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European scale analysis of phospholipid fatty acid composition of soils to establish operating ranges

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ABSTRACT

Recent preoccupations regarding possible negative effects of pollution, inappropriate land management, climate change, desertification, erosion, compaction or over-exploitation on soils has led to initiatives for the survey of soils. One of them, EcoFINDERS, launched a pan-European survey in order to define normal operating ranges for soil biodiversity and quality, through the use of several methodologies. The objective of the current work was the characterization of European soils under different land uses and from representative bio-geographical locations, using a PLFA method developed in the context of the mentioned survey, in order to recognize and define operation ranges for soil PLFA. PLFA analysis demonstrated to be a valuable tool in the evaluation, comparison and distinction of several land uses and biogeographical (BG) zones. The analysis of the PLFA diversity with PCA and PERMANOVA/SIMPER demonstrated a good separation of soil samples relatively to each defined land use and BG zone. Soils of the same BG zone and land use group showed an average biomarker constitution with consistent differences of PLFA/biomarker compositions relatively to other groups, especially concerning land uses. Total PLFA biomass was consistently higher in non-arable environments, i.e., forest or grass soils. Arable soils contained a total PLFA biomass that was in average 2.5–2.9 times lower than grassland or forest soil. Arable and grassland soils contained significantly low relative quantities of the saprophytic Fungi biomarker 18:2ω6,9c (which decreased more than 18:1ω9c), and low Total Fungi biomarkers/Bacteria biomarkers ratio (TF/B). The opposite occurred in forestry soil samples, and the Boreal BG zone stood out, showing the highest total fungal composition, with a most important contribution of the 18:2ω6,9c saprophytic Fungi biomarker. Grasslands (all BG zones) showed to be the richest (3.5–3.8%) in Arbuscular Mycorrhizae Fungi biomarker, 16:1ω5c. High proportions of Gram-positive, relatively to Gram-negative biomarkers occurred essentially in arable soils, in this study, but also in Alpine grasslands, which main Gram-positive biomarkers were a15:0, and i15:0. Total biomass, PLFA Biomarker groups, and different balances between individual PLFA enabled the discrimination of samples originating from both different BG zones and land uses.

1. Introduction

In 2002, the soil thematic strategy (EU, 2002) highlighted the role that soils played in society, providing a range of ecosystem services that are necessary for human life. These services include the provision of food and fibre, cycling of nutrients and carbon, water filtration and a habitat for soil biodiversity. In 2005 the ENVironmental ASsessment of Soil for monitoring (ENVASSO) project (Kibblewhite et al., 2008) was established. This project developed consistent indicators for soil threats, to assess the potential degradation of soils across Europe. In 2006 the Soil Framework Directive was communicated (EU, 2006), which highlighted the need for soil protection, to ensure that the services described above were protected. However, the Soil Framework Directive was never ratified and was withdrawn in 2014. The ENVASSO project highlighted the need for a soil monitoring framework, which consistently applied indicators of soil quality. Indicators were identified for a range of soil threats, including the

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loss of soil biodiversity (Bispo et al., 2009). This work set the scene for future research at a European scale for the application of indicators in a monitoring framework, utilising legacy spatial data to provide a sampling framework stratified by land use and soil types found across Europe. This system was envisaged to provide baseline information (operating range, OR) on the status of soils, from which assessment of change should be made. The definition of OR is fundamental for the establishment of EU policies for protection of the quality of soils. More recently, the project EcoFINDERS launched a new survey with the aim of covering these aspects left open (http://ecofinders.dmu.dk/).

Ecofinders launched a soil sampling campaign intended to cover all representative soil types, including different land uses (forest, grass and arable) of all European biogeographical zones (BG zones) (Continental, Atlantic, Boreal, Alpine and Mediterranean). This campaign intended to provide all necessary samples for the study of biodiversity of soils across Europe. Soil biodiversity is the driving factor behind the services provided by soils (nutrient cycling (carbon, phosphate and nitrogen), productivity, water purification) and contributes to plant and animal health.

PLFA analysis is one of the methods used by this project to evaluate soil biodiversity and ecosystem function on this new pan-European campaign. The objective of the current work was the characterization of European soils under different land uses and from representative biogeographical locations, using a PLFA method developed in the context of the mentioned survey, in order to recognize and define PLFA operating range for different soils.

