Soil Biology & Biochemistry 84 (2015) 158–167

Contents lists available at ScienceDirect

Soil Biology & Biochemistry

journal homepage: www.elsevier.com/locate/soilbio

# Water-extractable organic matter linked to soil physico-chemistry and microbiology at the regional scale

J. Guigue [a, *], J. Lévêque [a], O. Mathieu [a], P. Schmitt-Kopplin [b, c], M. Lucio [b], D. Arrouays [d], C. Jolivet [d], S. Dequiedt [e], N. Chemidlin Prévost-Bouré [f], L. Ranjard [e, g]

[a] UMR 6282 Biogéosciences, Université de Bourgogne, 6 Boulevard Gabriel, F-21000 Dijon, France
[b] Helmholtz Zentrum München, German Research Center for Environmental Health, Analytical BioGeoChemistry, Ingolstädter Landstraße 1, D-85764 Neuherberg, Germany
[c] Chair of Analytical Food Chemistry, Technische Universität München, Alte Akademie 10, D-85354 Freising-Weihenstephan, Germany
[d] INRA, US 1106, INFOSOL, F-45075 Orleans, France
[e] INRA, AgroSup Dijon, Université Bourgogne, UMR 1347 Agroécologie – Plateforme GenoSol, 17 Rue Sully, BP 86510, F-21065 Dijon Cedex, France
[f] AgroSup Dijon, UMR 1347 Agroécologie, 17 Rue Sully, BP 86510, F-21065 Dijon Cedex, France
[g] INRA, UMR 1347 Agroécologie, 17 Rue Sully, BP 86510, F-21065 Dijon Cedex, France

ARTICLE INFO

*Article history:*
Received 16 September 2014
Received in revised form
12 February 2015
Accepted 16 February 2015
Available online 5 March 2015

*Keywords:*
Soil biogeochemistry
Pressurised hot-water-extractable organic carbon
Microbial community structure
$\delta^{13}C$
Burgundy region

ABSTRACT

A better understanding of the links between dissolved organic matter and biogeochemical processes in soil could help in evaluating global soil dynamics. To assess the effects of land cover and parental material on soil biogeochemistry, we studied 120 soil samples collected from various ecosystems in Burgundy, France. The potential solubility and aromaticity of dissolved organic matter was characterised by pressurised hot-water extraction of organic carbon (PH-WEOC). Soil physico-chemical characteristics (pH, texture, soil carbon and nitrogen) were measured, as was the $\delta^{13}C$ signature both in soils and in PH-WEOC. We also determined bacterial and fungal abundance and the genetic structure of bacterial communities. Our results show that the potential solubility of soil organic carbon is correlated to carbon and clay content in the soil. The aromaticity of PH-WEOC and its $\delta^{13}C$ signature reflect differences in the decomposition pathways of soil organic matter and in the production of water-extractable organic compounds, in relation to land cover. The genetic structure of bacterial communities is related to soil texture and pH, and to PH-WEOC, revealing that water-extractable organic matter is closely related to the dynamics of bacterial communities. This comprehensive study, at the regional scale, thus provides better definition of the relationships between water-extractable organic matter and soil biogeochemical properties.



## 1. Introduction

Soil-monitoring networks serve to investigate the links between soil characteristics and environment, through the analysis of very large datasets, integrating soil diversity and environmental factors. Several soil-monitoring networks have been established around the world (Morvan et al., 2008; Van Wesemael et al., 2011). Many studies have been conducted using the French Soil Quality Monitoring Network ("Réseau de Mesures de la Qualité des Sols": RMQS), allowing large-scale assessment of soil organic carbon stocks (Martin et al., 2011), abundance of microorganisms (Dequiedt et al., 2011), and trace metal concentrations (Saby et al., 2009), for example. Large-scale investigation of the complex variability of soil biogeochemistry becomes possible, because of the extensive sample set available with this soil-monitoring network (n = 2200), The RMQS project provides an excellent opportunity to study the soluble organic matter in soils, a central component of soil biogeochemistry.

The soluble organic matter in soils generally corresponds to less than 2% of the soil organic matter, but is considered very sensitive, due to its high solubility and turnover rate (Kaiser and Kalbitz, 2012; Chantigny et al., 2014). This pool of soil organic matter has been identified as being linked with vegetation (Kalbitz et al., 2000a; Sanderman and Amundson, 2008), soil mineralogy (Kaiser

* Corresponding author. Tel.: +33 380396364.
*E-mail address:* julien.guigue@u-bourgogne.fr (J. Guigue).

http://dx.doi.org/10.1016/j.soilbio.2015.02.016
0038-0717/

et al., 2001; Schneider et al., 2010), climate (Camino-Serrano et al., 2014) and microbial activity (Lerch et al., 2010). The soluble organic matter concentration in soil solution is controlled by its production, leaching, stabilisation and degradation (Kalbitz et al., 2000b). Molecular investigation has revealed that thousands of different compounds compose the soluble organic matter in soils (Ohno et al., 2010). Its sources, as well as the interactions between the numerous environmental variables involved in these processes, are complex and controversial, and studies with large sample sets may help to identify general trends in the dynamics of soluble organic matter, and its relationship with other soil biogeochemical characteristics.

