08	3.45	3.90	4.20	4.90	6.80	7.86	4.48	4.46	4.51	1.31	4.34
H	161	0	0	3.24	3.31	3.90	4.00	4.48	5.92	6.60	4.20	4.11	4.30	1.44	5.63
M01	5201	0	0	3.20	3.69	4.16	4.50	5.10	7.76	8.60	4.82	4.79	4.85	1.55	4.84
M12	3927	0	0	3.48	3.92	4.48	4.80	5.30	8.10	8.80	5.12	5.09	5.16	1.61	4.96
M24	3564	0	0	3.60	4.08	4.60	5.00	5.60	8.29	8.80	5.34	5.31	5.38	1.44	4.23
M48	3150	0	0	3.70	4.20	4.72	5.18	5.80	8.40	9.06	5.52	5.48	5.56	1.31	3.80
H01	341	0	0	2.93	3.30	3.67	3.98	4.44	6.75	7.22	4.23	4.14	4.32	1.58	5.04
H12	232	0	0	3.10	3.31	3.70	4.00	4.84	6.73	7.30	4.35	4.23	4.46	1.22	3.85
H24	177	0	0	3.29	3.34	3.80	4.13	4.90	6.55	7.11	4.43	4.30	4.56	1.16	3.67
H48	87	0	0	3.30	3.33	3.71	4.53	5.66	6.91	7.01	4.73	4.50	4.97	0.42	1.82

Carbonates (g kg^{-1})

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	$MeanCI_{95\%}$		Skew	Kurt
												LCL	UCL		
OL	108	71	65.7	<3.0	0.04	0.48	1.93	8.18	111	287	16.1	9.31	22.9	4.79	32.2
OFH	1104	568	51.4	<3.0	0.33	3.50	10.2	66.0	357	677	55.1	49.4	60.8	2.60	10.5
H	2	1	50.0	<3.0	NA	NA	NA	NA	NA	NA	3.89	NA	NA	NA	NA
M01	1786	823	46.1	<3.0	0.49	5.11	15.3	149	531	879	103	95.9	111	1.70	5.0
M12	1174	550	46.8	<3.0	0.43	4.93	14.9	170	567	834	111	101	121	1.64	4.7
M24	935	538	57.5	<3.0	0.12	2.26	7.97	71.9	572	785	81.3	71.3	91.3	2.34	7.8
M48	904	506	56.0	<3.0	0.14	2.54	9.01	79.3	661	949	94.5	82.8	106	2.28	7.6
H01	28	19	67.9	<3.0	0.02	0.20	0.66	4.3	59.7	91.5	11.0	3.80	18.3	3.08	12.6
H12	18	11	61.1	<3.0	0.09	0.38	1.13	5.0	37.5	43.0	8.50	3.23	13.8	2.24	6.8
H24	12	8	66.7	<3.0	0.10	0.37	0.79	4.0	19.1	20.0	6.40	2.87	9.93	1.63	4.1
H48	12	7	58.3	<3.0	0.50	1.09	2.09	6.0	15.7	16.8	6.32	3.70	8.95	1.15	3.2

Organic Carbon (g kg^{-1})

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	$MeanCI_{95\%}$		Skew	Kurt
												LCL	UCL		
OL	1532	0	0.0	50.9	194	395	454	492	547	750	432	427	436	-1.25	4.74
OFH	4653	0	0.0	8.8	93.1	280	366	438	520	597	352	348	355	-0.60	2.86
H	161	0	0.0	153	246	386	456	497	546	581	435	423	448	-0.89	3.42
M01	6698	9	0.1	<1.2	6.0	18.5	33.1	55.9	152	344	43.8	42.9	44.7	2.31	10.9
M12	4690	42	0.9	<1.2	3.1	10.2	18.0	31.1	92.8	221	25.1	24.4	25.7	2.68	13.6
M24	3705	152	4.1	<1.2	1.4	5.5	10.2	18.0	65.5	233	15.6	15.0	16.2	4.21	30.8
M48	3294	607	18.4	<1.2	0.4	1.8	4.27	8.5	39.9	319	8.1	7.58	8.54	9.32	160
H01	367	0	0.0	102	177	384	485	516	549	575	441	431	452	-1.25	3.56
H12	252	0	0.0	121	171	407	504	535	575	593	461	447	474	-1.31	3.83
H24	192	0	0.0	133	204	453	520	549	590	601	487	473	501	-1.65	5.47
H48	96	0	0.0	132	201	424	491	531	580	587	462	441	482	-1.37	4.33

Total Nitrogen (g kg^{-1})

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	$MeanCI_{95\%}$		Skew	Kurt
												LCL	UCL		
OL	1531	0	0.0	3.4	6.83	11.7	13.9	16.2	21.2	37.0	14.0	13.8	14.2	0.47	4.79
OFH	4653	0	0.0	0.7	4.33	10.5	13.4	16.2	21.9	38.4	13.3	13.2	13.4	0.07	3.50
H	160	0	0.0	8.7	9.59	13.6	16.3	19.1	29.7	31.3	17.0	16.2	17.8	0.97	3.66
M01	6699	29	0.4	<0.1	0.31	1.00	1.91	3.47	9.10	21.6	2.63	2.57	2.68	2.11	9.54
M12	4688	59	1.3	<0.1	0.20	0.60	1.10	2.00	5.80	21.3	1.60	1.56	1.64	3.09	19.7
M24	3159	136	4.3	<0.1	0.11	0.39	0.70	1.40	4.50	14.4	1.11	1.06	1.15	3.34	20.8
M48	2793	368	13.2	<0.1	0.05	0.20	0.40	0.78	2.70	24.6	0.65	0.61	0.70	11.0	230
H01	367	0	0.0	4.4	8.21	14.4	18.3	23.4	31.5	35.4	18.8	18.2	19.5	0.29	2.73
H12	252	0	0.0	3.6	8.63	15.3	18.9	23.7	31.6	35.0	19.5	18.8	20.3	0.10	2.49
H24	192	0	0.0	5.1	7.93	14.5	19.2	23.9	29.3	33.6	19.3	18.4	20.1	-0.09	2.34
H48	96	0	0.0	4.8	7.91	14.1	18.8	24.3	29.7	31.8	19.0	17.8	20.2	-0.06	2.23

Free H^+ ($cmol_+$ kg^{-1})

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	$MeanCI_{95\%}$		Skew	Kurt
												LCL	UCL		
OL	248	42	16.9	<0.1	0.1	0.32	0.76	1.49	5.97	13.2	1.23	1.02	1.43	3.9	24.0
OFH	3472	483	13.9	<0.1	0.12	0.58	2.20	5.17	11.8	20.4	3.35	3.24	3.46	1.2	4.0
H	139	5	3.6	0.1	0.48	2.43	5.74	8.32	13.8	22.7	5.97	5.30	6.64	0.7	4.0
M01	6081	2135	35.1	<0.1	0.02	0.10	0.25	0.61	2.79	25.0	0.57	0.54	0.60	7.2	85.1
M12	4216	2213	52.5	<0.1	0.01	0.05	0.11	0.27	1.31	5.12	0.27	0.26	0.28	4.4	31.9
M24	3580	2229	62.3	<0.1	0.01	0.03	0.07	0.19	1.10	9.52	0.22	0.21	0.24	11.5	224
M48	3167	2227	70.3	<0.1	0.01	0.02	0.05	0.13	0.83	14.8	0.19	0.18	0.21	20.6	565
H01	328	14	4.3	<0.1	0.17	1.31	3.62	9.74	17.2	30.0	6.00	5.38	6.62	1.0	3.3
H12	222	14	6.3	<0.1	0.2	1.26	3.08	7.59	17.5	27.6	5.21	4.52	5.91	1.4	4.8
H24	180	10	5.6	<0.1	0.17	1.14	2.77	7.07	15.6	20.0	4.72	4.03	5.41	1.2	3.4
H48	85	12	14.1	<0.1	0.11	0.53	1.50	5.05	14.6	15.7	3.20	2.34	4.06	1.7	5.1

Exchangeable acidity ($cmol_+ kg^{-1}$)

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	$MeanCI_{95\%}$		Skew	Kurt
												LCL	UCL		
OL	250	33	13.2	0.04	0.06	0.23	1.04	1.99	6.87	15.93	1.68	1.41	1.96	2.9	14.8
OFH	3457	127	3.7	0.04	0.32	2.18	5.71	9.90	17.19	28.46	6.46	6.29	6.62	0.7	3
H	139	3	2.2	0.1	1.38	10.2	13.6	16.7	22.44	25.3	13.07	12.14	14.0	-0.5	3
M01	6088	1020	16.8	<0.1	0.12	0.49	2.24	4.33	11.8	41.36	3.09	3.00	3.17	2.3	12.3
M12	4210	783	18.6	<0.1	0.12	0.43	1.53	3.05	8.19	19.25	2.15	2.08	2.21	1.8	8
M24	3576	676	18.9	<0.1	0.10	0.32	1.10	2.41	6.50	21.58	1.68	1.62	1.74	2.3	12.6
M48	3143	761	24.2	<0.1	0.05	0.21	0.66	1.83	5.66	19.13	1.32	1.26	1.38	3.1	19.6
H01	328	3	0.9	0.09	0.28	3.99	9.83	15.71	20.99	30.01	9.85	9.14	10.6	0.1	2.1
H12	222	7	3.2	0.03	0.25	3.20	9.11	14.01	21.34	27.6	9.18	8.3	10.1	0.4	2.3
H24	180	7	3.9	0.1	0.23	3.19	8.14	13.64	19.91	23.0	8.63	7.74	9.52	0.2	2
H48	85	12	14.1	0.01	0.16	0.64	2.73	9.33	18.75	19.81	5.51	4.29	6.74	0.9	2.7

Exchangeable K ($cmol_+ kg^{-1}$)

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	$MeanCI_{95\%}$		Skew	Kurt
												LCL	UCL		
OL	299	0	0.0	0.05	0.78	1.39	1.94	2.80	5.26	8.69	2.22	2.09	2.36	1.5	7
OFH	3493	35	1.0	<0.03	0.21	0.80	1.25	1.90	3.80	10.0	1.45	1.42	1.48	1.8	9.5
H	138	2	1.4	0.03	0.07	0.42	1.09	1.68	2.94	3.94	1.11	0.98	1.25	0.7	3.1
M01	6145	508	8.3	<0.03	0.02	0.07	0.15	0.29	1.26	7.09	0.25	0.24	0.26	5.6	59.4
M12	4260	978	23.0	<0.03	0.01	0.04	0.08	0.18	0.81	4.62	0.16	0.15	0.17	5.8	57.1
M24	3634	1225	33.7	<0.03	0.01	0.03	0.06	0.14	0.73	3.25	0.13	0.12	0.14	5.7	48.6
M48	3222	1062	33.0	<0.03	0.01	0.03	0.06	0.15	0.65	5.01	0.13	0.12	0.14	8.9	132
H01	328	3	0.9	0.03	0.08	0.31	0.62	1.16	2.16	3.18	0.80	0.74	0.87	0.9	3.2
H12	222	10	4.5	<0.03	0.04	0.15	0.26	0.44	1.19	2.29	0.34	0.30	0.38	2.6	13
H24	180	17	9.4	<0.03	0.03	0.09	0.14	0.25	1.11	1.86	0.22	0.18	0.26	3.2	15.6
H48	86	18	20.9	<0.03	0.01	0.04	0.10	0.19	1.25	1.86	0.23	0.16	0.30	2.7	10.4

Exchangeable Ca ($cmol_+ kg^{-1}$)

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	$MeanCI_{95\%}$		Skew	Kurt
												LCL	UCL		
OL	299	2	0.7	0.03	4.58	13.4	21.4	34.9	64.4	84.4	25.6	23.8	27.5	1.0	3.5
OFH	3493	9	0.3	<0.03	0.96	7.92	13	22.8	82.3	197	19.9	19.2	20.6	2.6	11.5
H	138	0	0.0	0.08	1.06	6.08	9.08	14.2	80.8	97	14.1	11.2	17.0	3.3	14.3
M01	6145	94	1.5	<0.03	0.05	0.31	1.23	7.9	46.9	169	7.61	7.26	7.97	3.5	21.4
M12	4260	192	4.5	<0.03	0.01	0.15	0.51	4.82	38.9	127	5.65	5.31	6	3.3	18.2
M24	3634	293	8.1	<0.03	0.01	0.10	0.35	3.62	33.4	105	4.51	4.2	4.82	3.4	18.1
M48	3223	345	10.7	<0.03	0.01	0.08	0.43	4.3	25.8	139	4.02	3.75	4.29	4.3	41.1
H01	328	0	0.0	0.08	0.41	4.58	9.06	23.1	129.8	286	25.6	21.3	29.9	2.8	13.5
H12	222	3	1.4	<0.03	0.45	4.03	9.30	25.0	130.1	159	25.6	20.7	30.5	1.9	5.6
H24	180	0	0.0	0.08	0.62	4.14	10.4	27.6	136.3	167	26.9	21.3	32.5	1.9	5.7
H48	86	0	0.0	0.07	0.17	5.36	14.0	79.5	146.0	245	42.7	32.1	53.3	1.4	4.7

Exchangeable Mg ($cmol_+ kg^{-1}$)

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	$MeanCI_{95\%}$		Skew	Kurt
												LCL	UCL		
OL	299	2	0.7	0.03	1.21	3.80	5.77	8.60	14.4	21.4	6.43	6.02	6.84	1.0	4.3
OFH	3493	16	0.5	<0.03	0.46	1.70	2.89	4.99	13.4	69.1	3.97	3.84	4.09	4.0	41.5
H	138	1	0.7	<0.03	0.32	1.80	2.85	4.31	8.02	14.0	3.32	2.93	3.71	1.7	7.4
M01	6145	517	8.4	<0.03	0.01	0.10	0.38	1.20	7.13	32.4	1.15	1.09	1.20	5.5	44.3
M12	4259	783	18.4	<0.03	0.01	0.05	0.18	0.77	6.03	24.3	0.83	0.77	0.88	4.9	36.7
M24	3631	998	27.5	<0.03	0.00	0.03	0.11	0.68	5.70	18.2	0.76	0.70	0.81	4.1	24.9
M48	3222	966	30	<0.03	0.00	0.03	0.14	0.93	6.60	16.6	0.92	0.86	0.98	3.6	19.4
H01	328	2	0.6	0.03	0.45	1.68	3.48	5.69	12.3	167.8	4.62	3.59	5.66	15.2	259
H12	222	5	2.3	<0.03	0.40	1.26	2.41	4.64	12.1	167.8	4.26	2.75	5.77	13.1	186
H24	180	2	1.1	0.03	0.19	1.22	2.66	5.71	13.1	167.8	4.82	2.96	6.69	11.7	150
H48	86	2	2.3	0.03	0.22	1.45	3.22	6.35	21.5	167.8	6.63	2.79	10.5	8.3	73.6

Exchangeable Na ($cmol_+ kg^{-1}$)

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	$MeanCI_{95\%}$		Skew	Kurt
												LCL	UCL		
OL	302	93	30.8	<0.03	0.01	0.03	0.08	0.21	1.40	2.00	0.23	0.19	0.27	2.6	9.8
OFH	3493	285	8.2	<0.03	0.03	0.10	0.16	0.29	1.15	6.00	0.26	0.25	0.27	5.3	49.5
H	138	3	2.2	<0.03	0.07	0.16	0.20	0.28	0.63	0.65	0.23	0.21	0.25	1.3	5.2
M01	6145	2662	43.3	<0.03	<0.03	0.02	0.04	0.07	0.43	2.06	0.08	0.07	0.08	6.5	66.7
M12	4260	2145	50.4	<0.03	0.00	0.01	0.03	0.06	0.43	3.54	0.08	0.07	0.08	9.2	139
M24	3633	1922	52.9	<0.03	0.00	0.01	0.03	0.06	0.42	2.53	0.08	0.07	0.08	8.2	98.3
M48	3221	1620	50.3	<0.03	0.00	0.01	0.03	0.07	0.43	2.94	0.08	0.08	0.09	8.6	107
H01	328	6	1.8	<0.03	0.06	0.20	0.30	0.68	2.33	4.17	0.54	0.48	0.61	2.4	9.9
H12	222	10	4.5	<0.03	0.04	0.17	0.25	0.50	2.12	2.89	0.45	0.38	0.52	2.4	8.9
H24	180	4	2.2	0.03	0.04	0.17	0.24	0.45	2.16	2.65	0.45	0.37	0.53	2.3	7.9
H48	86	5	5.8	<0.03	0.03	0.16	0.30	0.63	2.09	2.30	0.54	0.42	0.66	1.6	4.7

Exchangeable Al ($cmol_+ kg^{-1}$)

