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Review

Study of soil–vegetation relationships on the Butte Montceau in Fontainebleau, France: Pedagogical exercise and training report☆

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ABSTRACT

This article illustrates a short training course for students at the Master's level, which explores relationships between plants and soil. It takes place in the Forest of Fontainebleau (France), where a reception centre with a large room (30 m2) is located containing a Berlese equipment, and many microscopes. On the first day, students are accompanied by their professors in the field and visit the four sites which are located along an ecological transect. Vegetation and soils at each site are presented to them by specialists. In the laboratory, indications are written on a black board, explaining how to use relatively simple tools for biological investigations (microscopes, GPS, Berlese funnel, photometer, flora and fauna guides…). Students are then divided into 4 groups of 4–6 students. Each group is assigned a site which is then described and analysed. At the end, each group produces a written report. Are the measured parameters interrelated within each site? Are there functioning principles that may distinguish the four stations? Three professors are always present and accompany the students in the field or in the laboratory so as to provide help when necessary. After a brief moment of uncertainty, students are able to quickly organise themselves and after three days identify the essential elements of these ecosystems. They also learn how a real biologist observes a forest ecosystem. They discover that plants, soil and animals are interconnected and form a natural functioning system. Students thus learn that nonetheless, it is difficult to have clearly identified boundaries between the investigated forest stations, because the gradient between them is gradual and ecologically indefinite.

1. Foreword

This study is a pedagogical exercise, part of the academic course SOLT, proposed yearly by Paris-Saclay and Pierre et Marie Curie Universities (France) in the Biodiversity, Ecology, and Evolution Master. The training course takes place at the Station d'Ecologie Forestière de Fontainebleau-Avon (Université de Paris 7, Diderot).

The aim of the course is to give students an opportunity, through field experience, to observe and measure the main ecological variables in a forest ecosystem. Faced with an ecological question, students develop ways to answer it while dealing with field constraints: what can be measured, with what means, and for what purpose?

SOLT is a five-day training course divided into three phases: 1) field work, after a brief explanation recalling the content of previous courses, collection of vegetation and soil data (about 12 h); 2) data analysis in a training room at the Ecological Station of Fontainebleau-Avon (12 h);

☆ Background music while reading?: Jean-Charles Gandrille: Toccata minimaliste (Coralie Amedjkane) d'Aivars KALĒJS: https://www.youtube.com/watch?v=Haxs7J_fg5U.

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3) statistical analysis of data and report writing (16 h).

Even if the report has the structure of a scientific paper, its content has the value of only a few days of training experience, not one of a scientific publication. It lacks precision in the measurements (use of field tests for chemical data, lack of time for necessary scientific field and laboratory investigations, first time experience for many students to analyse a soil profile or make a phytosociological sampling list…). The report is also a training experience that places them in front of the difficulties of data analysis interpretation. Students learn how data collection, data analysis, and results are interconnected and interdependent. Another goal of the course is to show that the quality of an ecological scientific publication strongly depends on feedback that helps the researcher adopt and improve his or her preliminary investigation plan and also develops her or his capacity to fruitfully collaborate with other colleagues.

The teaching staff accompanied the students along a transect passing through four different types of forest stations. The transect was relatively small (length < 1 km; width: 200 m) and could be considered climatically homogeneous. The group stopped at each forest station, making observations and measurements of the vegetation and soil with the goal to be able to answer the following fundamental questions:

- Are there main ecological factors that can explain the observed subdivisions in forest stations?
- What are the differences at the level of soil and vegetation biodiversity and how is it possible to investigate and present these differences?
- Are soil and vegetation interdependent?
- Is it possible to predict the evolution of these systems in response to processes of climatic global warming?

The students were divided into 4 groups, each of them collecting data from a single station. The data was then shared at the end of the second day with the other groups for statistical analysis. Each group prepared their own statistical analysis and report. This article is based on the report presented by Tanguy F., Jouhanique T. and Terrigeol A., translated in English by Indorf M.-F. The other students made a similar report and proofread this one which had a clearer structure. The teaching staff accompanied the process while giving students liberty to develop and carry out their own actions and initiatives. The corresponding author coordinated the redaction of this paper and realised the photographic report.

2. Introduction

Understanding of the soil functioning is crucial, especially in considering agricultural needs and climate regulation. Exchanges are made between air, water, and living organisms but we still don't understand all the processes involved. These compartments are not isolated as numerous interactions occur between the soil, the flora, and the fauna.

