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Relation between 3D morphological characteristics of natural earthworm burrows and water transfers in soil

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Introduction

Soil is an interactive system in which the physical, chemical and biological characteristics are strongly linked (Coleman & Odum, 1992). In temperate regions, earthworms have a large impact on soil properties (physical, chemical and biological properties), in particular, they modify the soil porosity by their burrowing and casting activities. The burrows network (macropore space, >1mm) can act as preferential flow paths of water through the soil profile (Schrader *et al.*, 1995) and the water movement depends on the geo-morphological characteristics of each burrow. In relation to the spatial organisation of the burrow networks, an information in two dimensions is not sufficient, it is advisable to use tools that give the representation of this macroporosity in three dimensions. In fact, a number of studies have documented burrow characteristics using X-ray tomography (Joschko et al., 1991; Jégou et al., 1999; Capowiez et al., 1998; Bastardie et al., 2003) which proved to be a suitable technique to give a global representation of 3D soil macroporosity. Those different studies, carried out in artificially soil or in soil scores collected from the field, often link the burrow characteristics to only one earthworm species but they neglect the strong interactions which exist between earthworms species. Moreover, it is now largely documented that earthworm are influenced by the agricultural practices (Cluzeau et al., 1992; Curry et al., 2002), but a lack of information still exists on the consequences of the agricultural practices on the burrow networks and the water movements.

The aim of our study was 1) to characterise in three dimensions the earthworm burrows observed in natural conditions under different agricultural practices, and to link the characteristics to the earthworm species sampled *in situ*, 2) to assess the relation between the morphological burrow characteristics and the water infiltration (K_{sat}) in order to identify the most efficient geo-morphological characteristics on the water movement.

Investigations were conducted in western Brittany (France) under three very common agricultural practices (a continuous maize field, a rye-grass/maize rotation, an old pasture). Natural earthworm communities were sampled in field using the formaldehyde method (Cluzeau et al., 1999). Earthworm communities were characterized by their abundance (number collected per m^2) and their specific structure (species).

After the earthworm sampling, soil blocks (25*25*25 cm) were extracted just under the earthworm sampling area (cut by knife, extracted by hand). In order to limit physical perturbations, they were plastered before they were scanned. The X-ray spiral tomography technique was applied (160 kV; 180 mA; resolution of 0.41 mm in X and Y, 1 mm in Z). The slices were then treated using a method (Delerue, 2002) which permits to characterize the burrow network or the individual burrow by the volumique characteristics or the structural organization. The burrow networks were characterised by their total length (cm), the volume of total porosity and effective porosity (cm^3), the branching rate (number of nodes), and the depth; each burrow was characterised by its average diameter (mm), its length (mm), its orientation (°), its tortuosity (mm/mm), its branching rate (number) and its continuity (opening to the surface or not).

Afterwards, the saturated water conductivity K_{sat} of each block was measured, and the two data bases (morphological characteristic and conductivity) were compared.

0.1 Results and discussion

The burrows created by epi-anecic species as *L. terrestris* and *L. friendi* are quite similar in terms of continuity (they are always open at the surface and continuous), they present a low branching rate, a low interconnectivity, a vertical orientation. The burrow are not interrupted by soil plugs, which demonstrates their state of "permanent burrows". They can be observed below 30 cm in-depth even if the soil is very compacted (presence of a plough pan under maize field). Similar characteristics are noted for *L. r. rubellus* which is usually considered as an epigeic species.

The agricultural practices, even if they influence the density of earthworms (less under maize *vs* permanent pasture), do not modify the main morphological characteristics of the burrow and neither the number of burrow. The density of burrow is more related to the foraging activity of the animal and in consequence it can not be directly related to the earthworm density.

There is no correlation between the number of burrows or the geometrical properties, except the rate of branching, and the infiltration rate. The total length of the network or the volume of effective porosity are not major for the soil hydraulic conductivity; on contrary, the increase of the branching rate tends to decrease the conductivity. The infiltration rate seems to be essentially linked to the continuity of the burrows (connections of burrows with the soil surface). The radius of the opening pore at the surface, the surface state and the stability of this surface states are the major parameters in the infiltration of soil water.

These results suggest the major influence for the infiltration process of the (i) the soil surface state, which can be modified by the dejection of earthworm at the surface (casts), and (ii) the maintenance of the opening of the burrow at the soil surface, which is different depending on the species.

In conclusion, earthworms, by creating specific burrow network, influence the infiltration of water in soil. In order to understand the relation between the earthworms and the water movements, it appeared necessary to have a specific approach of the earthworm communities; moreover the integration of the growth stage of the earthworms can increase the quality of the biological information.

0.1.1 References

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