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	$MeanCI_{95\%}$		Skew	Kurt
												LCL	UCL		
OL	299	109	36.5	<0.02	<0.02	0.02	0.04	0.10	0.77	2.27	0.12	0.09	0.15	5.3	37.5
OFH	3465	383	11.1	<0.02	0.03	0.22	1.32	3.15	9.16	23.4	2.19	2.10	2.28	2.2	10.0
H	138	7	5.1	0.02	0.81	4.11	7.25	9.93	16.58	19.7	7.17	6.47	7.88	0.4	3.0
M01	6128	1015	16.6	<0.02	0.03	0.20	1.45	3.23	9.04	25.4	2.24	2.18	2.31	2.3	11.9
M12	4241	628	14.8	<0.02	0.03	0.22	1.17	2.61	7.11	17.3	1.79	1.73	1.85	2.0	9.1
M24	3614	458	12.7	<0.02	0.03	0.20	0.85	2.13	5.65	15.6	1.43	1.38	1.48	2.1	10
M48	3209	466	14.5	<0.02	0.02	0.11	0.51	1.53	5.22	15.6	1.11	1.05	1.16	2.9	16.4
H01	327	27	8.3	0.02	0.06	0.74	2.04	5.38	12.9	23.3	3.60	3.17	4.02	1.6	6.3
H12	222	28	12.6	<0.02	0.07	0.88	2.33	5.55	14.9	25.5	3.88	3.30	4.45	1.8	6.8
H24	180	19	10.6	0.02	0.05	0.84	2.28	5.80	13.7	20.7	3.68	3.09	4.28	1.5	5
H48	85	22	25.9	<0.02	0.02	0.11	0.77	2.53	10.9	12.6	2.10	1.44	2.76	1.8	5.5

Exchangeable Fe ($cmol_+ kg^{-1}$)

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	$MeanCI_{95\%}$		Skew	Kurt
												LCL	UCL		
OL	299	263	88.0	<0.02	0.00	0.00	0.00	0.01	0.16	0.51	0.04	0.04	0.05	5.7	44.8
OFH	3462	896	25.9	<0.02	0.01	0.04	0.15	0.42	1.50	8.33	0.32	0.3	0.33	4.6	45.1
H	138	8	5.8	<0.02	0.06	0.45	1.06	1.74	5.17	5.96	1.38	1.16	1.60	1.6	5.30
M01	6125	2497	40.8	<0.02	0.00	0.02	0.04	0.13	0.70	3.84	0.13	0.12	0.13	6.5	67.0
M12	4239	2330	55.0	<0.02	0.00	0.01	0.02	0.06	0.32	3.35	0.06	0.06	0.06	10	213
M24	3614	2450	67.8	<0.02	0.00	0.01	0.01	0.03	0.19	3.64	0.04	0.04	0.05	21.7	671
M48	3207	2497	77.9	<0.02	0.00	0.00	0.01	0.02	0.13	9.45	0.04	0.03	0.04	39.1	1765
H01	328	42	12.8	<0.02	0.02	0.11	0.43	1.02	3.80	8.45	0.81	0.68	0.93	3.2	16.3
H12	222	32	14.4	<0.02	0.02	0.10	0.30	0.89	2.02	6.02	0.57	0.47	0.66	3.3	21.0
H24	180	25	13.9	<0.02	0.02	0.08	0.25	0.77	1.74	2.86	0.47	0.39	0.55	1.8	6.80
H48	86	26	30.2	<0.02	0.01	0.03	0.09	0.24	1.12	1.51	0.22	0.16	0.28	2.3	8.30

Exchangeable Mn ($cmol_+ kg^{-1}$)

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	$MeanCI_{95\%}$		Skew	Kurt
												LCL	UCL		
OL	300	14	4.7	<0.02	0.03	0.27	0.73	1.51	5.66	6.77	1.20	1.04	1.36	2.0	6.7
OFH	3480	135	3.9	<0.02	0.03	0.24	0.65	1.39	4.99	33.8	1.11	1.06	1.15	5.4	79.6
H	138	37	26.8	<0.02	<0.02	0.04	0.12	0.36	1.27	5.48	0.29	0.20	0.38	6.6	60.6
M01	6138	2573	41.9	<0.02	<0.02	0.02	0.04	0.14	0.68	3.87	0.12	0.12	0.13	5.6	52.8
M12	4253	2291	53.9	<0.02	<0.02	0.01	0.03	0.07	0.38	3.88	0.07	0.07	0.08	9.8	213
M24	3626	2253	62.1	<0.02	<0.02	0.01	0.02	0.05	0.29	2.10	0.06	0.05	0.06	6.8	86.7
M48	3217	2208	68.6	<0.02	<0.02	0.01	0.01	0.04	0.20	1.36	0.04	0.04	0.05	6.6	81.2
H01	328	114	34.8	<0.02	<0.02	0.02	0.05	0.19	1.13	2.09	0.18	0.15	0.22	3.4	16.4
H12	222	128	57.7	<0.02	<0.02	<0.02	0.02	0.06	0.72	2.93	0.10	0.06	0.13	7.3	69.3
H24	180	97	53.9	<0.02	<0.02	0.01	0.02	0.06	0.75	2.15	0.09	0.06	0.13	5.7	39.9
H48	86	38	44.2	<0.02	<0.02	0.01	0.03	0.07	0.80	1.57	0.10	0.05	0.14	4.9	29.4

Aqua Regia Extractable P (mg kg^{-1})

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	MeanCI$_{95\%}$		Skew	Kurt
												LCL	UCL		
OL	2270	0	0.0	56.6	200	596	810	1005	1499	8912	806	791	821	4.70	101
OFH	4237	171	4.0	<35.0	214	566	746	934	1416	4832	757	747	767	1.26	14.4
H	163	15	9.2	<35.0	380	724	960	1260	2093	2758	1013	940	1085	0.32	3.84
M01	5863	171	2.9	<35.0	51.8	186	321	524	1265	9400	407	398	417	6.29	104
M12	3267	73	2.2	<35.0	44.0	176	302	482	1314	6728	387	375	399	4.85	58.7
M24	2947	76	2.6	<35.0	41.8	162	276	447	1245	6400	358	346	370	4.47	53.0
M48	2595	86	3.3	<35.0	35.4	131	237	410	1190	3454	328	315	340	3.16	19.8
H01	370	31	8.4	<35.0	233	563	790	1080	1939	5589	872	818	927	2.50	19.2
H12	231	14	6.1	<35.0	156	397	640	1010	2090	4036	771	702	839	1.72	8.81
H24	194	12	6.2	<35.0	138	316	544	865	1605	2401	639	581	697	1.12	6.64
H48	99	12	12.1	<35.0	81.0	214	366	628	1404	2401	479	404	555	1.89	8.39

Aqua Regia Extractable K (mg kg^{-1})

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	MeanCI$_{95\%}$		Skew	Kurt
												LCL	UCL		
OL	2268	8	0.35	<80.0	581	1043	1471	2099	4314	18347	1724	1682	1767	3.31	34.9
OFH	4237	383	9.03	<80.0	217	670	1090	1730	5898	45869	1484	1436	1532	7.23	151
H	163	25	15.3	<80.0	122	350	661	978	1770	3260	689	610	768	1.67	8.53
M01	5872	159	2.70	<80.0	99.0	422	1192	2800	9216	61780	2097	2029	2165	5.12	78.8
M12	3260	40	1.22	<80.0	130	530	1547	3256	9275	24248	2368	2281	2455	2.17	10.1
M24	2938	30	1.02	<80.0	143	542	1510	3061	8001	22301	2184	2102	2265	2.44	13.2
M48	2587	21	0.81	<80.0	155	608	1713	3446	8844	26322	2436	2339	2532	2.64	16.0
H01	370	65	17.6	<80.0	116	253	539	796	1583	2022	579	538	620	0.97	4.03
H12	231	40	17.3	<80.0	35.3	110	210	363	1557	2036	320	275	365	2.84	12.0
H24	192	66	34.4	<80.0	15.5	42.4	111	249	1275	2245	250	203	297	3.44	16.9
H48	99	50	50.5	<80.0	3.80	19.5	59.7	173	1549	3609	264	169	358	4.41	26.9

Aqua Regia Extractable Ca (mg kg^{-1})

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	MeanCI$_{95\%}$		Skew	Kurt
												LCL	UCL		
OL	2268	0	0.00	223	2241	5524	8726	14133	39542	92286	11332	10950	11715	2.69	14.1
OFH	4229	14	0.33	<50.0	661	2150	3553	7991	42583	188403	7744	7392	8095	4.47	36.3
H	163	1	0.61	<50.0	588	1490	2323	3885	22038	24923	4261	3436	5086	2.48	8.40
M01	5872	50	0.85	<50.0	93.4	339	913	2811	75253	526778	7475	6849	8103	6.85	76.2
M12	3262	50	1.53	<50.0	63.7	244	660	3079	109314	616667	10284	9154	11415	6.18	62.8
M24	2940	48	1.63	<50.0	62.6	232	624	2755	115590	661481	10054	8804	11305	6.49	69.0
M48	2588	66	2.55	<50.0	18.2	240	675	2730	135583	367000	11216	9785	12647	4.90	30.7
H01	370	3	0.81	<50.0	211	1470	2517	5818	36965	85277	6751	5592	7909	3.35	16.8
H12	231	1	0.43	<50.0	396	1209	2280	5530	38234	123183	7333	5584	9082	4.26	28.9
H24	192	1	0.52	<50.0	374	1186	2319	7172	39543	75448	7385	5713	9057	2.67	11.1
H48	99	1	1.01	<50.0	304	1389	2634	20640	49254	75448	11159	8239	14079	1.76	6.15

Aqua Regia Extractable Mg (mg kg^{-1})

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	MeanCI$_{95\%}$		Skew	Kurt
												LCL	UCL		
OL	2268	0	0.00	60.0	357	733	1187	1919	6190	52252	1656	1571	1741	10.7	209
OFH	4234	0	0.00	38.8	276	527	930	1882	7602	56470	1762	1671	1853	7.95	94.8
H	163	0	0.00	103	177	404	556	907	2733	5690	792	680	904	3.15	16.9
M01	5872	41	0.70	<35.0	82.7	488	1550	3934	21546	178130	3647	3442	3853	8.07	101
M12	3262	31	0.95	<35.0	75.8	560	2048	4663	28817	162230	4552	4117	4888	7.03	73.1
M24	2940	23	0.78	<35.0	95.7	608	2123	4973	30149	204530	4760	4387	5133	7.70	94.2
M48	2589	10	0.39	<35.0	120	674	2480	5631	30477	160000	5086	4689	5482	6.55	61.9
H01	370	0	0.00	102	210	469	714	1214	3036	6638	964	884	1043	2.79	15.4
H12	231	0	0.00	109	156	325	582	1097	2955	4324	845	749	942	1.92	7.19
H24	192	0	0.00	72.0	123	326	595	1078	3077	7251	874	746	1002	3.40	20.0
H48	99	0	0.00	113	165	504	880	1356	3838	6651	1135	971	1339	2.46	11.0

Aqua Regia Extractable S (mg kg^{-1})

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	MeanCI$_{95\%}$		Skew	Kurt
												LCL	UCL		
OL	1978	2	0.1	8.2	616	965	1207	1586	2600	10576	1326	1301	1350	3.35	43.3
OFH	3450	0	0	34.0	463	1100	1410	1792	2741	10000	1468	1449	1488	1.69	17.8
H	162	0	0	49.0	930	1411	1682	2105	3929	11965	1968	1777	2159	4.60	33.0
M01	5119	61	1.2	<20.0	28.8	100	198	378	1090	6000	292	283	300	4.91	59.6
M12	1643	40	2.4	<20.0	20.4	59.6	110	230	770	2237	184	174	194	3.33	20.8
M24	1634	86	5.3	<20.0	13.2	44.5	86.0	171	564	3756	142	133	151	6.89	106
M48	1493	200	13.4	<20.0	9.21	28.8	52.9	122	482	4054	106	97.6	115	10.0	192
H01	340	0	0	484.3	913	1549	2173	2943	6154	7745	2428	2297	2558	1.55	6.36
H12	186	0	0	420.0	1081	1731	2237	3120	6531	10500	2645	2438	2853	2.16	9.89
H24	160	0	0	622.0	882	1494	2270	3300	6638	18450	2706	2402	3009	3.85	28.1
H48	74	0	0	823.0	1080	1652	2503	3910	6747	8354	3041	3650	3432	1.01	3.33

Aqua Regia Extractable Na (mg kg^{-1})

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	MeanCI$_{95\%}$		Skew	Kurt
												LCL	UCL		
OL	1890	39	2.06	<20.0	21.0	44.6	74.7	165	538	1396	136	130	143	2.56	12.4
OFH	3473	610	17.6	<20.0	14.4	42.5	86.0	141	474	1467	117	112	121	3.53	23.4
H	163	29	17.8	<20.0	25.5	48.4	84.2	122	186	223	87.5	80.1	95.0	0.38	2.42
M01	4983	589	11.8	<20.0	12.0	40.8	75.8	148	547	8033	127	122	133	16.5	503
M12	1556	175	11.2	<20.0	11.9	39.0	62.9	112	636	1877	116	108	124	4.17	27.6
M24	1553	159	10.2	<20.0	12.5	41.9	67.1	117	643	2362	123	114	132	5.00	40.9
M48	1441	160	11.1	<20.0	14.3	43.8	69.8	108	650	2470	115	106	125	5.89	52.3
H01	341	75	22.0	<20.0	11.1	40.4	72.6	140	483	908	115	102	128	2.54	11.3
H12	202	47	23.3	<20.0	8.38	27.2	58.0	92.6	390	740	92.8	78.0	108	2.95	13.8
H24	172	36	20.9	<20.0	9.07	31.0	57.5	108	416	473	91.6	77.2	106	2.22	7.81
H48	85	35	41.2	<20.0	3.40	15.8	41.0	99.8	485	540	99.8	73.7	126	2.13	6.77

Aqua Regia Extractable Al (mg kg^{-1})

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	MeanCI$_{95\%}$		Skew	Kurt
												LCL	UCL		
OL	2011	1	0.05	<10.0	208	600	1131	2534	11290	45830	2323	2178	2467	4.15	31.9
OFH	4009	37	0.92	<10.0	781	2114	3907	8099	25635	56800	6338	6134	6541	2.37	10.3
H	163	5	3.07	<10.0	372	1970	3792	6305	13085	28300	4675	4058	5292	2.33	11.9
M01	5845	5	0.09	<10.0	1100	4456	11634	22954	48486	134845	15478	15130	15826	1.40	6.02
M12	1895	0	0.00	269	1548	4975	14160	25890	51079	82390	17210	16578	17842	1.03	3.76
M24	1612	0	0.00	132	1717	5010	12800	24397	50659	88055	16266	15591	16942	1.38	5.37
M48	1488	3	0.20	<10.0	1656	4084	11880	25976	55187	90634	16720	15945	17495	1.35	5.09
H01	344	12	3.49	<10.0	253	970	2283	5353	17038	25912	4042	3575	4509	1.84	6.35
H12	190	8	4.21	<10.0	252	1052	2616	6114	18164	34639	4490	3720	5260	2.75	13.3
H24	163	6	3.68	<10.0	212	1132	2592	6311	19236	25912	4433	3683	5183	2.02	7.78
H48	76	7	9.21	<10.0	141	828	1782	4247	25980	35330	4084	2702	5465	3.11	13.8

Aqua Regia Extractable Fe (mg kg^{-1})

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	MeanCI$_{95\%}$		Skew	Kurt
												LCL	UCL		
OL	2062	3	0.15	<10.0	140	639	1349	2902	10900	64867	2463	2313	2612	5.91	73.5
OFH	4070	0	0.00	152	850	2433	4513	8989	23148	50000	6743	6547	6938	2.28	10.6
H	163	0	0.00	194	494	2025	3920	8484	26830	50000	6537	5335	7740	3.12	15.1
M01	5874	1	0.02	<10.0	889	4818	12527	23260	48748	260236	15957	15593	16320	2.39	22.2
M12	2006	0	0.00	90.1	1011	4504	13912	24464	54966	127591	16935	16271	17598	1.60	7.07
M24	1734	0	0.00	155	1126	4468	13178	25196	60107	136181	17439	16665	18212	1.63	6.81
M48	1618	0	0.00	143	1324	4099	12752	27688	62558	100568	18440	17576	19303	1.36	4.82
H01	371	0	0.00	67.4	756	1829	4458	10365	41278	50000	8423	7373	9472	2.19	7.66
H12	226	0	0.00	280	523	1544	3587	8710	42277	50000	7199	5928	8470	2.67	10.4
H24	189	0	0.00	203	351	1413	2775	7435	39621	50000	6387	4996	7778	3.74	20.4
H48	95	0	0.00	253	372	1382	3058	7130	24261	42532	5795	4323	7267	2.78	12.4

Aqua Regia Extractable Mn (mg kg^{-1})

