Can the smartphone application SLAKES distinguish between earthworm-influenced soil and bulk soil?

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Introduction

Soil fauna such as earthworms have important functions for soil fertility and sustainable agriculture (Bardgett and van der Putten, 2014). Earthworms can **support aggregate formation and stability** during gut passage, burrowing activity and secretion of polysaccharides (Hallam und Hodson, 2020). These ecosystem services of earthworms are vital for vulnerable soils, e.g. in dry areas which are prone to wind, water erosion.

Lumbricus terrestris with a vertical and permanent burrow has a central role for water infiltration and for adjacent **endogeic earthworms** (Andriuzzi et al., 2015; Butt and Lowe, 2007). Due to the increased activity of endogeic earthworms around the burrow of *L. terrestris* the adjacent soil is highly earthworm-influenced and connects the burrow with the bulk soil in terms of water flow (Schneider et al., 2018).

To impede soil erosion and to increase plant-available water, it can be useful to demonstrate to farmers the soil aggregate destruction of soil tillage. Therefore, soil aggregate stability was tested by the smartphone application SLAKES (University Sydney, Australia) as an easy to use and available measurement tool. A hypothetic gradient of earthworm activity zones of **middens > *L. terrestris* burrow with endogeic earthworms > bulk soil with lower activity** were analysed.

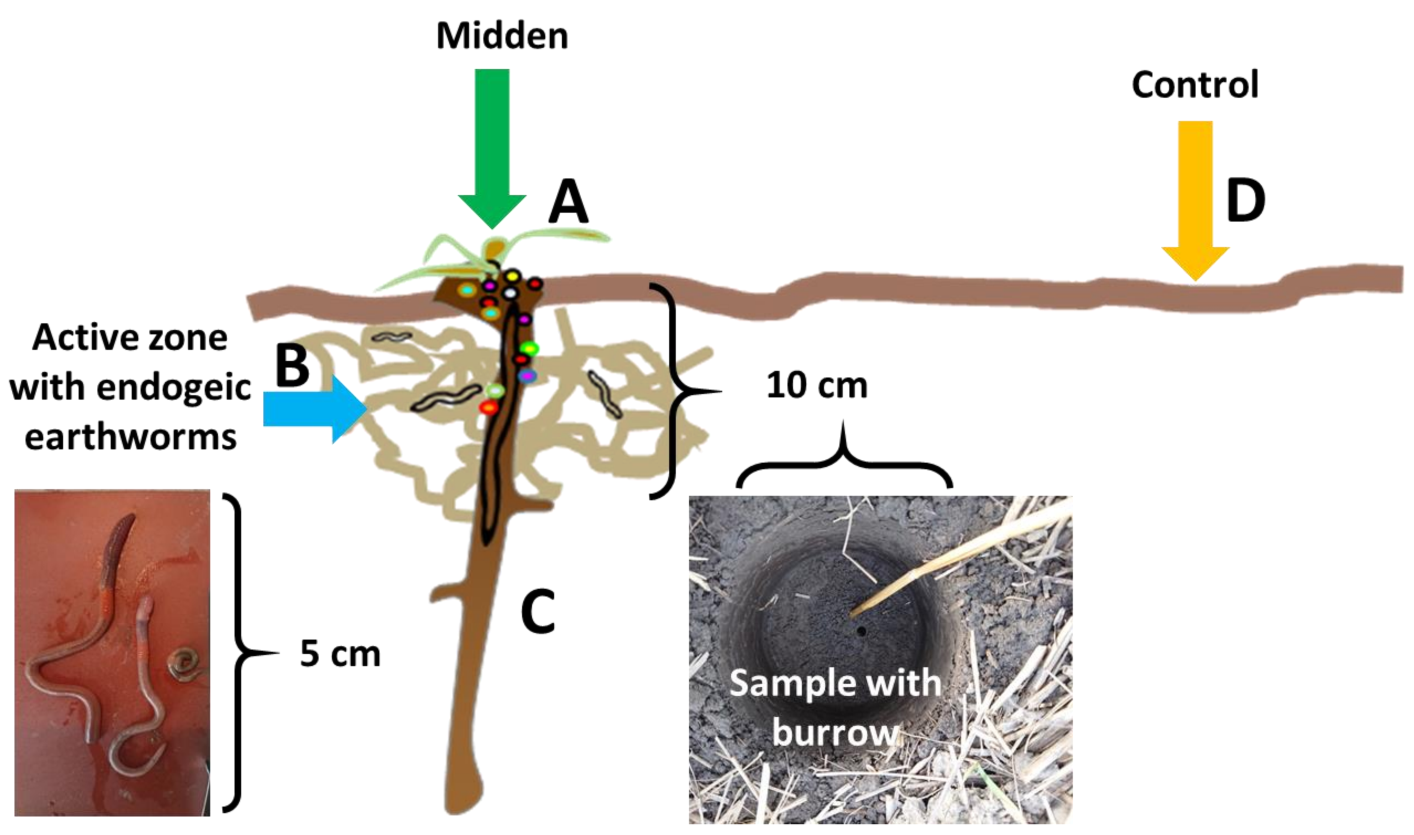

Figure 1 Scheme of soil sampling areas A) midden, B) burrow area with endogeic earthworms, C) burrow of *L. terrestris* and D) bulk soil without *L. terrestris.*

