Monitoring soil structure dynamics with passive acoustic emissions – soil biological activity

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Monitoring soil structure dynamics with passive acoustic emissions – soil biological activity

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Introduction

Biological activity plays an important role in natural and managed soil by generating and sustaining favorable soil structure. Plant roots and earthworms are particularly important in creating biopore networks that promote aeration and infiltration and in stimulating microbial activity forming biological hotspots. Available observation methods for soil structure quantification are often limited to episodic snapshot that may miss these highly dynamic biophysical processes. Some methods such as rhizotron imaging may provide qualitative insights within certain windows of observation, but the picture remains limited when inferring root system dynamics. Modern application of X-ray computed tomography have provided new insights into soil structure characteristics and the resulting soil bioturbation by earthworms and plant roots. However, such methods remain lab based and not yet available for *in situ* monitoring. We report application of passive acoustic emissions (AE) measurements that identify mechanical activity in soil. AE are generated by release of elastic energy due to modification of grain contacts, crack formation, friction between aggregates and grains, and changes in air-water interfaces (Michlmayr et al., 2012); all of which may occur during soil structure formation. The working hypothesis is that AE generated during soil displacement by growing plant roots and burrowing earthworms could be quantified continuously and *in situ*, and allow monitoring of windows of activity and soil structure dynamics.

Materials and methods

We monitored AE produced by earthworm activity and maize roots growing into soil using three separate experimental protocols. AE resulting from earthworm activities were monitored using glass cells: one kept empty to monitor background noise; two filled by a silt loam soil and closed to minimize soil water evaporation (one used to monitor earthworm activity, the other as a control). An endogeic earthworm, *Octolasiun cyaneum*, was placed into a glass cell at the beginning of the experiment. The second experimental protocol monitored AE resulting from roots growing in a glass cell filled with a sandy soil and supplied by a hanging water bottle to maintain constant water content. Three maize seeds were planted at the soil surface. Background noise occurring during the experiment was also monitored. For the first two protocols, AE were linked with time-lapse imaging to compare visually observable activity with measured AE. The third experiment monitored AE resulting from root growth in a square soil columns in order to explore the method feasibility for field like applications (using acoustic waveguides inserted in the soil). Two columns were filled with the sandy soil, one used for root growth monitoring and the other as a control (bare soil), and a constant water content was maintained. The AE monitoring system comprised of a digital multi-channels AE-measurement system (Vallen, DE) and passive piezoelectric AE-sensors with a wide frequency response. In the glass cell experiments, the AE sensors were in contact with the background glass face. For the "*in situ*" monitoring in the soil column experiment, glass acoustic waveguides were used to ensure good contact between the soil and the AE sensors and reduce attenuation of acoustic waves in soil.

Results and discussion

The AE recorded during the three experiments were in good agreement with independent (imaging) observations of earthworm burrowing and plant roots growing. For the earthworm experiment, the daily AE rate was strongly linked with creation of new tunnels (Fig. 1), and was less correlated with earthworm movement in soil, due to re-use of pre-existing tunnels. For the plant roots, observed root growth and elongation trends were strongly correlated with AE event rate. In contrast, temporal trends in evaporation did not correspond to AE events recorded in the same cell (i.e., the AE recording primarily mechanical deformation and not air-water interfaces). The number of AE recorded from the soil columns with growing maize roots were several orders of magnitude larger than AE emanating from bare soil under similar conditions. The results support the hypothesis that the soil bioturbation by both earthworms and plant roots generate measurable AE events that were highly correlated with the observed activities. The resulting AE patterns from the controls were clearly different (temporal patterns and magnitudes) from cells and column containing biological agents.

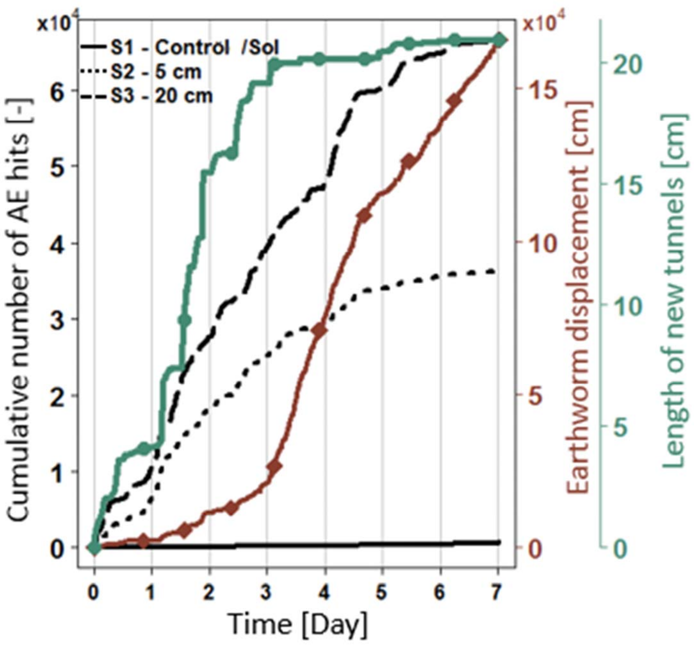

Figure 1. AE monitoring and earthworm activity in a soil filled glass cell.

Conclusions

The results of this studys are exploratory and monitoring using the AE method require further development and refinement for broader applications. Nevertheless, results suggest that AE monitoring could offer a window into largely unobservable dynamics of soil biomechanical questions such as when do roots grow? or how earthworm activity varies with time and with soil wetness conditions? Resolving such processes at the level of detail offered by AE could enhance our understanding of soil structure-forming processes and the mechanics of life below ground.

References

Michlmayr, G., Cohen, D. and Or, D., 2012.Sources and characteristics of acoustic emissions from mechanically stressed geologic granular media - A review. Earth-Science Reviews 112, 97-114.