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	MeanCI$_{95\%}$		Skew	Kurt
												LCL	UCL		
OL	2268	0	0.00	7.60	70.6	330	718	1313	3597	23542	999	955	1043	5.74	94.3
OFH	4237	1	0.02	<2.00	29.0	144	331	817	3504	39729	708	671	745	10.9	269
H	163	0	0.00	3.80	6.53	28.7	60.8	139	1660	91256	724	0	1820	12.6	160
M01	5874	35	0.60	<2.00	9.78	70.8	203	550	1885	8940	410	395	424	4.31	39.5
M12	3267	29	0.89	<2.00	8.27	97.4	293	695	1937	12760	488	467	510	5.28	66.9
M24	2947	27	0.92	<2.00	9.46	91.0	290	658	1866	15363	468	446	491	7.52	136
M48	2594	18	0.69	<2.00	10.8	80.0	254	558	1759	12610	425	402	449	7.18	104
H01	370	0	0.00	2.70	6.02	17.2	47.2	141	1155	39729	373	80.5	665	13.2	177
H12	231	2	0.87	2.00	3.25	7.70	17.4	66.9	935	39729	294	0	634	14.6	219
H24	194	3	1.55	<2.00	2.78	7.90	18.5	58.7	670	39729	296	0	698	13.6	188
H48	99	2	2.02	<2.00	2.19	10.2	37.7	87.2	1136	39729	535	0	1323	9.66	95.2

Aqua Regia Extractable Cu (mg kg^{-1})

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	MeanCI$_{95\%}$		Skew	Kurt
												LCL	UCL		
OL	2276	16	0.70	<1.00	3.20	6.84	9.62	13.3	33.1	156	11.5	11.1	11.9	5.89	59.9
OFH	4237	604	14.3	<1.00	2.16	6.20	9.91	15.3	40.1	373	12.6	12.1	13.0	9.63	178
H	163	29	17.8	<1.00	0.93	4.20	7.30	11.2	74.4	1849	23.0	0.72	45.3	12.4	157
M01	6036	775	12.8	<1.00	0.48	2.03	6.00	14.1	48.0	982	11.1	10.6	11.7	20.4	759
M12	1941	307	15.8	<1.00	0.45	1.61	5.80	14.2	51.0	531	11.5	10.6	12.5	12.0	245
M24	1669	328	19.7	<1.00	0.34	1.26	5.17	14.6	51.1	177	10.9	10.2	11.6	3.29	21.1
M48	1553	350	22.5	<1.00	0.33	1.23	5.20	17.9	55.1	450	12.0	11.1	13.0	9.33	193
H01	370	77	20.8	<1.00	0.99	2.90	6.41	11.7	33.9	107	9.26	8.14	10.4	4.25	29.7
H12	212	46	21.7	<1.00	0.52	2.10	4.65	9.45	35.1	261	9.16	6.36	12.0	9.08	104
H24	177	36	20.3	<1.00	0.56	2.10	5.20	11.4	35.1	111	8.86	7.09	10.6	4.39	32.7
H48	84	35	41.7	<1.00	0.18	0.89	2.52	5.70	22.3	82.1	6.13	3.79	8.47	4.81	31.1

Aqua Regia Extractable Pb (mg kg^{-1})

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	MeanCI$_{95\%}$		Skew	Kurt
												LCL	UCL		
OL	2270	271	11.9	<2.50	1.48	5.00	11.0	21.5	64.3	952	17.5	16.3	18.7	17.0	499
OFH	4233	560	13.2	<2.50	3.00	14.1	28.1	52.4	212	7959	53.4	47.1	59.7	26.2	835
H	163	26	16.0	<2.50	3.16	6.90	18.1	25.4	52.8	245	20.0	16.6	23.4	6.54	63.8
M01	6032	424	7.03	<2.50	3.01	10.5	21.3	37.5	106	18692	36.1	28.0	44.2	52.3	2844
M12	1938	83	4.28	<2.50	2.46	8.24	17.4	30.2	86.9	22300	35.3	12.8	57.9	43.8	1924
M24	1667	179	10.7	<2.50	1.63	4.62	10.8	20.5	58.2	539	15.9	14.8	17.0	10.5	206
M48	1552	321	20.7	<2.50	1.23	2.95	8.00	16.4	49.3	226	12.6	11.8	13.4	5.26	50.0
H01	368	74	20.1	<2.50	2.99	14.7	26.9	50.9	246	1570	55.8	43.2	68.5	8.30	88.1
H12	211	44	20.9	<2.50	1.11	6.20	12.5	22.0	119	61940	317	0.0	893	14.4	209
H24	177	41	23.2	<2.50	0.50	2.70	6.00	12.0	89.2	10350	72.4	0.0	187	13.1	174
H48	84	43	51.2	<2.50	0.02	0.33	1.55	7.30	108	2584	46.4	0.0	108	8.46	74.9

Aqua Regia Extractable Ni (mg kg^{-1})

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	MeanCI$_{95\%}$		Skew	Kurt
												LCL	UCL		
OL	2026	164	8.09	<1.0	0.73	2.50	5.19	9.80	30.9	226	8.13	7.62	8.64	7.59	96.3
OFH	4052	644	15.9	<1.0	1.32	4.40	8.70	14.0	45.6	317	11.7	11.3	12.1	6.12	84.2
H	163	29	17.8	<1.0	1.07	3.10	5.63	8.44	31.6	35.7	7.27	6.21	8.30	2.25	8.56
M01	5858	863	14.7	<1.0	0.42	2.04	6.40	19.0	60.1	916	14.5	13.8	15.3	14.7	354
M12	1865	191	10.2	<1.0	0.57	2.39	8.00	21.0	67.3	276	15.9	14.8	16.9	4.70	37.8
M24	1591	148	9.30	<1.0	0.55	2.67	7.60	21.5	79.3	300	17.4	16.1	18.8	4.74	36.8
M48	1477	136	9.21	<1.0	0.51	2.49	8.30	26.6	77.2	360	19.5	17.9	21.1	5.17	42.8
H01	369	80	21.7	<1.0	0.51	1.70	3.30	6.01	22.5	44.6	5.16	4.56	5.77	3.14	16.2
H12	211	54	25.6	<1.0	0.36	1.16	2.70	5.05	20.4	38.9	4.37	3.63	5.11	3.63	19.2
H24	176	46	26.1	<1.0	0.31	1.10	2.50	5.93	21.4	54.4	4.79	3.88	5.71	3.88	26.0
H48	83	38	45.8	<1.0	0.06	0.39	1.30	5.45	25.1	118	5.93	2.87	8.99	6.35	48.8

Aqua Regia Extractable Cr (mg kg^{-1})

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	$MeanCI_{95\%}$		Skew	Kurt
												LCL	UCL		
OL	1996	245	12.3	<1.0	0.46	2.00	5.10	12.7	49.8	225	10.4	9.72	11.2	5.30	47.7
OFH	4016	603	15.0	<1.0	1.26	5.40	11.9	21.4	91.6	464	19.0	18.1	19.9	5.55	51.7
OH	163	28	17.2	<1.0	1.24	3.90	9.78	18.1	46.1	110	13.8	11.4	16.2	3.34	19.2
M01	5845	429	7.34	<1.0	1.20	5.24	15.1	30.7	79.0	1067	22.8	21.9	23.7	11.6	263
M12	1845	64	3.47	<1.0	1.33	5.43	17.3	32.6	78.2	343	23.2	22.0	24.4	4.32	37.3
M24	1564	52	3.32	<1.0	1.37	5.46	16.0	32.0	79.9	327	23.0	21.6	24.3	4.41	37.8
M48	1443	59	4.09	<1.0	1.17	4.78	14.5	33.1	80.7	349	23.1	21.7	24.5	4.32	38.3
H01	343	77	22.4	<1.0	0.33	1.40	3.60	9.62	32.2	91.5	7.44	6.41	8.46	3.32	21.5
H12	189	53	28.0	<1.0	0.15	0.87	2.30	9.01	43.2	91.1	7.45	5.80	9.10	3.52	20.2
H24	162	44	27.2	<1.0	0.14	0.90	2.40	10.8	44.4	58.6	8.31	6.52	10.1	2.03	6.75
H48	75	38	50.7	<1.0	0.06	0.50	1.50	9.75	57.6	90.9	8.56	4.95	12.2	3.35	15.1

Aqua Regia Extractable Zn (mg kg^{-1})

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	$MeanCI_{95\%}$		Skew	Kurt
												LCL	UCL		
OL	2276	0	0.0	5.50	15.8	41.6	55.0	74.3	172	830	64.7	62.7	66.6	5.97	68.5
OFH	4236	56	1.3	<2.0	14.0	39.0	53.1	73.8	161	6151	64.8	61.3	68.2	40.3	2029
H	163	7	4.3	<2.0	2.38	8.65	24.0	42.9	99.5	1016	37.3	24.2	50.4	9.66	107
M01	6037	180	3.0	<2.0	2.75	13.1	31.2	64.0	166	2679	47.1	45.3	48.8	18.5	650
M12	1970	28	1.4	<2.0	3.51	14.4	33.0	63.8	151	2460	46.9	43.8	50.0	21.3	712
M24	1691	23	1.4	<2.0	3.02	13.6	30.7	62.4	136	382	42.8	40.9	44.8	2.35	12.9
M48	1566	18	1.1	<2.0	3.40	10.7	30.9	64.0	127	476	42.4	40.3	44.5	2.97	21.6
H01	370	6	1.6	<2.0	4.72	20.4	33.6	56.6	288	821	56.3	47.2	65.3	5.05	33.6
H12	198	5	2.5	<2.0	2.60	6.40	13.3	34.0	135	662	31.2	22.2	40.2	6.92	61.1
H24	166	8	4.8	<2.0	0.79	4.15	8.95	25.2	134	662	28.4	17.9	38.9	6.78	56.7
H48	80	7	8.8	<2.0	1.15	6.07	20.0	49.8	156	662	46.3	25.8	66.9	4.99	30.4

Aqua Regia Extractable Cd (mg kg^{-1})*

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	$MeanCI_{95\%}$		Skew	Kurt
												LCL	UCL		
OL	2267	1680	74.1	<0.50	0.05	0.15	0.25	0.52	1.45	9.75	0.62	0.60	0.64	8.13	107
OFH	4237	3180	75.1	<0.50	0.04	0.13	0.23	0.47	1.60	84.0	0.64	0.60	0.69	52.9	3185
H	163	126	77.3	<0.50	0.18	0.25	0.33	0.43	0.80	1.28	0.55	0.53	0.56	0.87	5.90
M01	5995	5145	85.8	<0.50	0.01	0.06	0.11	0.29	1.90	35.5	0.63	0.61	0.65	20.1	816
M12	1937	1655	85.4	<0.50	0.01	0.06	0.13	0.32	2.20	8.00	0.65	0.62	0.67	4.80	37.6
M24	1667	1406	84.3	<0.50	0.01	0.07	0.14	0.36	2.50	7.80	0.67	0.64	0.70	4.29	29.1
M48	1550	1330	85.8	<0.50	0.01	0.06	0.13	0.33	2.53	10.9	0.68	0.65	0.71	5.05	44.5
H01	370	242	65.4	<0.50	0.05	0.16	0.27	0.67	2.17	13.4	0.77	0.67	0.87	8.44	90.3
H12	212	184	86.8	<0.50	<0.01	0.01	0.04	0.13	1.40	13.4	0.70	0.56	0.85	9.48	103
H24	178	162	91.0	<0.50	<0.01	<0.01	<0.01	0.04	1.30	13.4	0.68	0.52	0.83	10.9	132
H48	84	77	91.7	<0.50	<0.01	<0.01	<0.01	0.02	1.43	13.4	0.89	0.56	1.22	7.81	66.5

* If more than 80 % of the observations are left censored, it is tenuous to estimate the percentiles or means with ROS methods and the resulting statistics are prone to uncertainties. Please use these statistics with care.

Aqua Regia Extractable Hg (mg kg^{-1})

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	$MeanCI_{95\%}$		Skew	Kurt
												LCL	UCL		
OL	749	172	23.0	<0.03	0.021	0.052	0.100	0.160	0.413	1.78	0.131	0.121	0.140	4.57	41.2
OFH	995	124	12.5	<0.03	0.038	0.100	0.200	0.300	0.757	9.52	0.241	0.219	0.264	17.9	447
H	23	0	0.0	0.10	0.100	0.200	0.200	0.300	0.400	0.40	0.243	0.205	0.282	0.03	2.15
M01	1750	424	24.2	<0.03	0.007	0.036	0.086	0.149	1.200	12.2	0.195	0.173	0.216	12.8	288
M12	517	103	19.9	<0.03	0.006	0.040	0.100	0.300	2.100	4.10	0.326	0.279	0.373	2.84	12.6
M24	518	125	24.1	<0.03	0.003	0.033	0.083	0.348	2.208	4.80	0.378	0.323	0.433	2.52	10.5
M48	477	149	31.2	<0.03	0.002	0.019	0.067	0.500	2.210	3.00	0.426	0.366	0.487	1.75	4.89
H01	118	68	57.6	<0.03	0.006	0.031	0.074	0.200	1.400	2.80	0.210	0.150	0.270	5.13	34.4
H12	42	26	61.9	<0.03	0.007	0.024	0.051	0.100	0.395	0.80	0.138	0.101	0.175	3.66	18.4
H24	34	19	55.9	<0.03	0.002	0.012	0.038	0.100	1.635	1.80	0.224	0.089	0.357	3.32	12.8
H48	25	14	56.0	<0.03	0.007	0.024	0.052	0.100	0.540	0.60	0.148	0.097	0.199	2.41	8.02

Total K* (mg kg^{-1})

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	$MeanCI_{95\%}$		Skew	Kurt
												LCL	UCL		
M01	595	2	0.3	80	2139	7234	12639	19720	34641	49691	14385	13645	15125	0.9	3.5
M12	557	1	0.2	80	2145	7741	12950	21399	37736	54785	15258	14431	16086	0.9	3.3
M24	523	1	0.2	80	2359	7934	13675	22744	38408	58962	15932	15045	16819	0.9	3.3
M48	420	2	0.5	80	2376	8236	15171	24201	40275	63000	17232	16156	18308	0.8	3.1

* Based on limited dataset originating from France and Germany only

Total Ca* (mg kg^{-1})

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	$MeanCI_{95\%}$		Skew	Kurt
												LCL	UCL		
M01	595	2	0.3	50	511	1208	2471	9752	126483	280197	14815	12051	17579	4.0	21.4
M12	557	1	0.2	50	432	984	2275	9073	147474	293274	17451	14104	20797	3.4	15.9
M24	523	1	0.2	50	398	1007	2165	9766	179804	311303	19617	15710	23524	3.3	14.0
M48	420	4	1.0	50	364	906	2014	5540	185127	299984	17968	13516	22421	3.5	15.6

* Based on limited dataset originating from France and Germany only

Total Mg* (mg kg^{-1})

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	$MeanCI_{95\%}$		Skew	Kurt
												LCL	UCL		
M01	595	33	5.5	35	178	1074	2841	5166	38012	121066	5369	4543	6195	5.4	42.6
M12	557	36	6.5	35	211	1175	3013	5220	38618	118092	5540	4652	6428	5.4	40.0
M24	523	33	6.3	35	245	1358	3207	5522	41624	98333	6017	5037	6996	4.9	30.3
M48	420	28	6.7	35	248	1606	3624	5843	34735	85640	5868	4910	6827	5.0	32.4

* Based on limited dataset originating from France and Germany only

Total Na* (mg kg^{-1})

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	$MeanCI_{95\%}$		Skew	Kurt
												LCL	UCL		
M01	595	3	0.5	20	475	1490	2814	6027	15899	22619	4407	4072	4741	1.7	5.7
M12	557	3	0.5	20	437	1489	2970	6033	16992	24194	4616	4246	4987	1.7	5.6
M24	523	3	0.6	20	457	1437	2923	6486	18171	27490	4771	4366	5176	1.6	5.4
M48	420	4	1.0	20	484	1402	2969	6489	18569	31816	4928	4447	5410	1.8	6.5

* Based on limited dataset originating from France and Germany only

Total Al* (mg kg^{-1})

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	$MeanCI_{95\%}$		Skew	Kurt
												LCL	UCL		
M01	595	1	0.2	10	4475	23563	43890	60882	81041	100673	42106	40277	43935	0	2
M12	557	0	0	717	5029	24998	45100	64928	87063	101508	44974	42967	46981	0	2
M24	523	0	0	528	5291	27982	47865	68115	92915	107121	47625	45470	49779	0	2
M48	420	0	0	980	5980	31617	53135	74400	96010	119192	52359	49772	54945	-0.1	2

* Based on limited dataset originating from France and Germany only

Total Fe* (mg kg^{-1})