Soil microorganisms are the most sensitive and rapid indicators of perturbations and land use changes. The quantitative description of microbial community structure and diversity therefore arises great interest as a potential tool for soil quality evaluation (García-Orenes et al., 2013). Soil organisms such as Fungi and Bacteria, have their cell membranes mainly composed of phospholipids. Cell membranes can be extracted and decomposed into their constituent fatty acids (PLFA—phospholipid-derived fatty acids) for analysis. Once esterified and methylated, PLFA (or FAME, fatty acid methyl esters) composition can be analyzed, providing both a quantitative and qualitative evaluation of the whole microbial biomass existing in a soil sample, including both culturable and unculturable microorganisms (Piotrowska-Seget and Mrozik, 2003). PLFA analysis provides also a reproducible method for the detection and quantification of biomarkers for specific groups of microorganisms present in soil viable

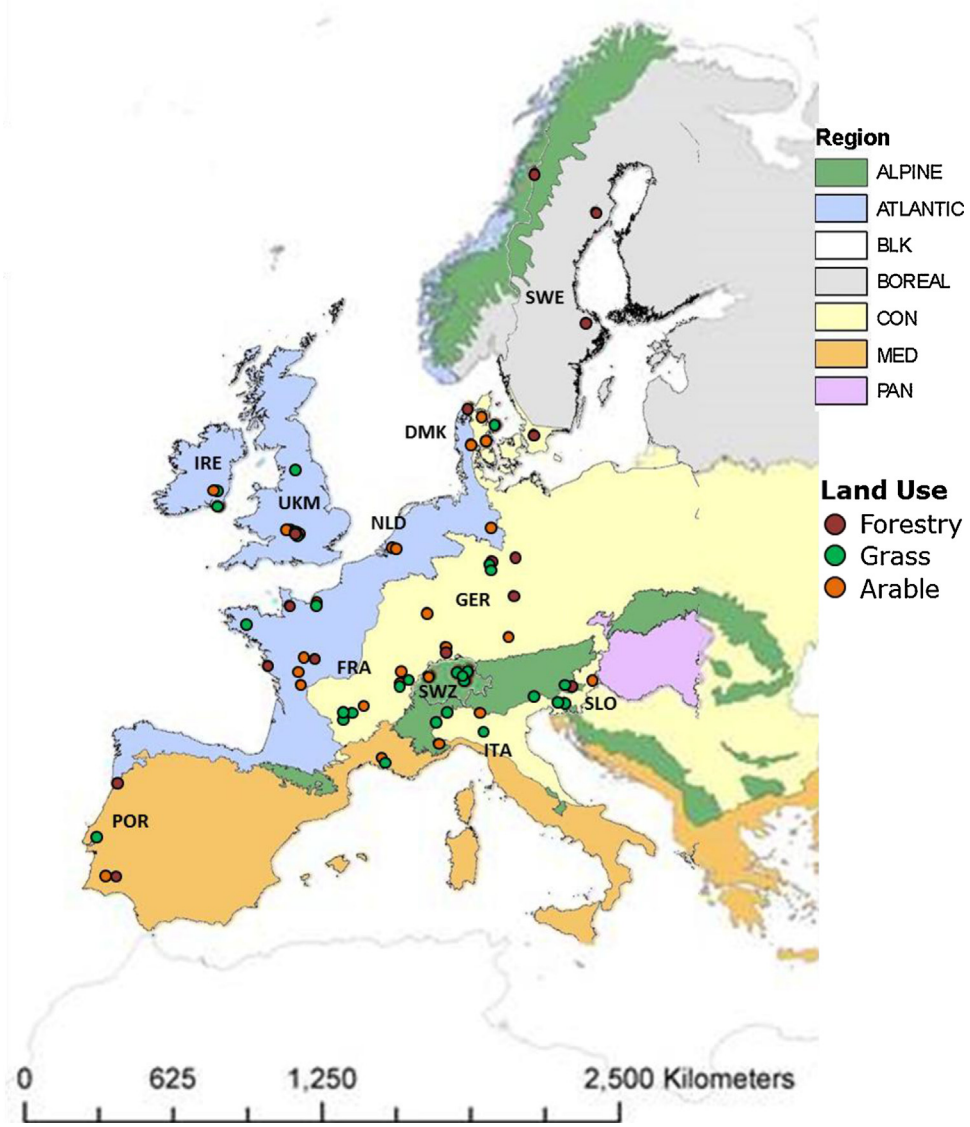

Fig. 1. Map of all 81 sampling sites of the campaign with BG zones and land use.