In this study, we analyse 120 samples from the RMQS project, collected in Burgundy, an area selected for its significant diversity in geology, soil type and vegetation. We determined the physico-chemical properties of soils and the characteristics of the water-extractable organic matter, using pressurised hot-water extraction of organic carbon (PH-WEOC) in the laboratory. We also measured the $^{13}C$ natural abundance in soil organic carbon (SOC) and in PH-WEOC, and we characterised the bacterial and fungal communities. Our first objective was to link the variability in water-extractable organic matter properties to soil biogeochemistry. We also hypothesised that water-extractable organic matter, a highly reactive pool, might interact with the dynamics of microbial populations and we therefore sought to identify the variables of soil biogeochemistry and PH-WEOC, related to the genetic structure of bacterial communities at the regional scale.

## 2. Materials and methods

### 2.1. Study area and soil samples

This study was conducted on 120 topsoil samples from the Burgundy region (Fig. 1), in the east of France, which has an area of 31,582 km$^2$ and where the elevation ranges between 50 m and 901 m asl. These soil samples were collected as part of the project "Réseau de Mesures de la Qualité des Sols" (RMQS), the French National Soil Quality Monitoring Network (Jolivet et al., 2006) and consisted of systematic sampling of soils (0–30 cm, except in the case of thinner soils) on a 16 km regular grid across the French territory. At the centre of each 16 × 16 km cell, a 20 m × 20 m zone was divided into 25 subzones (4 m × 4 m), and each subzone was randomly sampled, thus corresponding to an unaligned sampling design. The 25 cores were combined to produce a composite soil sample for each site. Soil samples were air-dried, sieved to 2 mm and stored before further analysis. More details on the RMQS project and on the sampling protocol are available in Jolivet et al. (2006).

In Burgundy, the land cover is a mosaic of forest (9950 km$^2$), permanent grassland (8000 km$^2$) and cropland (10,580 km$^2$) in balanced proportions (Fig. 1). Deciduous and coniferous forests are both present. Croplands are mainly areas of intensive agriculture, and all grasslands have been permanent for at least ten years.

There are three contrasted geological ensembles in the region (Fig. 1), leading to a diversity of soil parental material. The Massif du Morvan, in the centre, is composed of Hercynian granite, Palaeozoic volcanic rocks, and metamorphic rocks (granite, basalt and gneiss) and is bordered by continental sediments (sandstone and clay). In the northern part of the region, are found marls and calcareous sedimentary rocks dating from Trias and Jurassic (marl, limestone) and younger marine sediments dating from Cretaceous (clay and chalk). In river valleys, in the south-east, the south-west and the north-west of the region, recent alluvial sediment dating from Cenozoic are found.

Each of the 120 samples was assigned to two categories. The first categorical variable is land cover, composed of three classes: cropland (n = 46), forest (n = 33), and grassland (n = 41). The second categorical variable, soil class, was determined first by

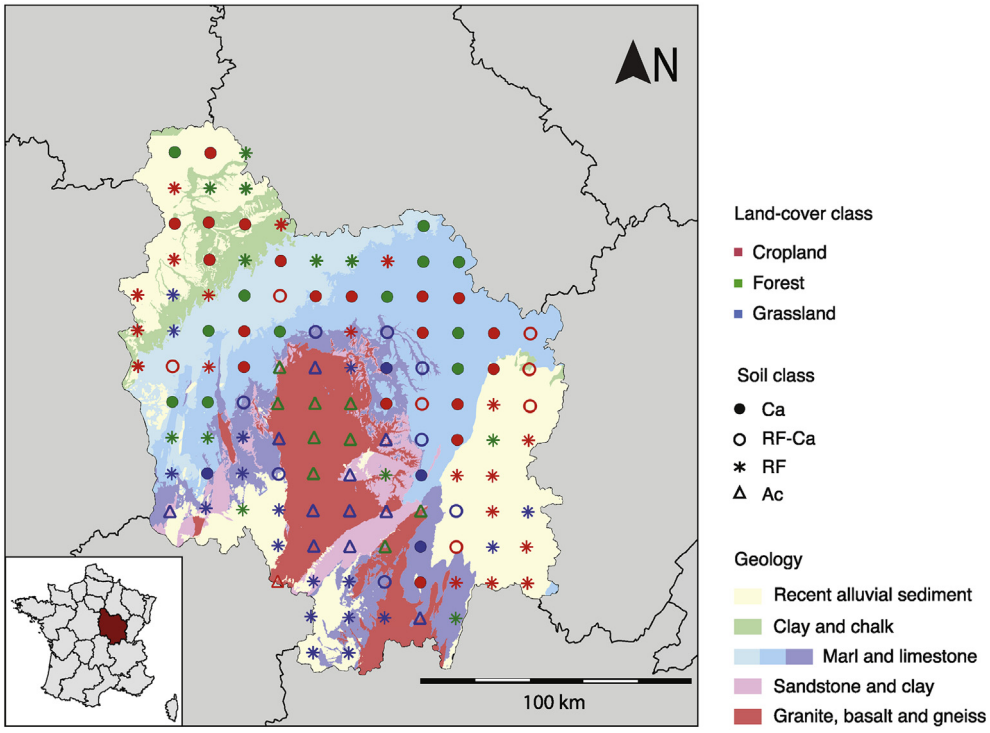


**Fig. 1.** Simplified geological map of the Burgundy region, with the sampling locations, and indications of land cover (colour of symbol) and soil classes (form of symbol). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)