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	$MeanCI_{95\%}$		Skew	Kurt
												LCL	UCL		
M01	595	3	0.5	10	761	8799	20311	32964	54488	89979	22113	20860	23367	0.8	4.0
M12	557	2	0.4	10	742	10515	21702	33826	55112	97081	23248	21919	24576	0.9	4.6
M24	523	2	0.4	10	884	12009	22280	34798	61495	100382	24540	23092	25988	1.1	5.0
M48	420	2	0.5	10	993	13486	24384	35695	62757	200727	26348	24467	28229	2.3	18.0

* Based on limited dataset originating from France and Germany only

Total Mn* (mg kg^{-1})

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	$MeanCI_{95\%}$		Skew	Kurt
												LCL	UCL		
M01	595	8	1.3	2	19.0	171	461	908	1840	5027	607	562	651	1.9	11.2
M12	557	7	1.3	2	16.8	175	476	910	1893	6077	613	563	663	2.8	19.7
M24	523	5	1.0	2	17.0	208	451	877	1942	6039	605	553	657	3.3	24.3
M48	420	7	1.7	2	15.0	139	387	711	1663	3015	501	455	546	1.8	7.2

* Based on limited dataset originating from France and Germany only

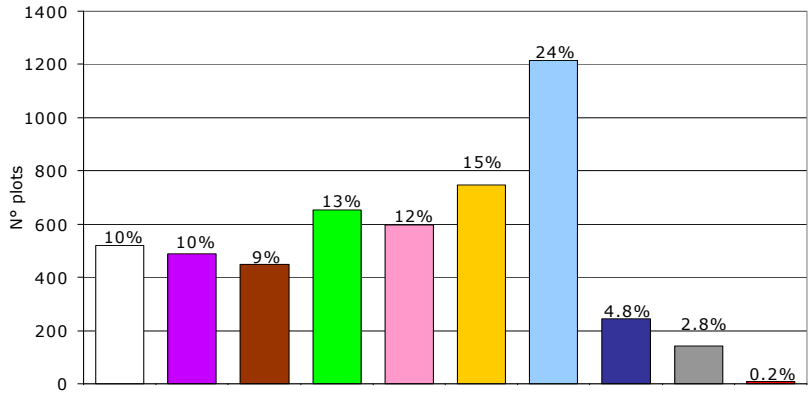
Reactive Fe (mg kg^{-1})

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	$MeanCI_{95\%}$		Skew	Kurt
												LCL	UCL		
OL	87	0	0	178	195	344	627	1018	2345	5422	809	657	962	3.4	20.3
OFH	1627	21	1.3	<50	171	791	1207	2087	9037	55834	2003	1859	2147	7.3	93.8
H	35	0	0	200	294	875	1600	3171	15190	18750	3308	1837	4779	2.1	6.8
M01	3848	50	1.3	<50	154	1100	2140	4099	11792	33314	3173	3069	3278	2.9	17.1
M12	2827	45	1.6	<50	193	1290	2310	4495	12894	38292	3505	3371	3640	3.0	18.3
M24	2760	36	1.3	<50	172	1100	2120	4190	12338	43834	3259	3126	3392	3.3	21.7
M48	2405	35	1.5	<50	107	710	1628	3496	10236	55103	2612	2484	2740	4.8	49.7
H01	210	0	0	303	505	1703	3966	8379	35655	89667	7242	5892	8591	4.0	26.9
H12	119	0	0	370	480	1342	3277	7426	31542	87392	6620	4728	8512	4.7	32.0
H24	85	0	0	207	325	1207	2673	6524	40078	69417	5877	3720	8034	4.2	23.4
H48	66	0	0	190	293	979	2739	5638	11114	16301	3781	2932	4630	1.2	4.2

Reactive Al (mg kg^{-1})

Layer	n	Cen n	Cen %	Min	$P_{2.5}$	P_{25}	P_{50}	P_{75}	$P_{97.5}$	Max	Mean	$MeanCI_{95\%}$		Skew	Kurt
												LCL	UCL		
OL	88	1	1.1	50	91	229	394	558	1475	3630	495	390	600	4.1	23.4
OFH	1627	22	1.4	<50	169	579	872	1410	6670	24611	1415	1310	1519	5.9	47.3
H	35	0	0	210	320	788	1500	2650	8915	13194	2242	1403	3080	2.9	11.9
M01	3849	33	0.9	<50	170	681	1313	2443	7328	35658	2002	1918	2085	5.9	54
M12	2827	34	1.2	<50	209	982	1699	3032	10194	42418	2601	2480	2721	5.5	50
M24	2760	22	0.8	<50	242	1058	1722	2930	10301	47200	2671	2535	2807	6.3	61.2
M48	2405	21	0.9	<50	188	802	1351	2390	10062	46000	2231	2103	2360	5.8	53.1
H01	210	0	0	90	335	889	1603	2670	7850	22848	2213	1892	2533	4.3	31.8
H12	119	0	0	180	306	738	1362	2324	12449	24395	2277	1694	2861	4.2	24.1
H24	85	0	0	150	204	637	1040	2408	6422	13888	1863	1415	2310	2.9	14.6
H48	66	0	0	110	126	571	901	2192	9162	11681	1959	1367	2552	2.2	7.4

Annex III. Maps



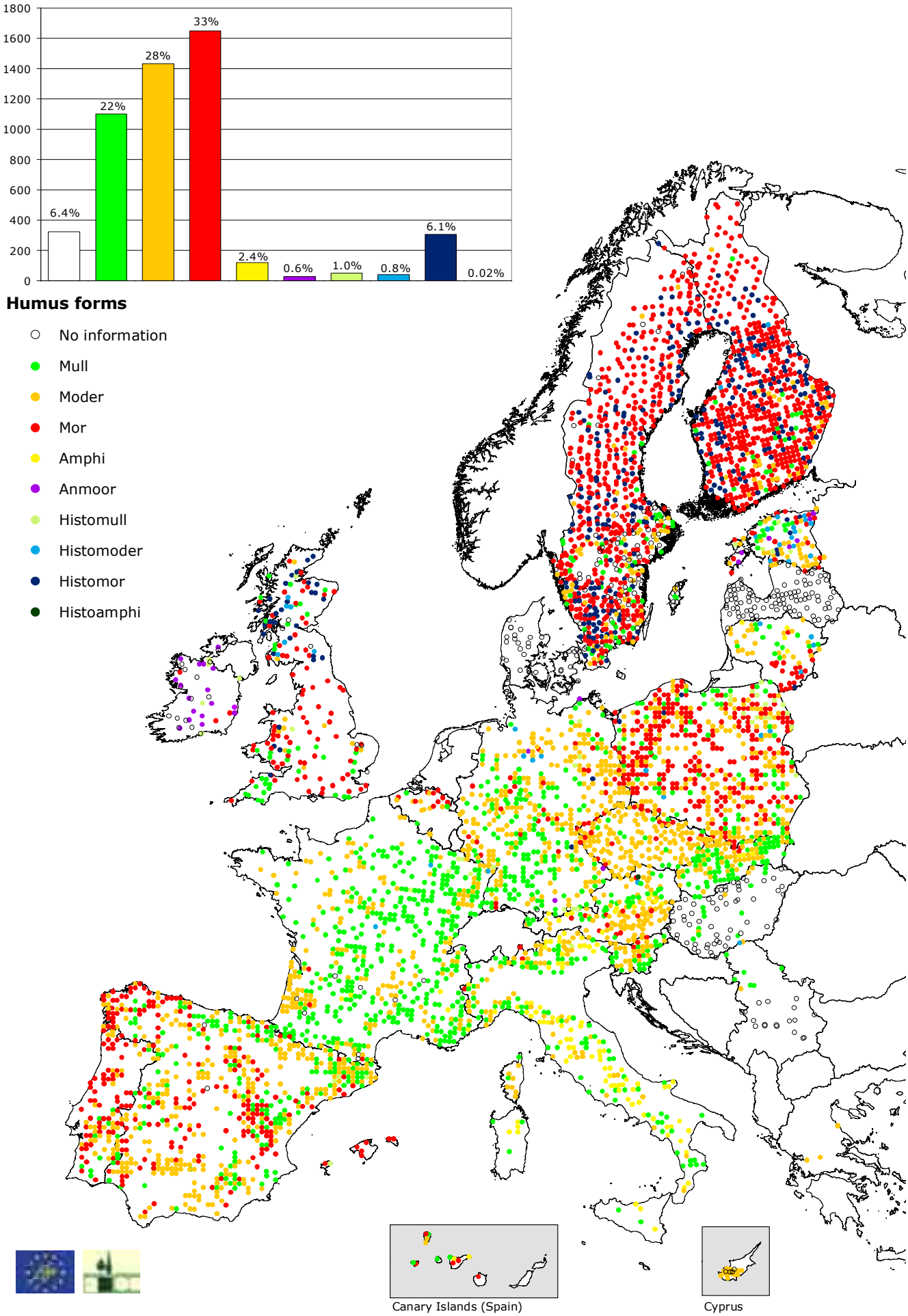
Parent material class

- No information
- Consolidated clastic sedimentary rocks
- Sedimentary rocks
- Igneous rocks
- Metamorphic rocks
- Unconsolidated deposits
- Unconsolidated glacial deposits/ drift
- Eolian deposits
- Organic materials
- Anthropogenic deposits

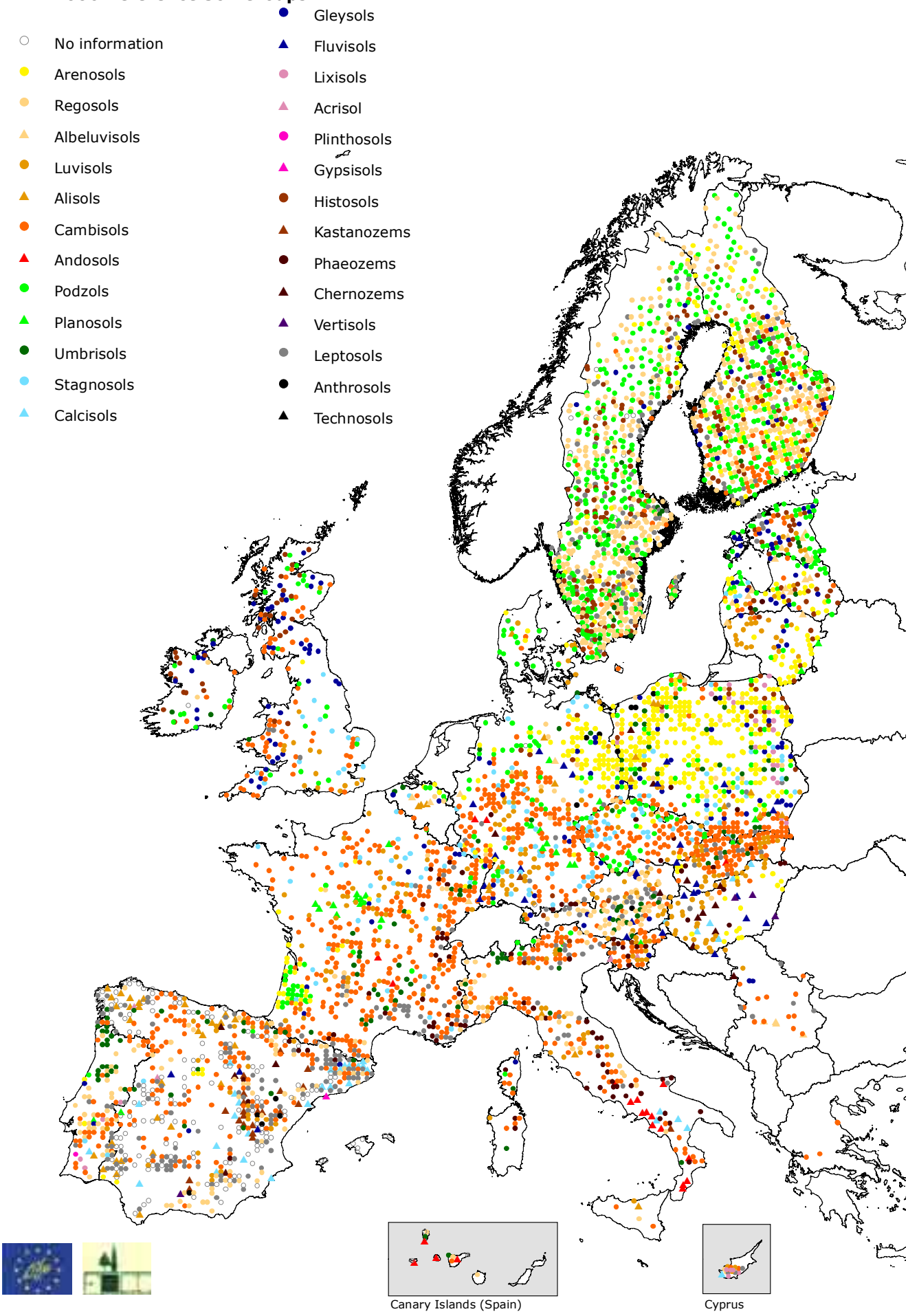
Canary Islands (Spain)

Cyprus

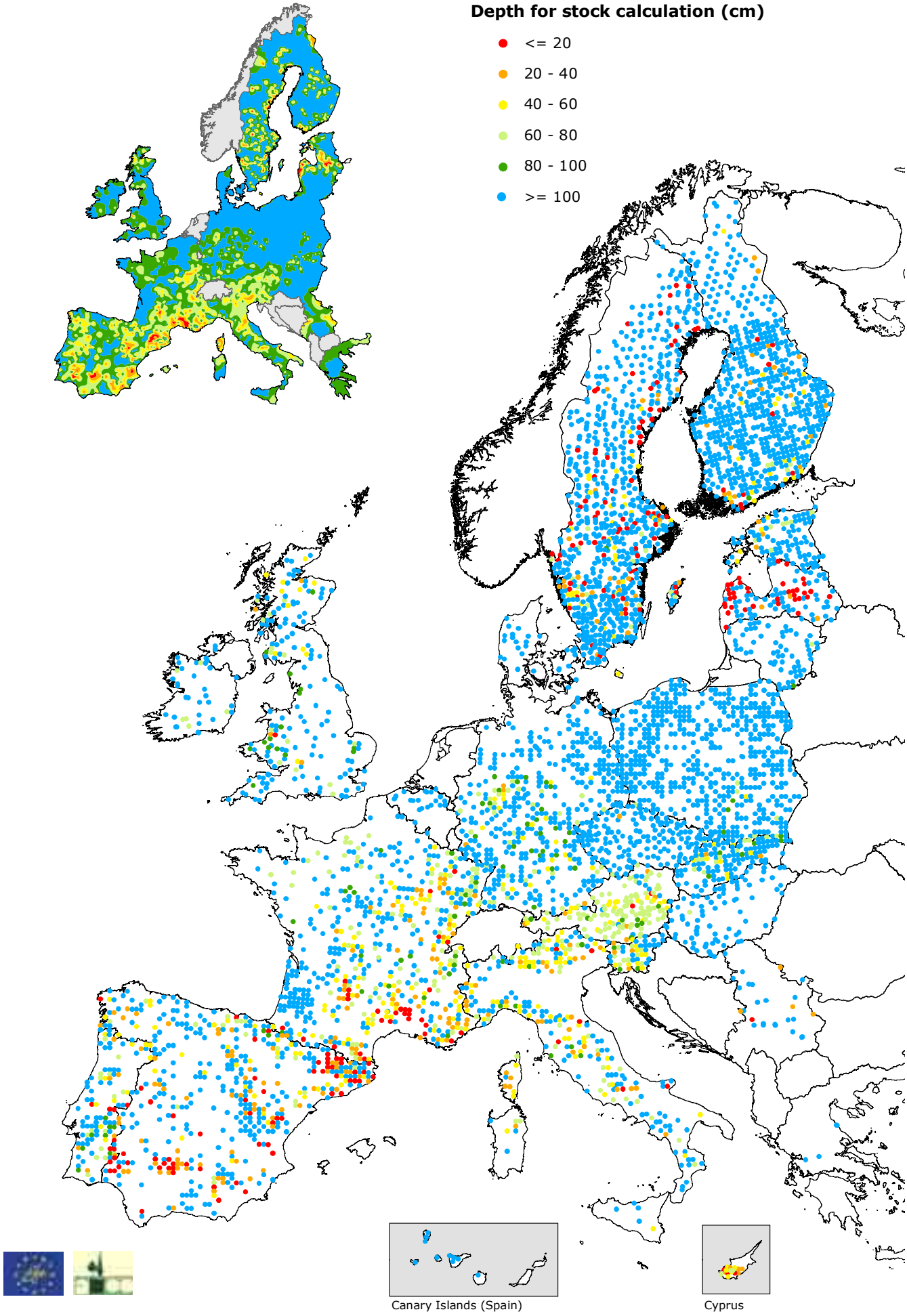
Map 1. Geographical distribution of the parent material classes (Lambert et al. 2002) of the BioSoil+ Level I and II plots



