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Integration of biodiversity in soil quality monitoring: Baselines for microbial and soil fauna parameters for different land-use types

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ABSTRACT

The French programme *Réseau de Mesures de la Qualité des Sols – Biodiversité* was carried out at a regional scale (Brittany, west part of France) i) to produce a first statement regarding soil biodiversity, ii) to identify bioindicators of anthropic constraints, and iii) to determine baseline values for several biological groups depending on land uses. In this study, 109 monitoring sites were investigated using a systematic framework (a 16 km × 16 km regular grid). Six biological groups were studied within four major categories, i.e., macrofauna (all soil macro-invertebrate taxa and earthworms), mesofauna (Acari and Collembola), microfauna (nematodes), and micro-organisms (microbial biomass and functional genes). The abundances of earthworms, nematodes, Acari and the bacterial community (assessed by their encoded 16S rRNA) as well as microbial biomass and earthworm species richness discriminate land uses (crops from meadows from forests). Macro-invertebrate abundance, Collembola abundance and richness, and nematode richness are only relevant for the discrimination of agricultural practices (e.g., management system or fertilisation intensity). Most of the soil biological groups (except Collembola) exhibit lower values of abundance and community richness in croplands than in meadows. This programme allows us to set up a first reference database for soil biological data for France covering microflora and fauna. This substantial reference database will be used to calibrate future research results and to develop management baseline values for stakeholders to assess the status of soil biodiversity under several policies, e.g., the Common Agricultural Policy, Soil Framework Directive, EU and national biodiversity strategies, and policies related to contaminated land management. Therefore it should assist stakeholders in the choice of good agricultural practices.

1. Introduction

The Convention on Biological Diversity (CBD) recognises the importance of biodiversity for ecosystem functioning and the provisioning of soil services to mankind [1] (www.cbd.int). The soil biota is thought to harbour a large part of the world's biodiversity [2], but this soil biodiversity is assumed to have decreased, and the Thematic Strategy for the Protection of Soil adopted by the European Commission in September 2006 (http://ec.europa.eu/environment/soil/index.htm) has identified loss of soil biodiversity as a soil degradation process. Therefore, the EU has required research to characterise biological species and functions to develop tools for soil management policies [3]. However, although soil biodiversity appears to be important in terms of quantity and quality (functions), there is still a lack of knowledge regarding soil organism distributions and the impact of anthropic or natural

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constraints. In contrast, physical and chemical parameters are well understood and readily available to scientists and stakeholders and are commonly used as indicators of soil quality [4]. Therefore, at the European scale, the European project ENVASSO (ENVironmental ASsessment of Soil for mOnitoring, http://www.envasso.com) reported that physical or chemical indicators are often integrated into soil monitoring, whereas only a few soil biodiversity networks have been recorded [5,6], i.e., in Germany, the Netherlands, Ireland, Italy, Austria, Latvia, and Estonia [7–9]. ENVASSO also emphasised the need to increase the number of soil biological references to be able to propose baseline values (i.e., reference values defined by a lower value and an upper value) that should assist stakeholders in soil management [6].

In these scientific and policy contexts, the French programme *Réseau de Mesures de la Qualité des Sols – Biodiversité* (*RMQS BioDiv* programme) was developed at a regional scale in Brittany (west part of France) i) to produce a first statement at the regional scale regarding soil biodiversity in relation to land use and pedoclimatic parameters and ii) to propose baseline values for each biological group. This *RMQS BioDiv* programme implemented a French national soil quality monitoring network (referred to as *Réseau de Mesures de la Qualité des Sols*, i.e. *RMQS*) that monitored physical, chemical and agronomical parameters throughout France (http://www.gissol.fr/programme/rmqs/rmqs.php [10]). In *RMQS BioDiv* programme, a large national research network (12 research teams) was developed, which allowed the investigation of six biological groups within four major categories, i.e., macrofauna (all soil macro-invertebrate taxa and earthworms), mesofauna (Acari and Collembola), microfauna (nematodes), and micro-organisms (microbial biomass as well as structural and functional genes).