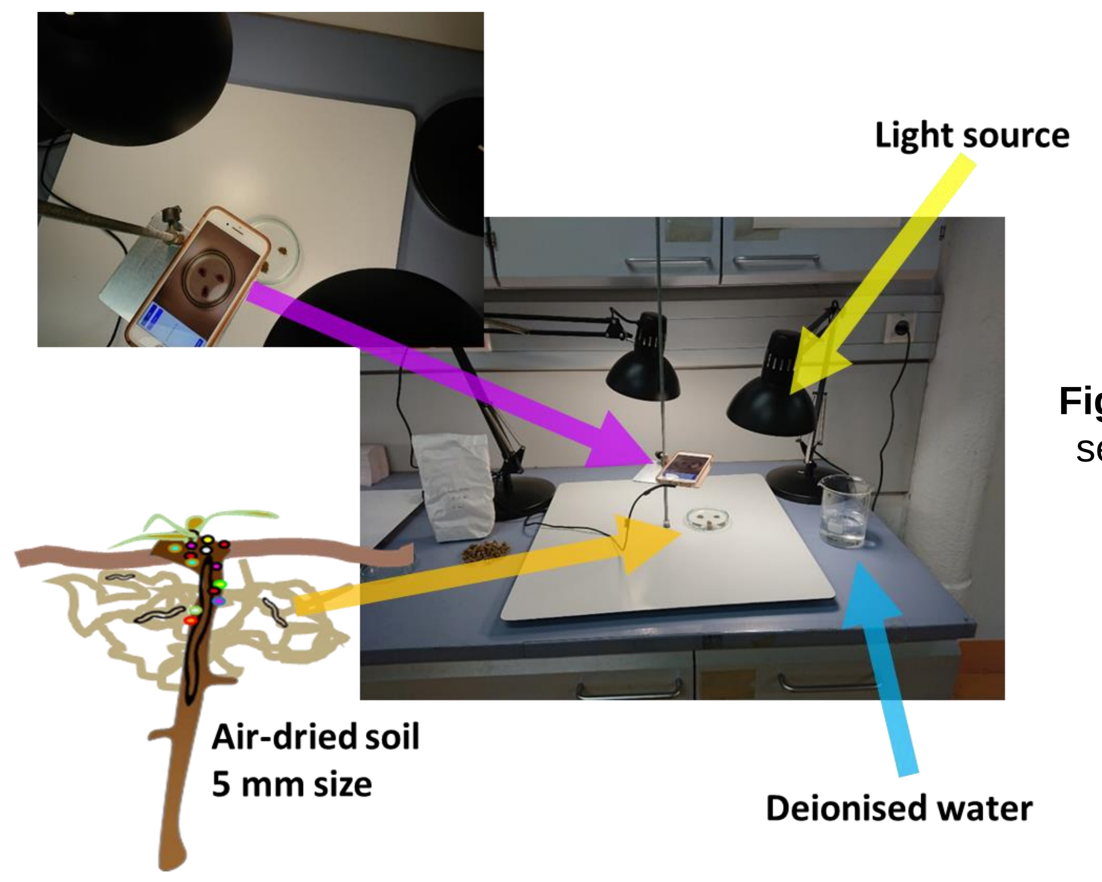

Figure 2 Laboratory set-up of SLAKES analysis.

Materials and methods

In two long-term soil tillage trials in Austria (Hollabrunn in 2019; established in 2009; Raasdorf in 2020; established in 1996) additional 14 *L. terrestris* m^{-2} were released in enclosures of 7 m^2 after the seeding of maize in May in **plough, cultivator or no-till** treatments. After the maize harvest in each November, soil samples were taken from active earthworm zones of middens or burrowing area of *L. terrestris* (Fig. 1A-C) and compared to bulk soil without *L. terrestris* (Fig. 1D) to a depth of 10 cm and 10 cm in diameter. Samples were hand-searched for earthworms or air-dried and sieved through a vibratory sieve shaker to determine mean-weight diameter (MWD) from 40 -1.25 mm (6 levels). Five mm samples were then analysed with **SLAKES a smartphone application** devised by the University of Sydney (Australia). Within 10 mins, SLAKES measures the slaking index (alpha coefficient) of soil aggregates immersed in deionized water using an image recognition algorithm.