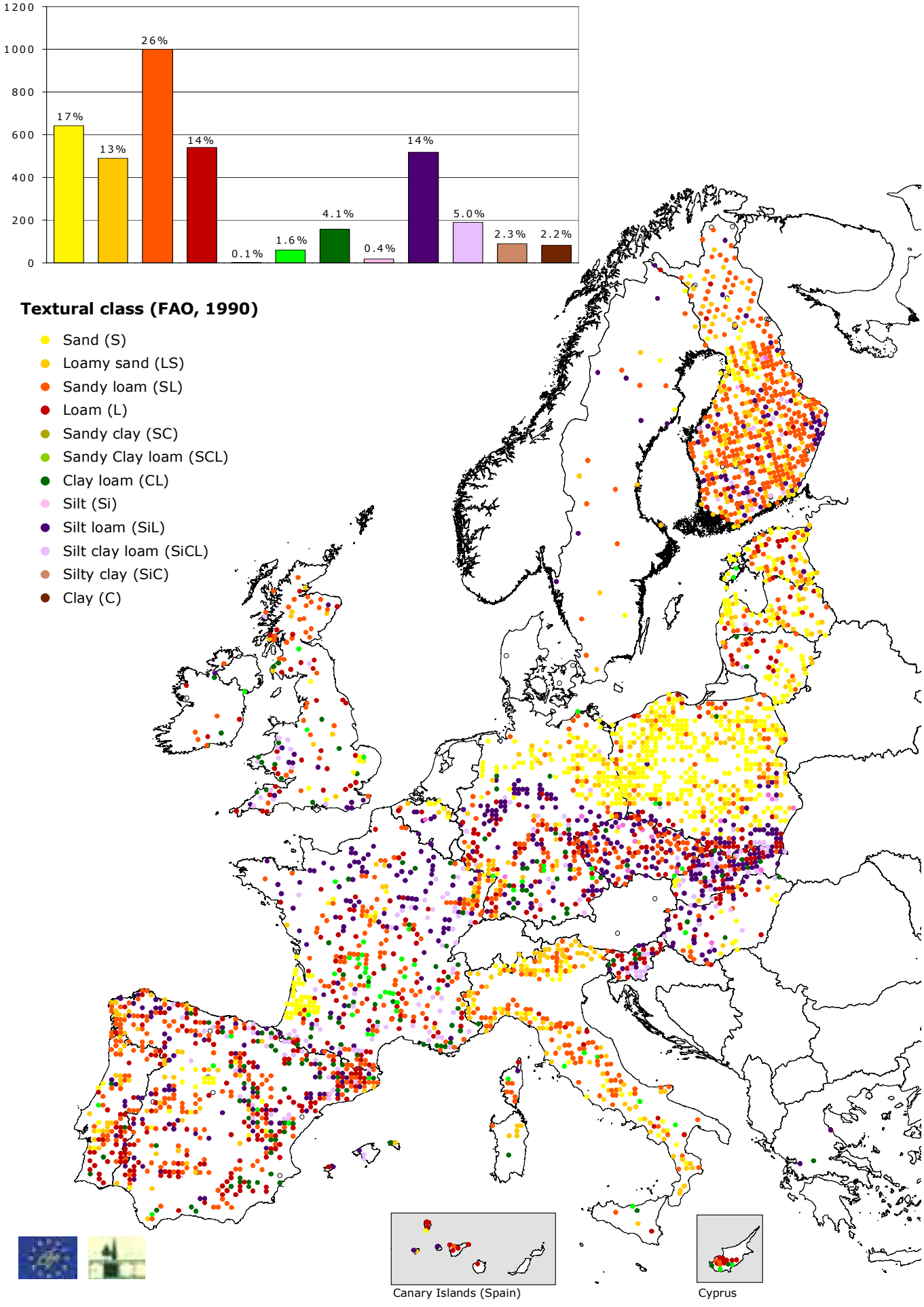
Map 2. Geographical distribution of the humus forms on the BioSoil+ Level I and II plots



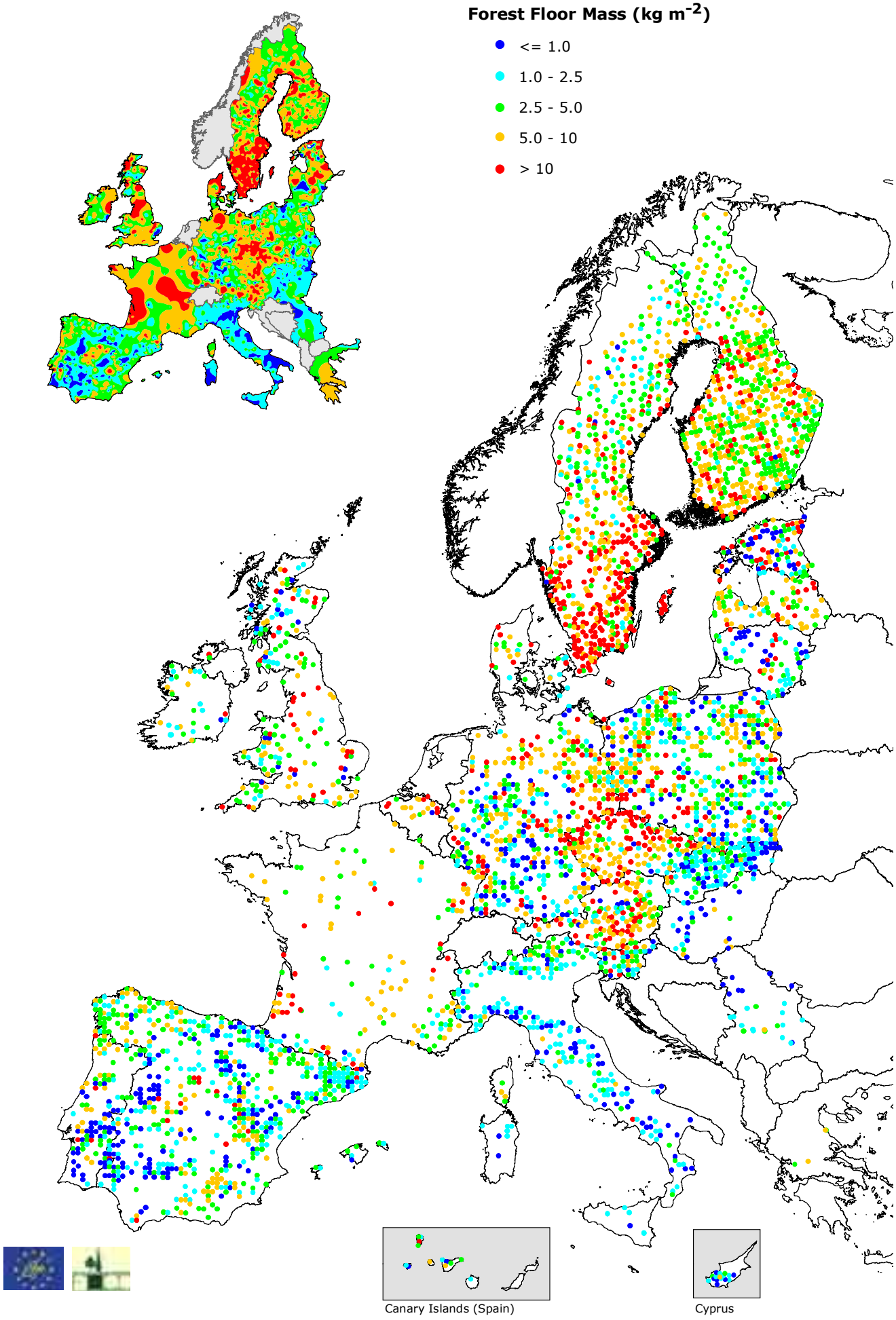
Map 3. Geographical distribution of the WRB 2006 Reference Soil Groups on the BioSoil^{+} Level I and II plots



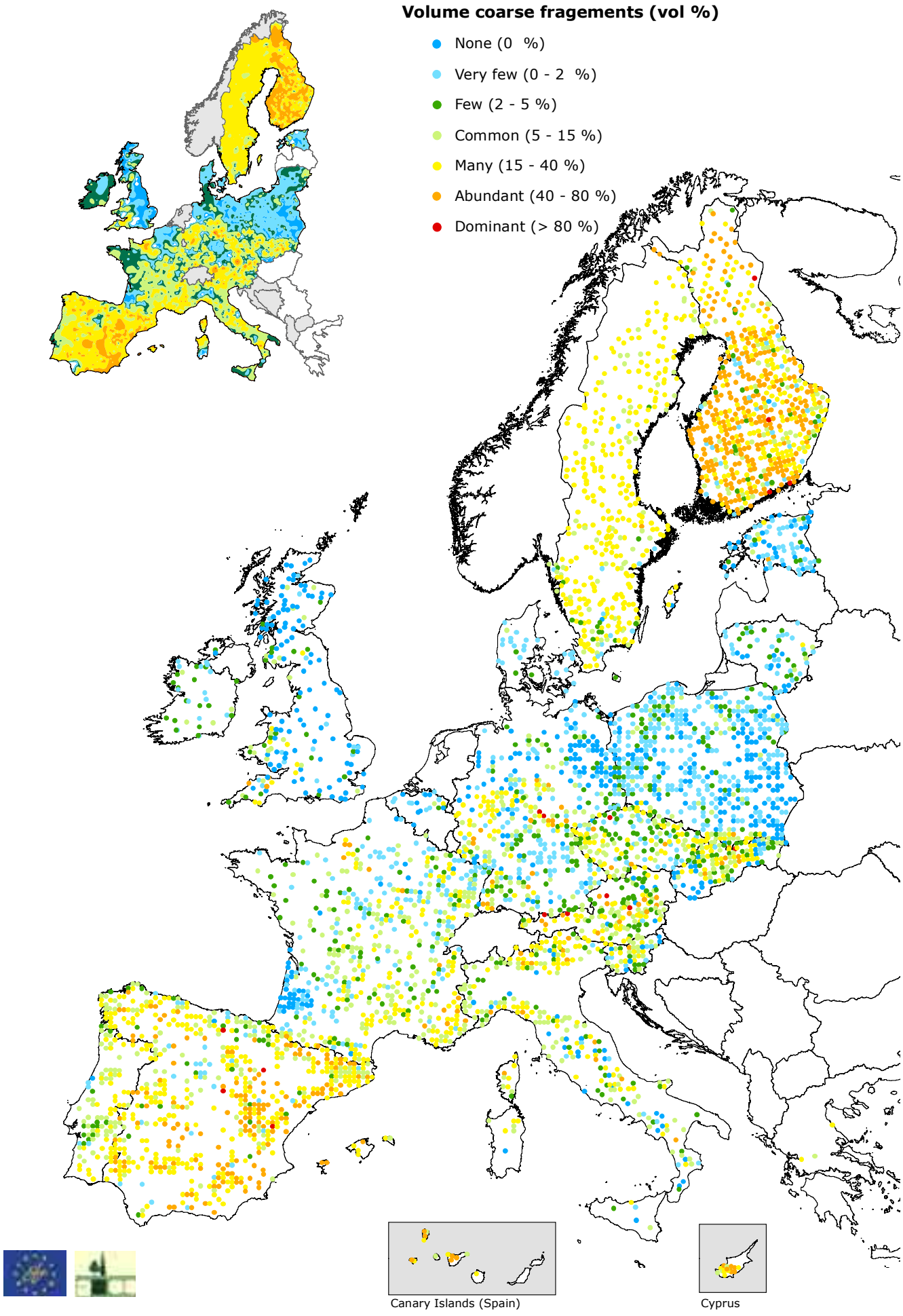
Map 4. Geographical distribution of the solum depth for stock calculations of the BioSoil⁺ Level I and II plots



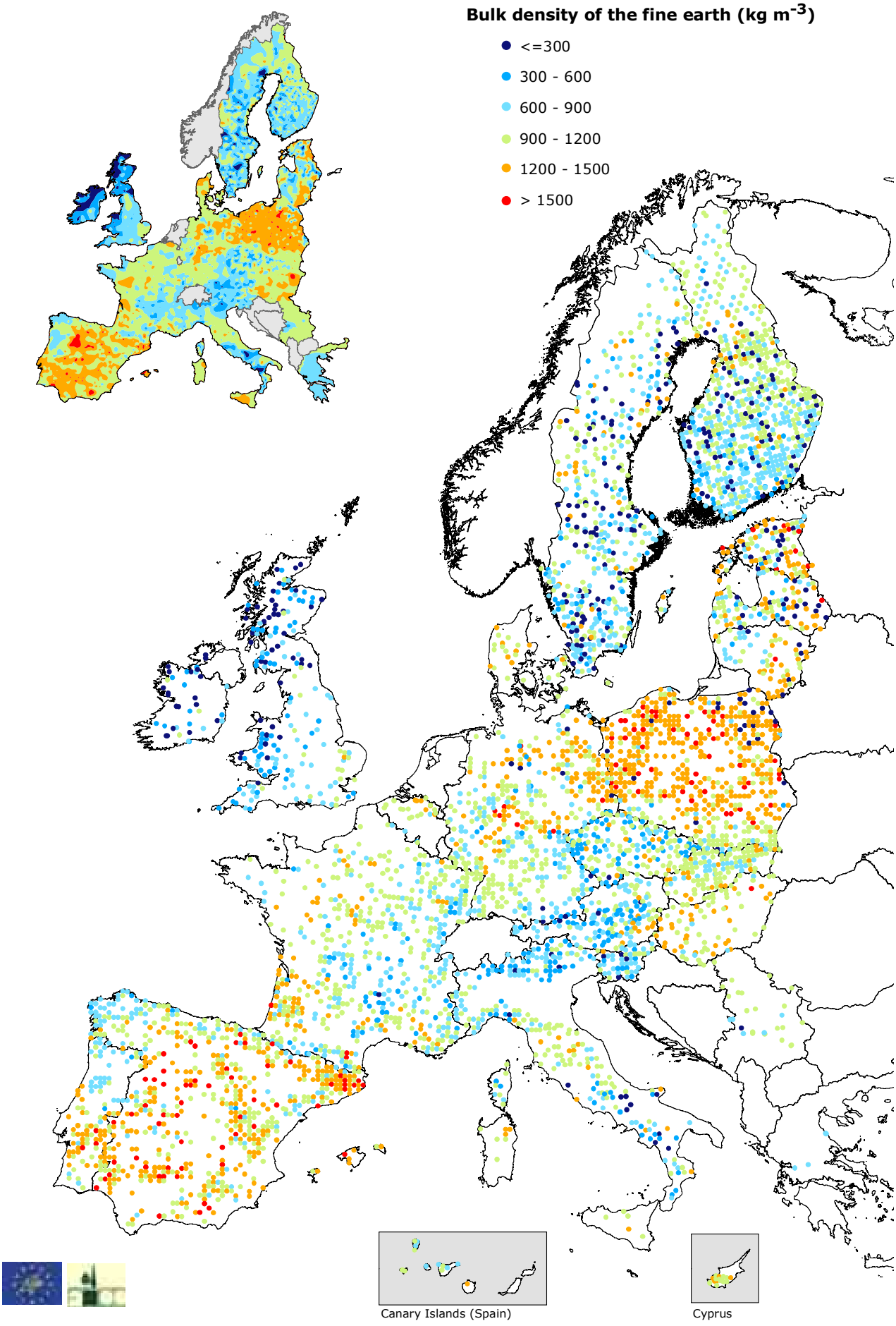
Map 5. Geographical distribution of the textural class according to FAO (1990) in the upper 10 cm of mineral soils of the BioSoil+ Level I and II plots



