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3D representation of soil distribution: An approach for understanding pedogenesis

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Abstract

Soils are characterised by a spatial variability in the three dimensions (3D) of space. However, 3D studies remain scarce due to the qualitative nature of many soil horizon characteristics, notably the horizon designation. Indeed, existing 3D tools are mainly developed for quantitative data. To solve this difficulty, we propose a new approach based on the interpolation of the horizon thickness to derive digital elevation models for both the upper and the lower limits of each horizon. This approach was applied to Planosols previously extensively studied with 2D approaches. The pseudo 3D obtained representation evidences soil processes that were missed in 2D approaches. As an example, we evidence the impact of differential weathering, resulting from the mineralogical heterogeneity of the parent material, on the subsequent pedogenesis. ***To cite this article: F. Delarue et al., C. R. Geoscience 341 (2009).***

Résumé

Représentation 3D des sols, apports à la compréhension de la pédogenèse. Les sols sont des continuums tridimensionnels (3D), caractérisés par une variabilité spatiale dans l'ensemble des directions de l'espace, mais les études 3D demeurent rares. Une des difficultés majeures des approches 3D est due à la nature qualitative de nombreuses caractéristiques des horizons, dans la mesure où la plupart des outils 3D existants sont principalement développés pour l'interpolation 3D de données quantitatives. En substitution à l'interpolation directe de la variable « nom de l'horizon », nous proposons une approche basée sur l'interpolation de l'épaisseur des horizons pour calculer les modèles numériques d'altitude correspondant aux limites de chaque horizon, permettant ainsi une visualisation pseudo 3D. Cette étude, appliquée à des Planosols bien caractérisés en 2D par ailleurs, montre que

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la représentation 3D des sols permet de souligner des processus omis lors des approches précédentes, tels que l'impact de l'altération différentielle, résultant de l'hétérogénéité initiale du matériau parental, sur une pédogenèse ultérieure. ***Pour citer cet article : F. Delarue et al., C. R. Geoscience 341 (2009).***

Keywords: 3D representation; Modelling; Horizon; Soil volume; Pedogenesis; Parent material; Soil spatial distribution

Mots clés : Représentation 3D ; Modélisation ; Horizon ; Volume de sol ; Pédogenèse ; Matériau parental ; Distribution spatiale des sols

1. Introduction

Soil is a three-dimensional (3D) continuum characterised by a spatial variability in all the dimensions of space. Its thickness (generally decimetres to metres) is relatively small compared to its lateral extension (from hectometres to kilometres). This represents a substantial difficulty for 3D approaches. Thus, despite their obvious 3D organisation, soils are generally studied in two dimensions by pedological approaches in sequences or by geostatistics.

Pedological approaches in sequences were first theorised by Jenny [14] who studied the impact of a single factor on the evolution of the soil through time and space. For instance, he discussed the impact of the slope by studying soil distribution along toposequences, keeping all other factors as constant as possible. In this case, topography is only represented by one terrain attribute. This approach has been widely used in many pedological studies and remains a valuable tool to study soil evolution as recently discussed by Huggett [13]. However, soil sequences are generally designed to emphasise the impact of one factor of variation – often a single attribute, the slope –, while the others are generally neglected. In order to overtake this limitation, an approach called ''structural analysis'' was developed [3,4,9,16]. In these approaches, 3D blocks diagrams of soil distribution were derived from the analysis of several toposequences varying in intensity and orientation of the slope**.** As these block diagrams are based on the interpretation of the toposequences, they do not allow the observation of variations that would have been missed in the 2D approach.

Approaches based on geostatistics were developed in order to acquire an exhaustive quantification of the soil variability [17]. They aim classically at obtaining the spatial estimate of a soil variable. Nevertheless, these approaches deal mainly only with one horizon and more rarely with two that are compared [5].

Salvador-Blanes and coworkers [23,24] demonstrated that maps are useful for understanding pedogenesis by coupling toposequence and geostatistical approaches. We deduce from this work that a 3D representation of soils, as 2D maps, should improve our understanding of pedogenesis.

Despite many attempts in recent years [1,2,12,20,21], 3D numerical modelling of soils can still be considered as being in its infancy and is generally based on soil properties [22,26] less frequently on the organisation of soil volumes in the 3D space.

In this paper, we demonstrate how a 3D representation of soils evidences soil processes that were missed in the two dimensional approaches. For the sake of our demonstration, we will discuss the distribution of Planosols since their pedogenesis is driven by lateral processes [8]. These soils represent thus an ideal case for such a study.

2. Study site and sampling method

2.1. The study site

The study site is located on the Aigurande plateau in the northern part of the French Massif Central (Fig. 1). It is underlain by amphibolite and gneiss. It is a footslope where Planosols developed on B-horizons and alterites

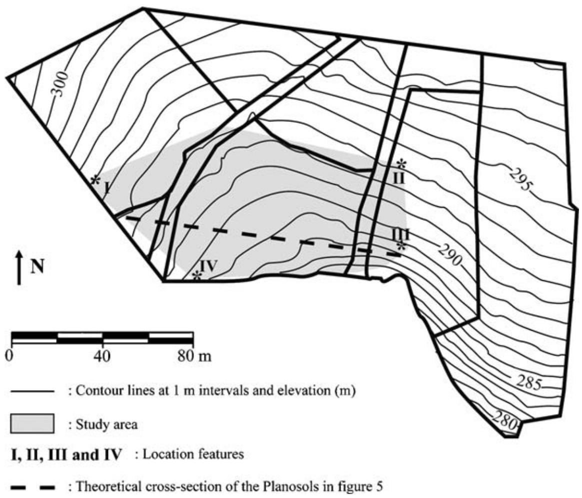

Fig. 1. Location of studied sector after Salvador-Blanes et al. [25].

Fig. 1. Localisation du secteur étudié d'après Salvador-Blanes et al. [25].