Results and discussion

Preliminary results showed an **increased abundance of earthworms around burrows compared with controls** in November 2020 as similarly seen by Butt and Lowe (2007), but no differences in MWD (Fig. 3).

With **increasing soil tillage intensity soil aggregate stability decreased** at both sites with **no-till > cultivator ≥ plough**. The slaking index was twice as high in plough then no-till ($P < 0.05$) and no-till therefore twice as stable. No-till was more stable than cultivator ($P < 0.05$), but cultivator was similar to plough (Fig. 4). In general, SLAKES was able to detect differences in the soil tillage systems at both sites (Bagnall und Morgan, 2021; Flynn et al., 2020).

While testing the earthworm-influenced soil the major differences were within soil tillage treatments. In detail, **middens were more stable than control**, except in Raasdorf in no-till. No-till in Hollabrunn middens were three to four times more stable than in the burrow area or control**.** These preliminary results indicate that SLAKES can also distinguish between earthworm-influenced soil and bulk soil and need to be verified with standard methods.

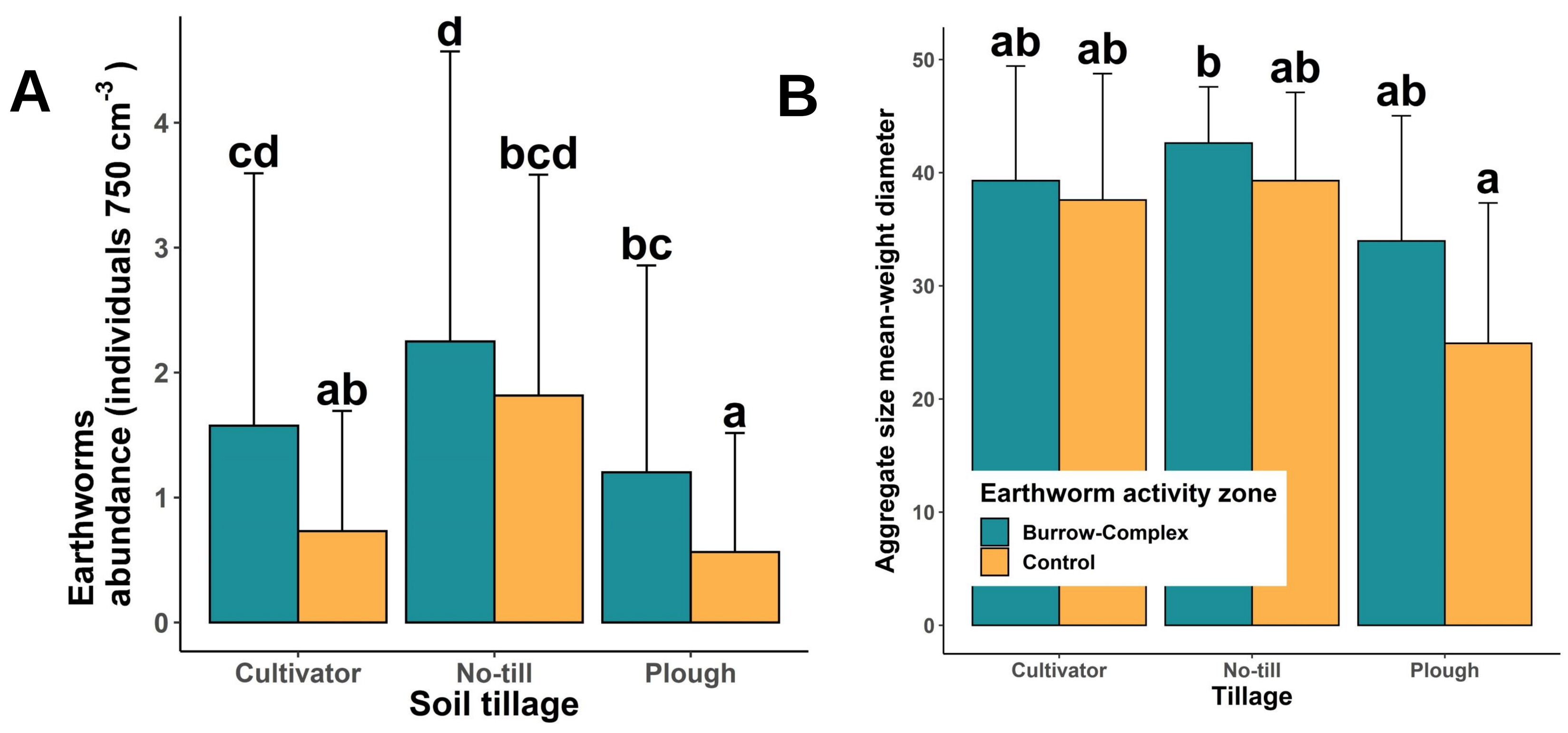

Figure 3 A) Earthworms abundance and B) mean-weight diameter of soil aggregate size in the burrow-complex of *L. terrestris* and in control without influence of *L. terrestris* under three soil tillage systems and two earthworm activity zones in Raasdorf November 2020. Variables without similar letters are significantly different (2-way LMM; Tukey; $P < 0.05$).