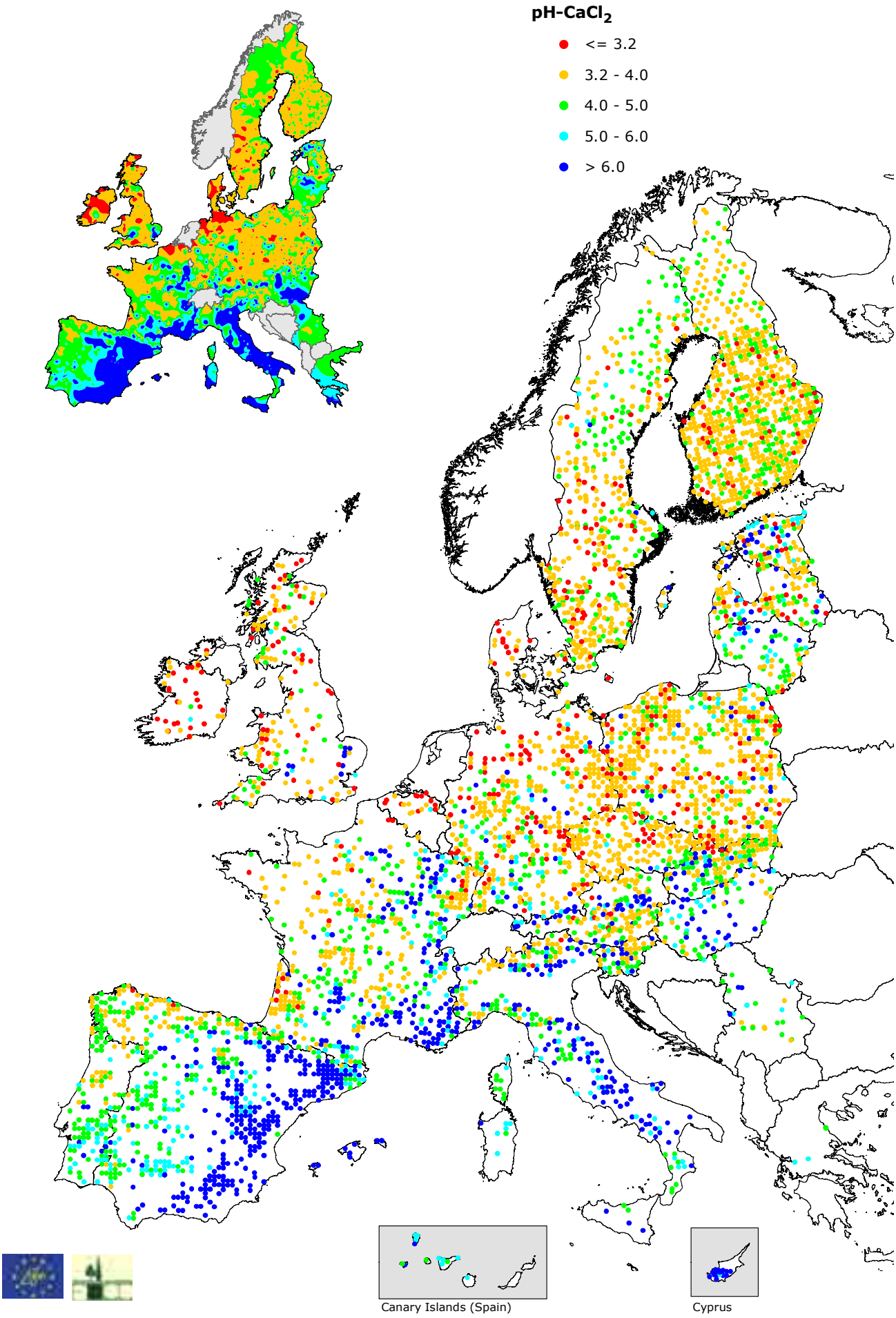
Map 6. Geographical distribution of the forest floor mass on the BioSoil+ Level I and II plots



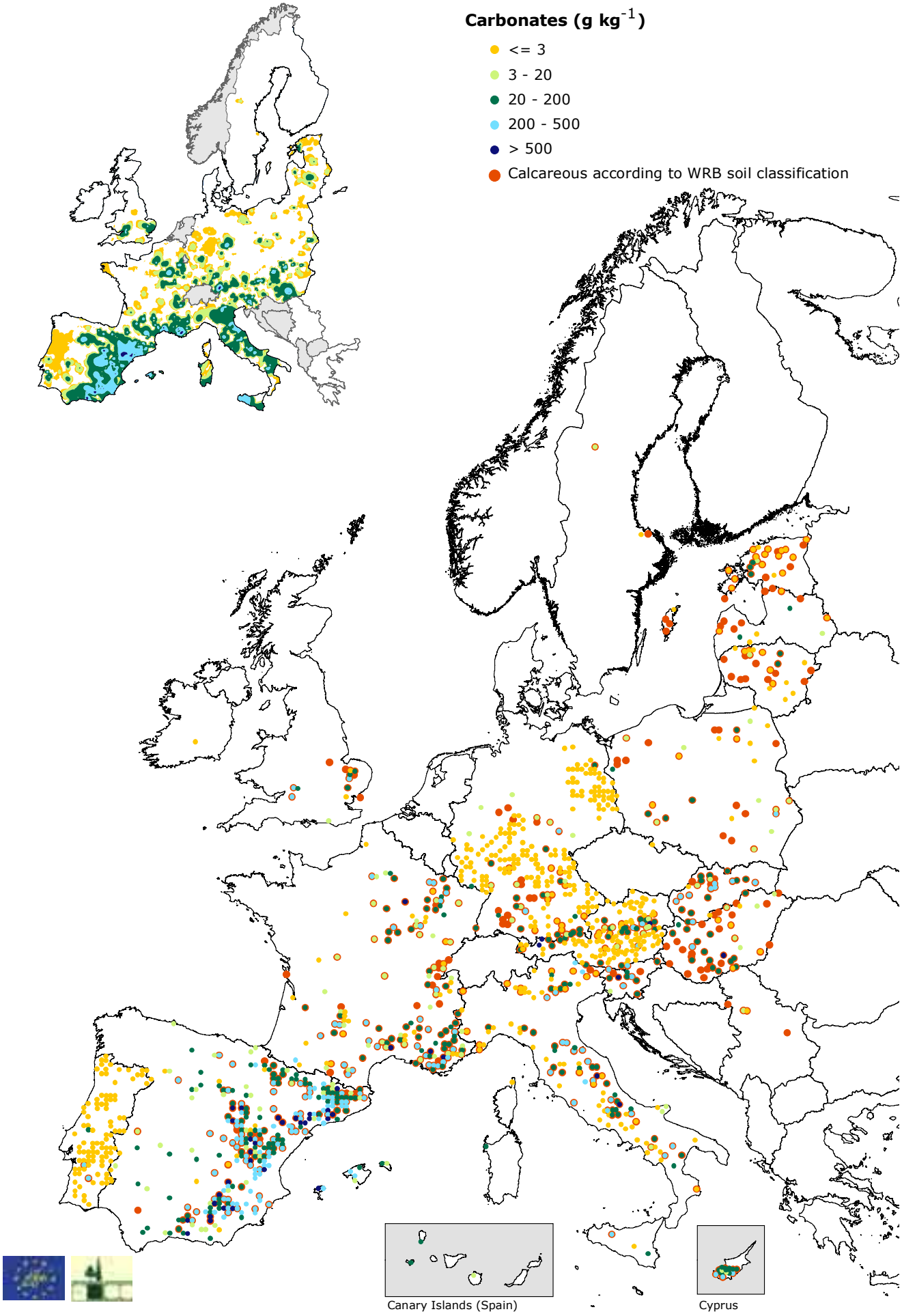
Map 7. Geographical distribution of the coarse fragments (vol %) in the upper 10 cm of mineral soils and peat soils of the BioSoil+ Level I and II plots



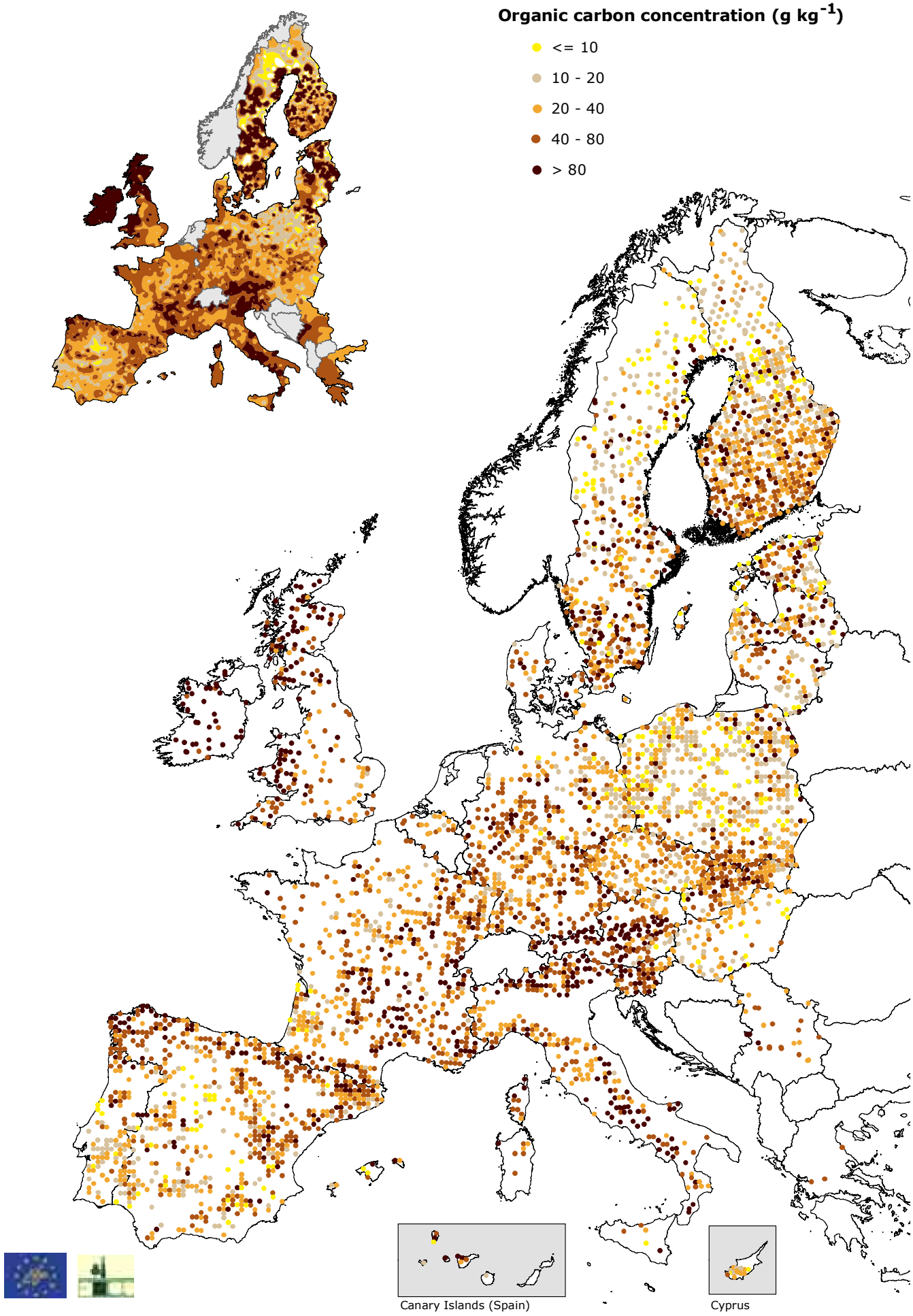
Map 8. Geographical distribution of the bulk density of the fine earth (kg m^{-3}) in the upper 10 cm of mineral soils and peat soils of the BioSoil+ Level I and II plots



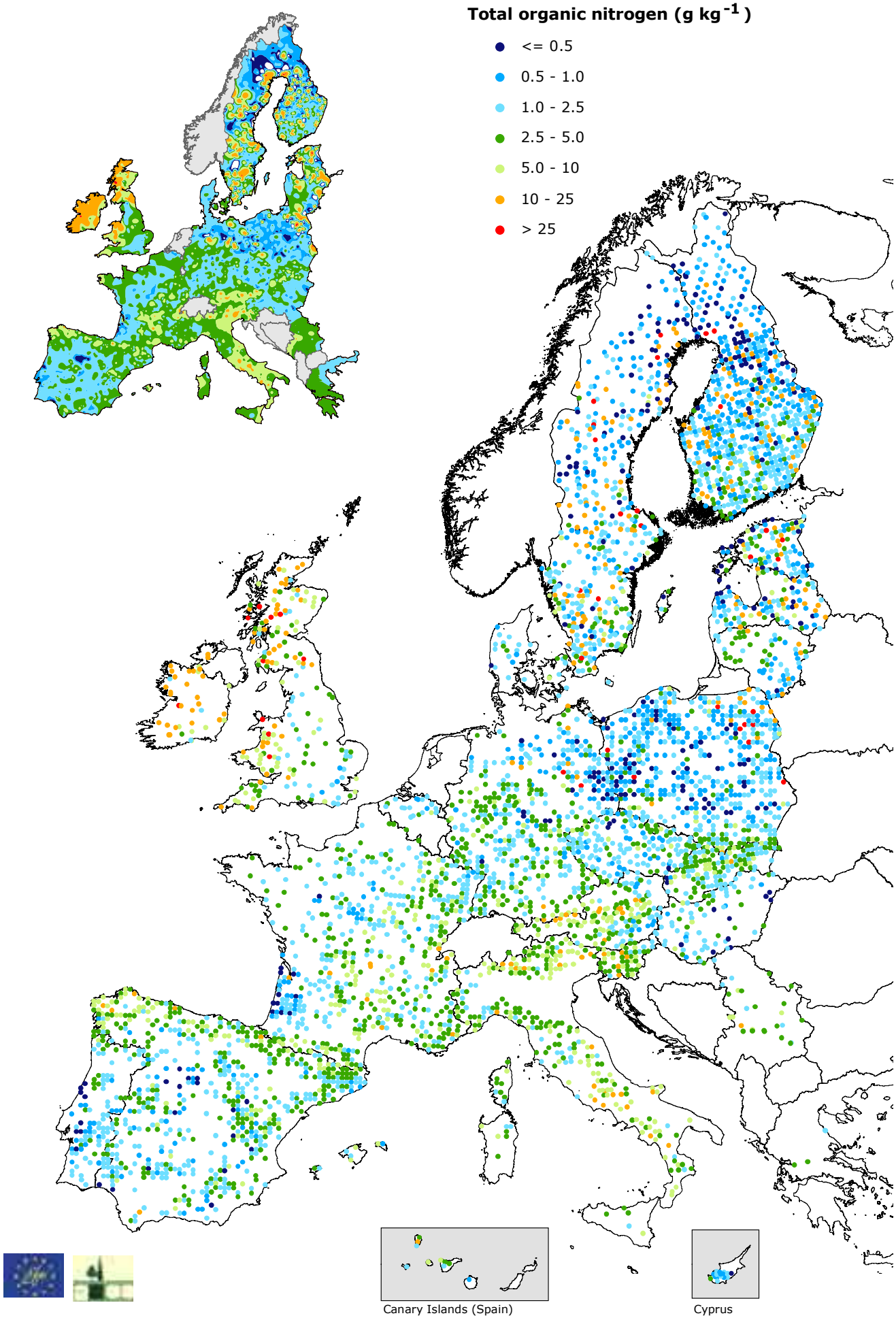
Map 9. Geographical distribution of the pH-$CaCl_2$ in the upper 10 cm of mineral soils and peat soils of the BioSoil$^+$ Level I and II plots



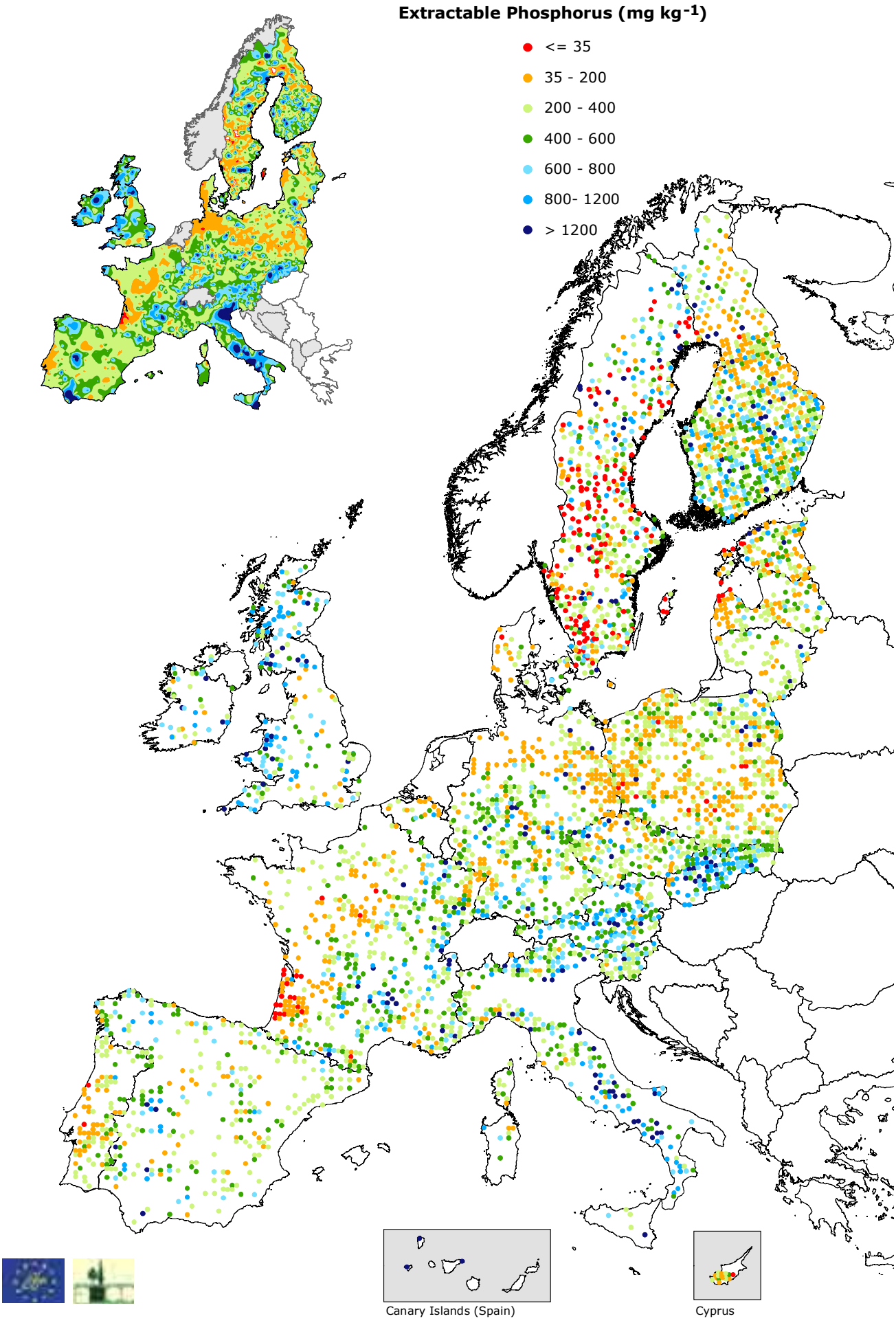
Map 10. Geographical distribution of the carbonate concentration (g kg^{-1} oven dry soil) in the upper 10 cm of mineral soils and peat soils of the BioSoil^{+} Level I and II plots