Soil micro-organisms like bacteria et archaea are important actors in this process. They have the ability to digest all the organic compounds in the soil, even the humic or phenolic ones such as tannins (Lavelle et al., 1995a; Barot et al., 2007; Clause et al., 2014; Dickson and Broyer, 1972; Lavelle, 2009). However, their activity remains limited without the macro-organisms which modify the environment in time and space (Lavelle et al., 1995b).

Plants, for their part can influence soil properties by producing chemicals and organic compounds affecting litter, humus, and soil (Van der Putten et al., 2013; Ponge et al., 2014, 2011, 1997).

The goal of this study is to demonstrate how pedogenesis soil formation under the same climate can vary within short distances due to different geological subsoil structures, and how this drives the entire ecosystem, from soil organisms to plant cover.

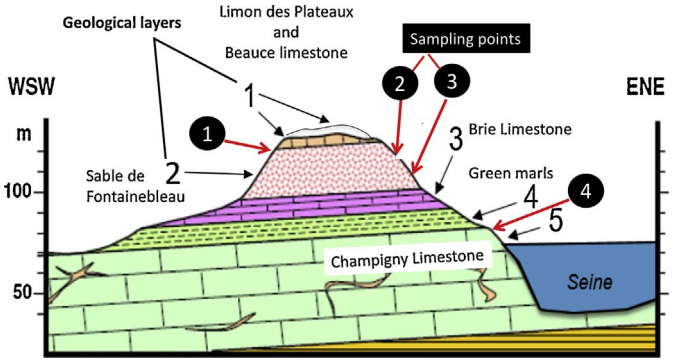

Fig. 1. Geological profile of the Butte Montceau at Fontainebleau going from the peak of the Butte to the bank of the Seine River. The following geological strata can be observed: the ridge is capped by a thin layer (3–4 m) of Beauce limestone covered with a thin windy loam (Limon des Plateaux, < 50 cm (1); the limestone layer is followed by an important stratum of Fontainebleau sands (2), a soft slope of Brie limestone (3), a layer of Green marls (4) and finally the Champigny limestone which also forms the Seine bed (5). In black, the 4 sampling points corresponding to the different forest stations. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

3. Materials and methods

3.1. The Butte Montceau

The Butte Montceau (N48°24′34", E2°44′37") is a 125 m high hill located east of Fontainebleau along the Seine River. The Butte is made of several geological strata dating mainly from the Oligocene. The Sannoisian limestone form the first marine deposit, followed by the Brie Limestone (10–15 m thick). The 40 m thick stratum of sand forms the most imposing part of the Butte and dates back to the Stampian Stage. The Butte is mainly covered by forest vegetation. The different study stations are characterised by their soil, exposition, and floristic composition (Fig. 1).

The Butte Montceau, along with other similar rises just south of the town of Avon, is quite remarkable as it stands apart from the initial sedimentary stratum (the Beauce limestone) that can be found further south, stretching from the town of Étampes to the Cher Valley. In this region, the initial sedimentary stratum is usually 40 m thick.

3.2. Sampling design

We studied four contrasted stations along a 500 m transect. Each station hosted a different subsoil structure and exposure. As mentioned above, they are all located on the Butte Montceau and identified in Fig. 1 by their number. Station 1 corresponds to summit, and station 4 is next to the Seine River.

Flora and fauna: Five square patches of 100 m2 were laid out at each station and these were used as replicates for floristic inventories and soil and litter samples. The patches were aligned along a transect that was perpendicular to the slope, so that all replicates were at the same altitude. A distance of 10 m was respected between each patch corresponding to the width of a patch. The five patches provided a prospection zone large enough for the floristic inventory.

A quadrat of 50 cm x 50 cm was placed in the centre of each patch (Fig. 2a, b, c). All litter (approximately OL + OF horizons), inside the quadrats was then collected into a sack, weighed and identified for each tree species. White rot was evaluated for each species on a basis of a 10-leaf sample for each species.

Soil properties: a soil chunk (soil without "litter", i.e. soil without OL and OF horizons) of about 1000 cm^3 (10 × 10 × 10) was then carefully extracted from each quadrat, in order to preserve at best, the different horizons for future chemical analyses. This chunk corresponded mainly to the A horizon in stations 1, 3 and 4, and to (OH