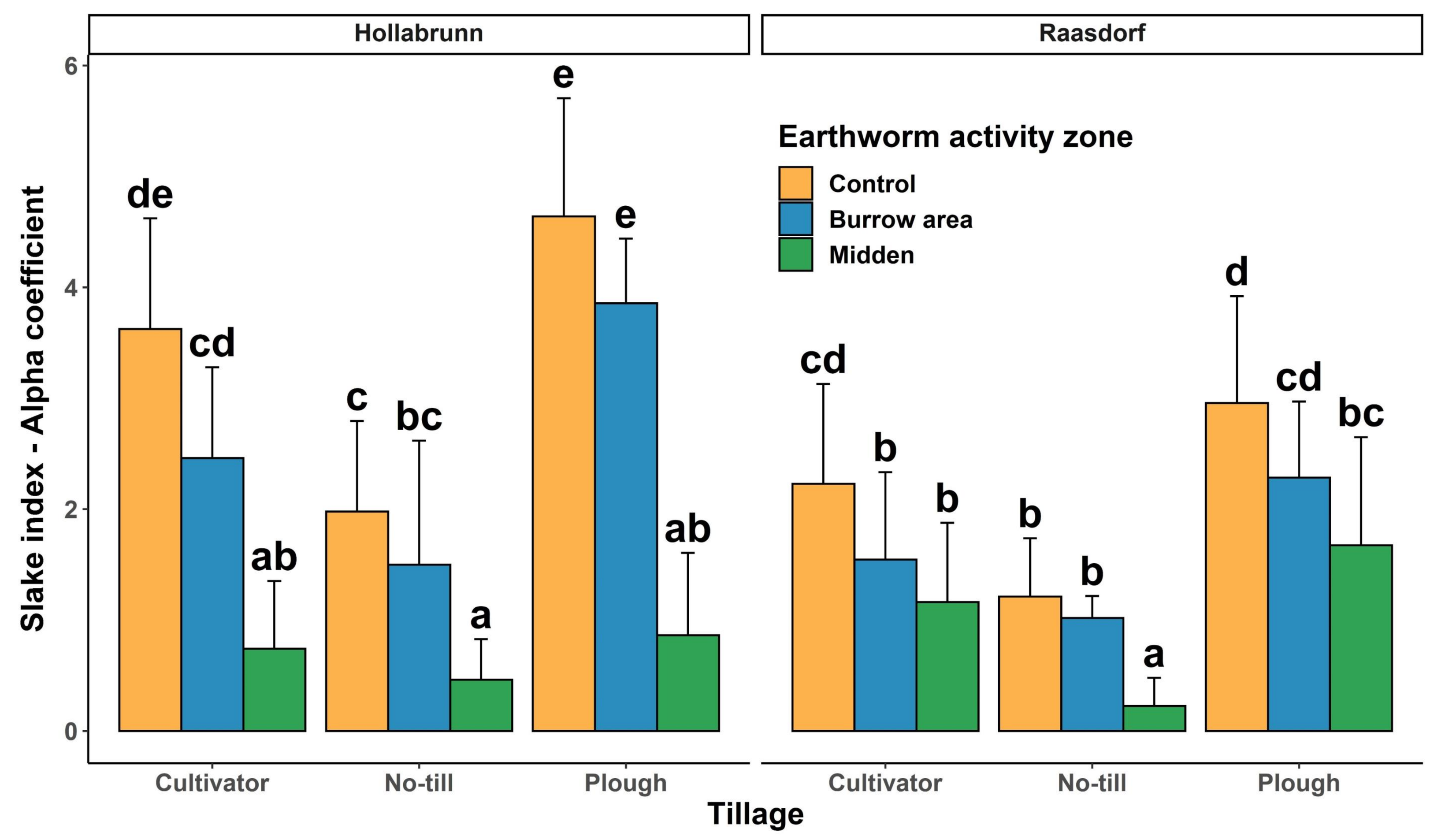

Figure 4 Slaking index (alpha coefficient) under three soil tillage systems, three earthworm activity zones at two sites. Variables without similar letters are significantly different (3-way LMM; Tukey; $P < 0.05$).

Conclusion

L. terrestris has major impacts on earthworm abundance and on soil aggregate stability, but not on soil aggregate size. In addition, SLAKES is a simple method and first results show that it has the potential to identify earthworm-processed soil. The smartphone application can be used by farmers to monitor management decisions, adapt to climate change and to value earthworm ecosystem services.

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