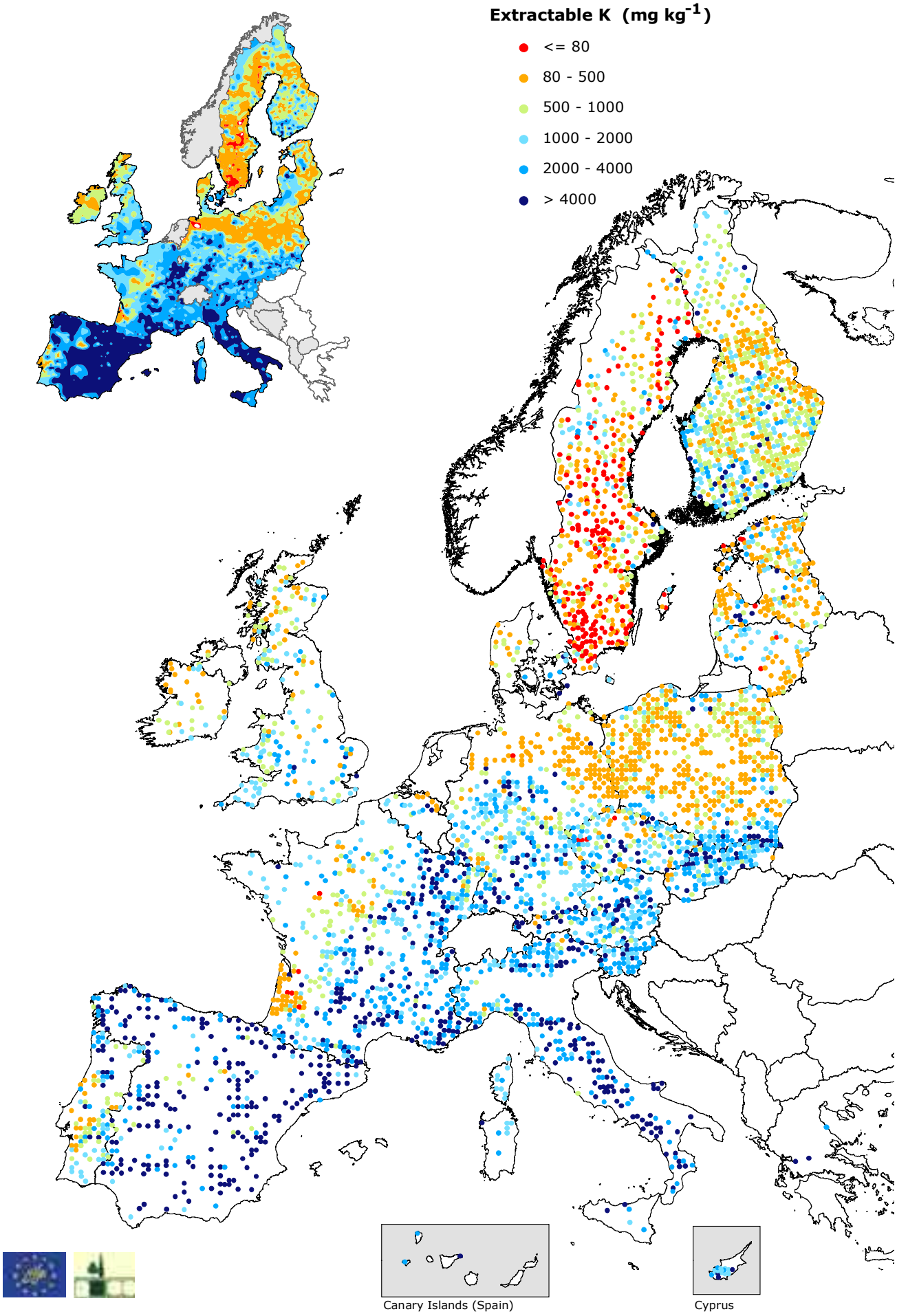
Map 11. Geographical distribution of the total organic carbon concentration (g kg^{-1} oven dry soil) in the upper 10 cm of mineral soils and peat soils of the BioSoil^{+} Level I and II plots



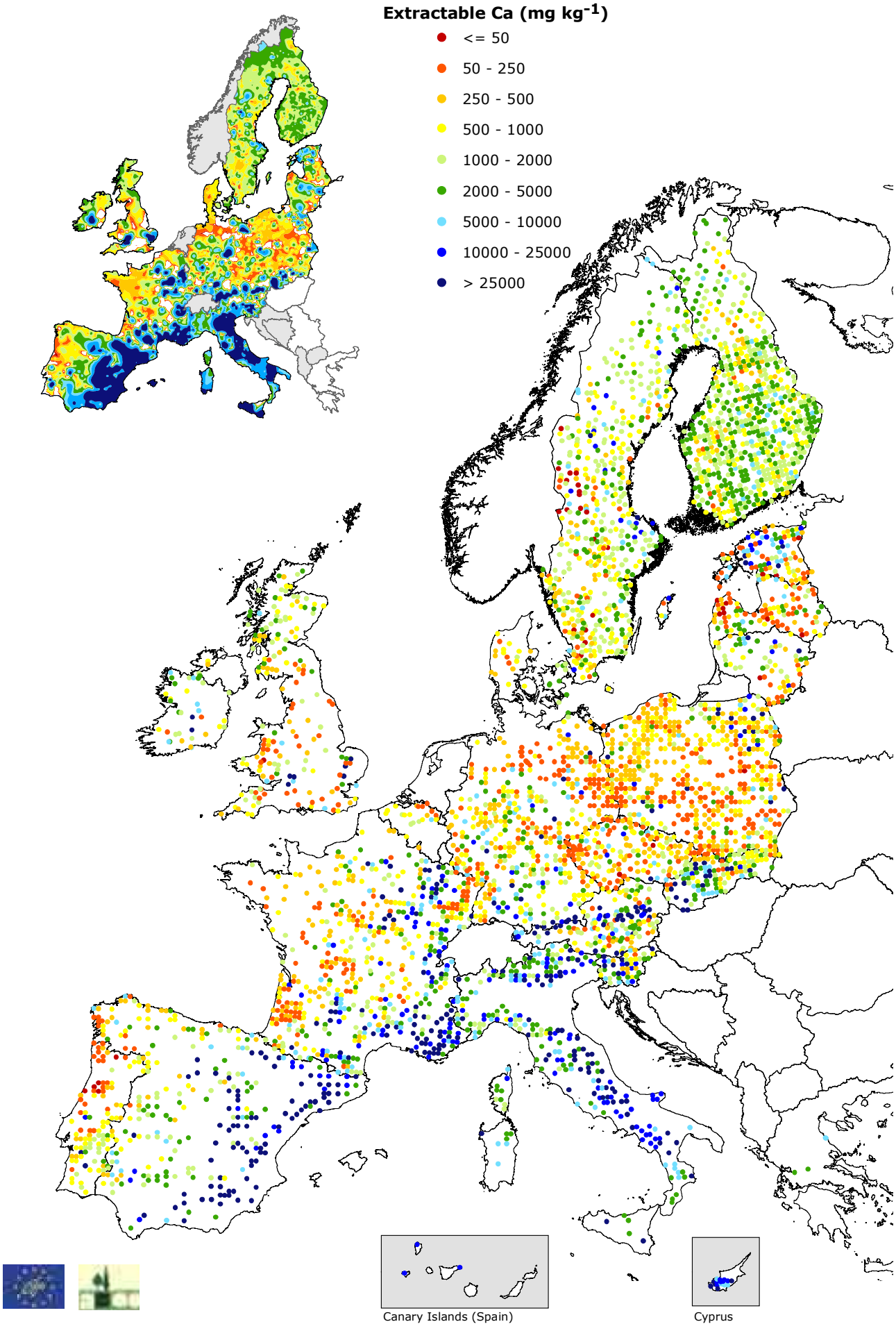
Map 12. Geographical distribution of the total organic nitrogen concentration (g kg^{-1} oven dry soil) in the upper 10 cm of mineral soils and peat soils of the BioSoil^{+} Level I and II plots



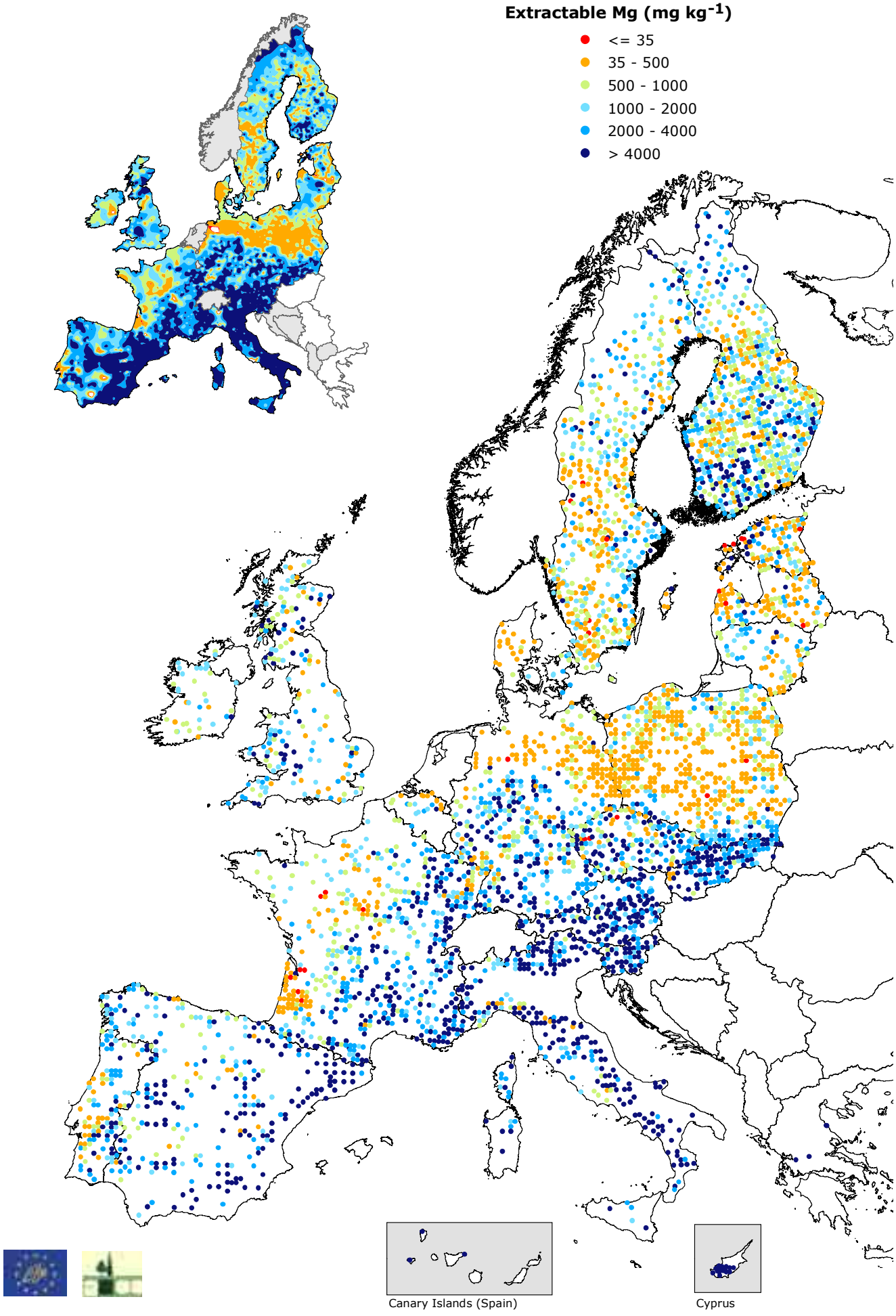
Map 13. Geographical distribution of the aqua regia extractable phosphorus concentration (mg kg^{-1} oven dry soil) in the upper 10 cm of mineral soils and peat soils of the BioSoil^{+} Level I and II plots



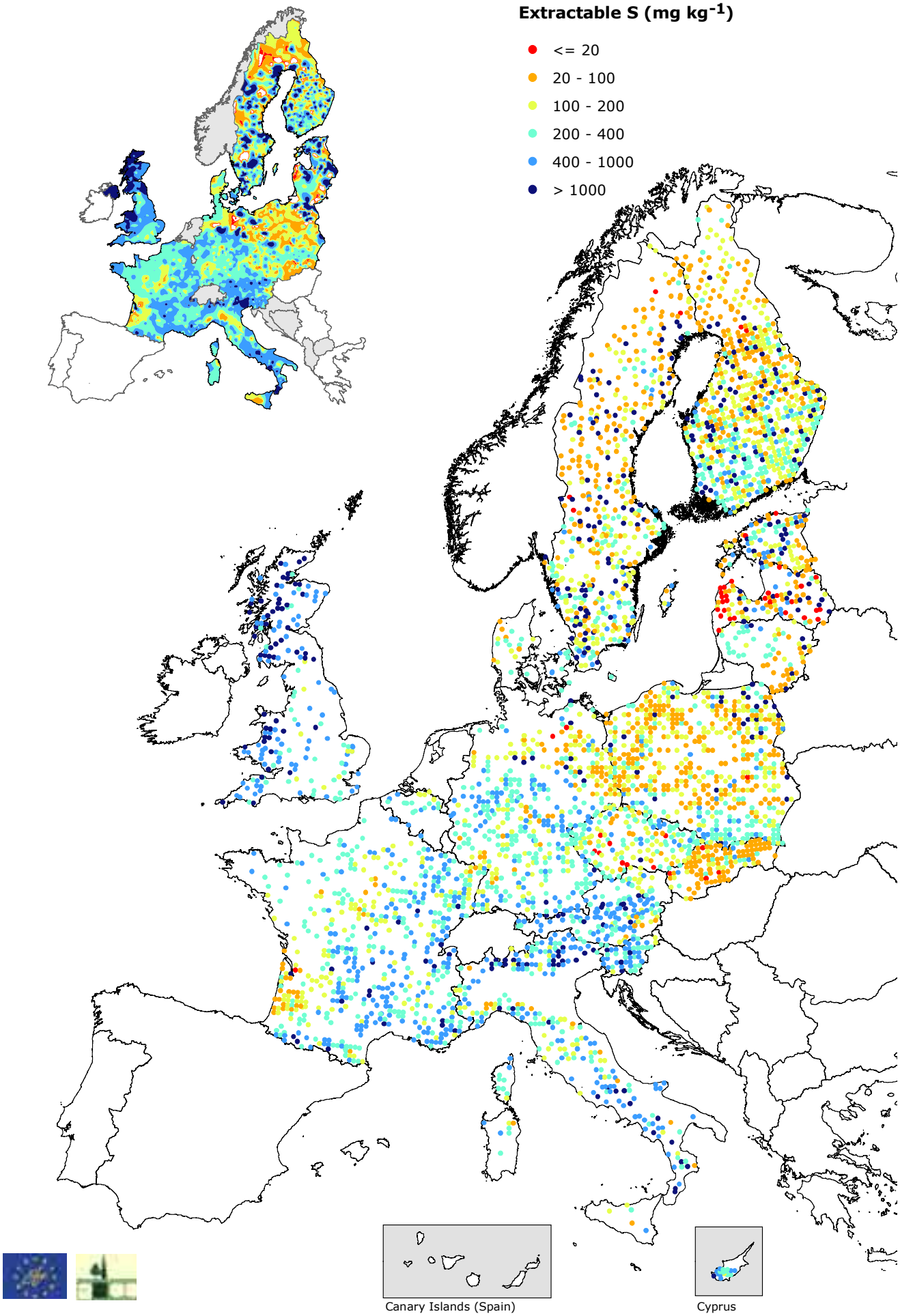
Map 14. Geographical distribution of the aqua regia extractable potassium concentration (mg kg^{-1} oven dry soil) in the upper 10 cm of mineral soils and peat soils of the BioSoil^{+} Level I and II plots