The strengths of this programme were the following: i) the multi-disciplinary approaches applied (a majority of the soil taxa are inventoried, from micro-organisms to macrofauna, within the same space-time); ii) the connection to the *RMQS* monitoring network, which permits combining biological data with many explanatory variables, such as land uses, agricultural practices, and physical and chemical soil data; and iii) the large number of sites ($N = 109$) and areas covered (regional scale), allowing comparisons of various geological and pedological situations to be made [10,11].

The objectives of this study were:

1. To supply reference values in terms of the richness and abundance of several biological groups at a regional scale,
2. To link indicative values of biological parameters to explicative variables, such as land use and agricultural practices (e.g., fertilisation, tillage).
3. To determine baseline values for different biological groups.

2. Materials and methods

2.1. Sampling site network

The sampling site network was located in the Brittany region in the western part of France (Fig. 1). The coordinates of the limits of the network were longitudes from 2 to 5° W and latitudes from 47 to 49° N. The climate is temperate oceanic with a mean annual air temperature ranging from 7.6° to 15.9° C and mean annual rainfall ranging from 1400 mm in the west to 700 mm in the eastern part of the region. Cambisols and Luvisols [12] are the two main soil types. The studied area, which included 109 monitoring sites, was based on a 16 × 16 km systematic grid covering the whole regional area (27 000 km^2) that corresponded to the grid used by the *RMQS* programme, which monitored physical and chemical soil parameters and agricultural practices [10]. To link the measured biological data to the recorded agro-physico-chemical data, the *RMQS BioDiv* sampling area was set up adjacent to the *RMQS* area (located 5 m apart). For each biological parameter, a specific sampling design was applied within the *RMQS BioDiv* area (Fig. 2). The biological sampling time was restricted from 15 February to 15 April in 2006 and 2007, when seasonal conditions are relevant in terms of soil moisture and air temperatures. Within the 109 sites, the land uses mainly consisted of meadows ($N = 47$, 43% of the studied sites) and arable land, i.e., crops ($N = 52$, 47%), with only a few forest sites ($N = 8$, 7%), 1 dune and 1 wasteland. Although it was limited to a regional scale, this study encompasses a rather large diversity of situations in terms of land management and soil types due to high variability in geology, pedology and climate contexts.

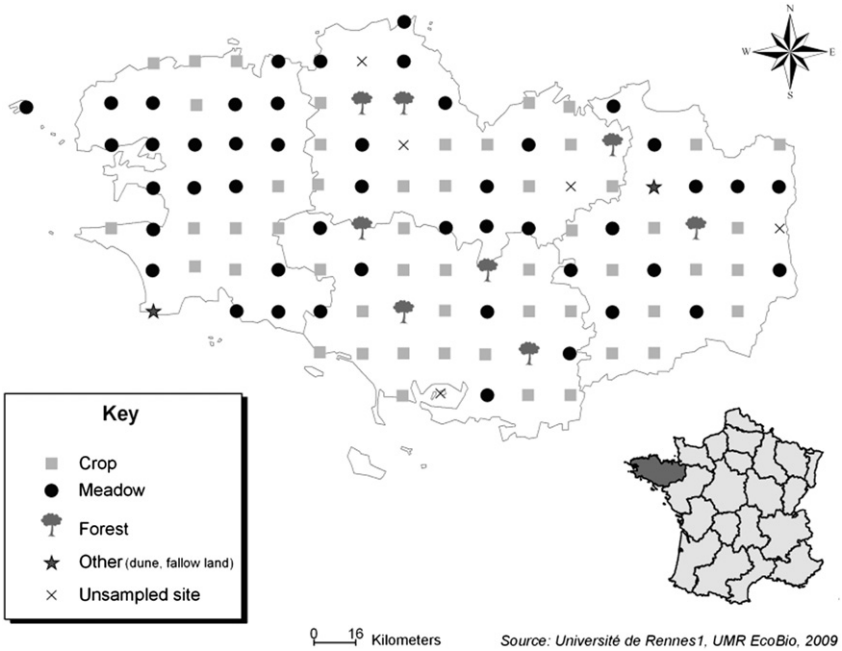

Fig. 1. Location and land use of *RMQS BioDiv* sites (16 km × 16 km systematic regular grid; $N = 109$) in Brittany region (France).