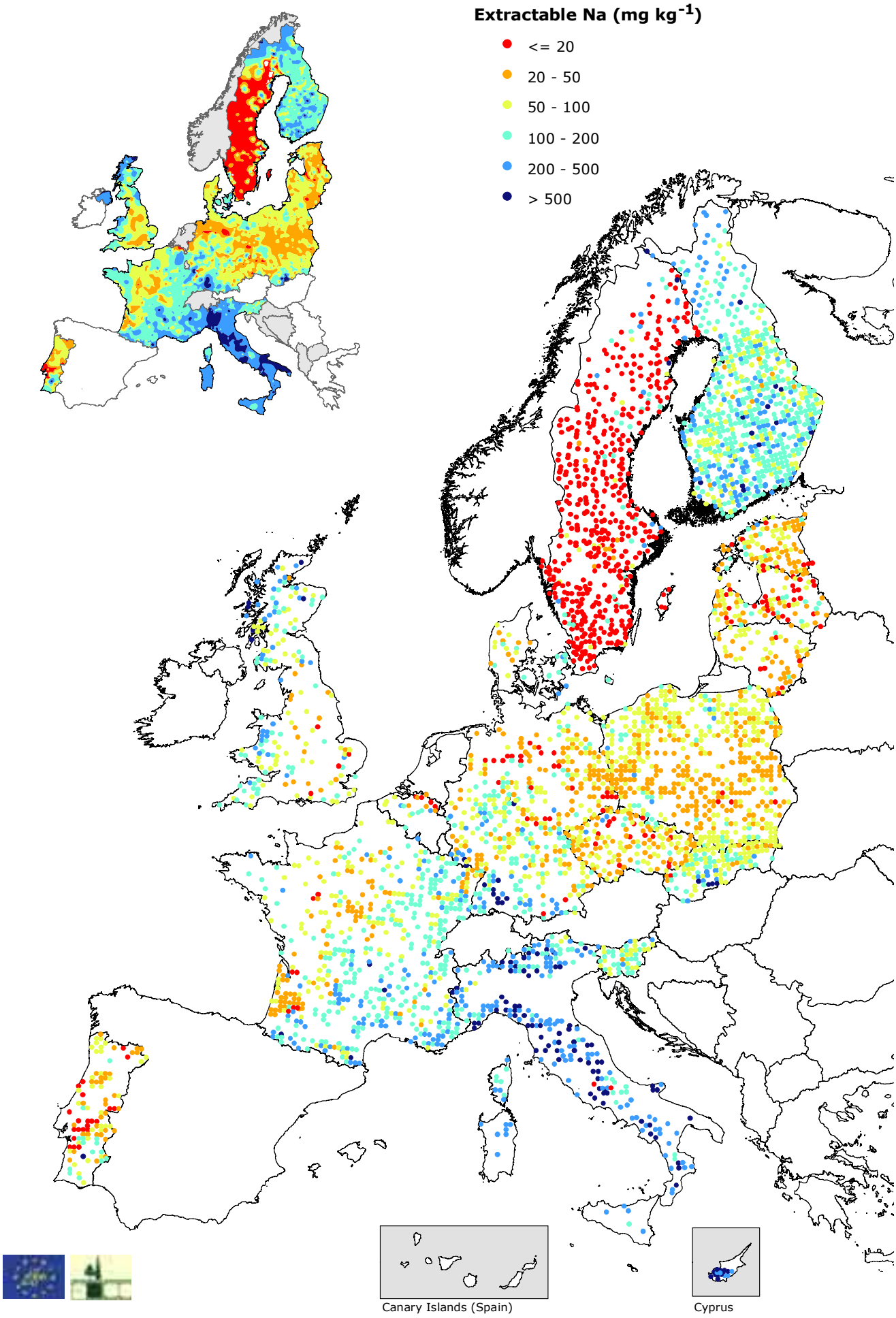
Map 15. Geographical distribution of the aqua regia extractable calcium concentration (mg kg^{-1} oven dry soil) in the upper 10 cm of mineral soils and peat soils of the BioSoil^{+} Level I and II plots



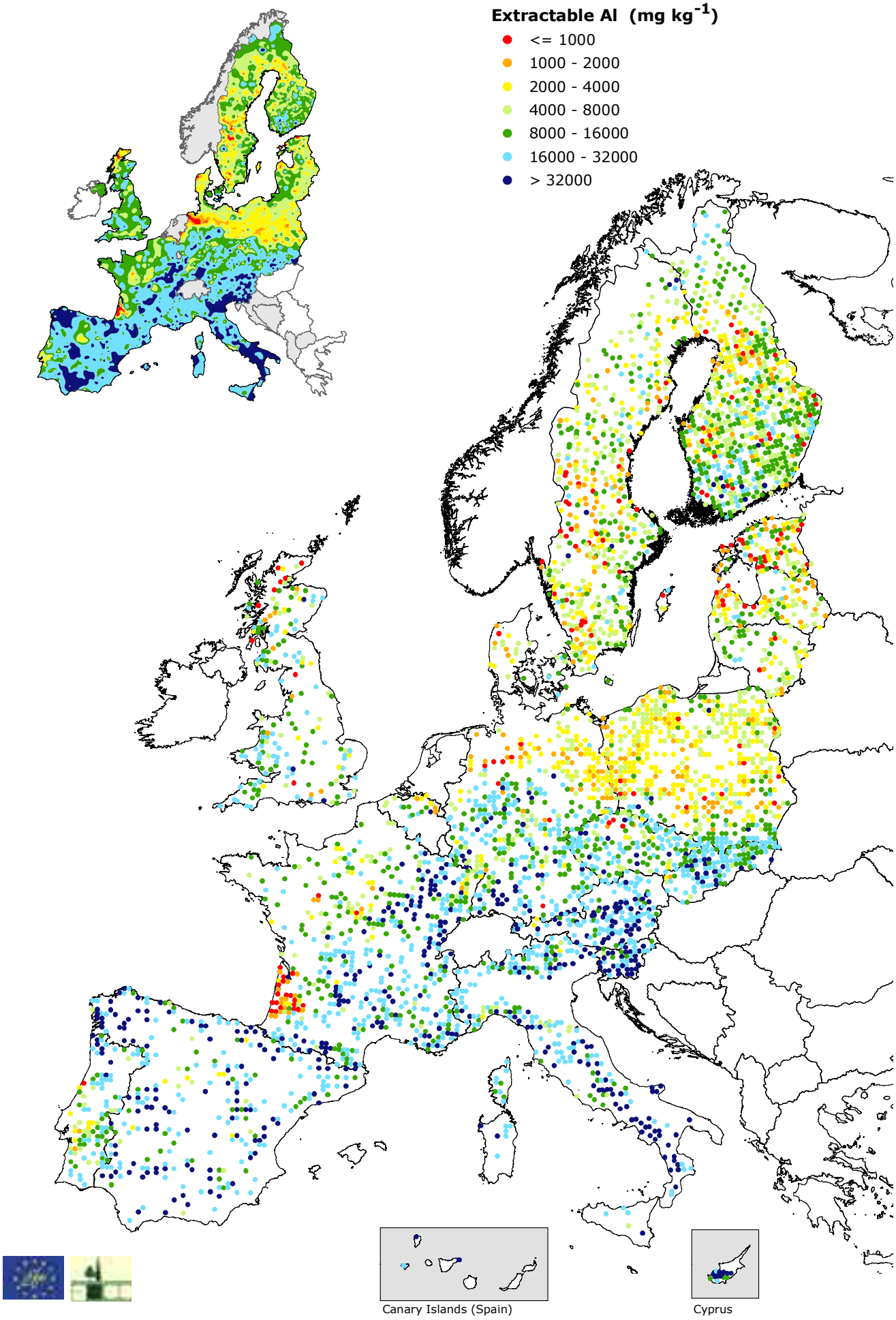
Map 16. Geographical distribution of the aqua regia extractable magnesium concentration (mg kg^{-1} oven dry soil) in the upper 10 cm of mineral soils and peat soils of the BioSoil^{+} Level I and II plots



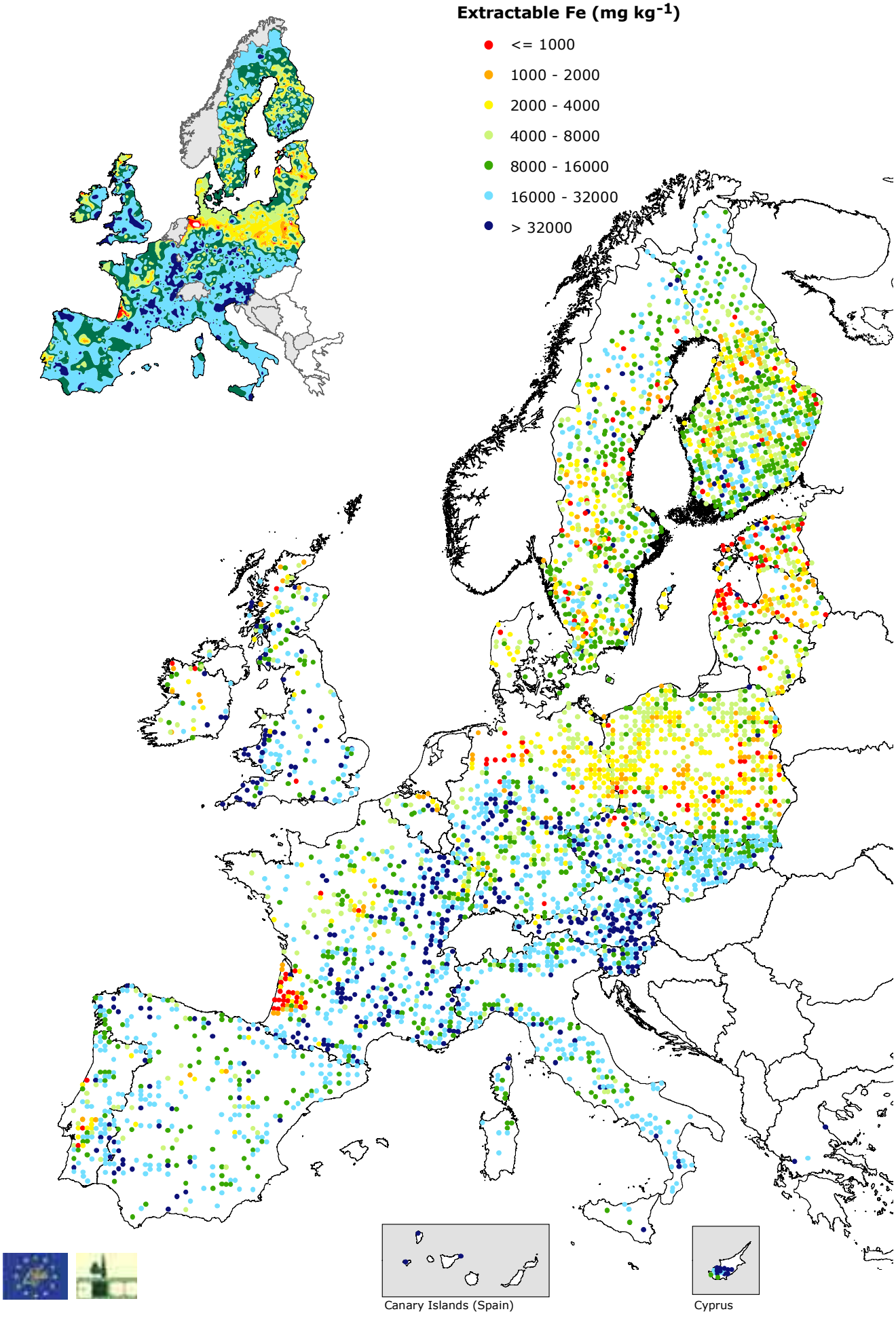
Map 17. Geographical distribution of the aqua regia extractable sulphur concentration (mg kg^{-1} oven dry soil) in the upper 10 cm of mineral soils and peat soils of the BioSoil^{+} Level I and II plots



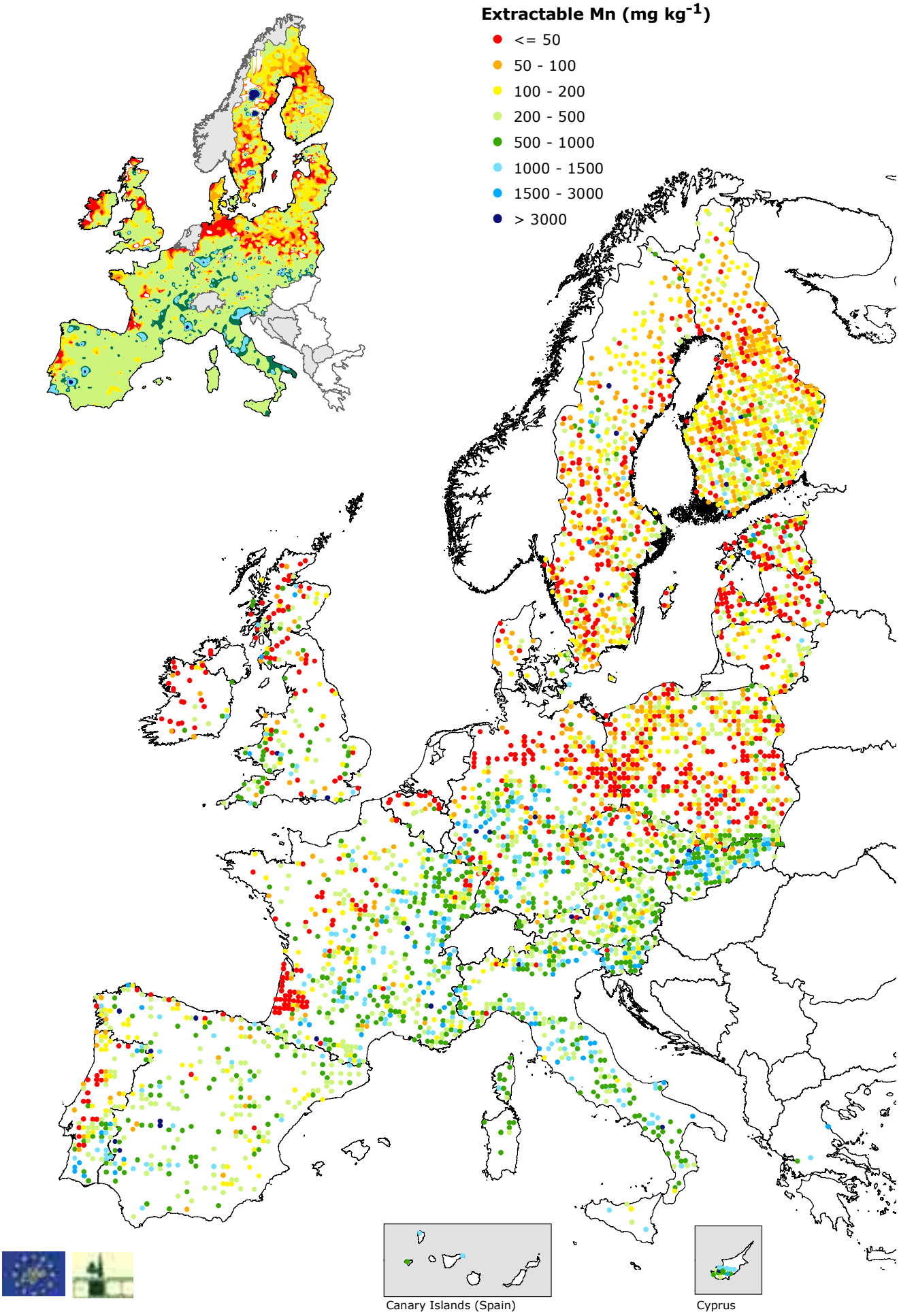
Map 18. Geographical distribution of the aqua regia extractable sodium concentration (mg kg^{-1} oven dry soil) in the upper 10 cm of mineral soils and peat soils of the BioSoil^{+} Level I and II plots



Map 19. Geographical distribution of the aqua regia extractable aluminium concentration (mg kg^{-1} oven dry soil) in the upper 10 cm of mineral soils and peat soils of the BioSoil^{+} Level I and II plots



Map 20. Geographical distribution of the aqua regia extractable iron concentration (mg kg^{-1} oven dry soil) in the upper 10 cm of mineral soils and peat soils of the BioSoil^{+} Level I and II plots



Map 21. Geographical distribution of the aqua regia extractable manganese concentration (mg kg^{-1} oven dry soil) in the upper 10 cm of mineral soils and peat soils of the BioSoil^{+} Level I and II plots