Short Term Scientific Mission (STSM)

Earthworm casts as a sediment-source on vegetated hillslopes: implications for connectivity

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Introduction

Earthworms are common in the majority of terrestrial ecosystems, where they frequently constitute a large proportion of the total soil faunal biomass. Deep burrowing, or anecic species are commonly found in most temperate countries and are principally responsible for the vertical movement of soil as they burrow and feed on a mixture of dead and decaying organic matter (OM) and fine-sediment. For this reason, earthworms are generally viewed as beneficial to soil development, as this incorporates OM into the A-horizon, which facilitates its decomposition, increases the soil organic carbon (SOC) content and generally promotes good soil structure. However, a direct effect of both burrowing and feeding is the production of casts which are egested on the soil surface (Fig. 1A).

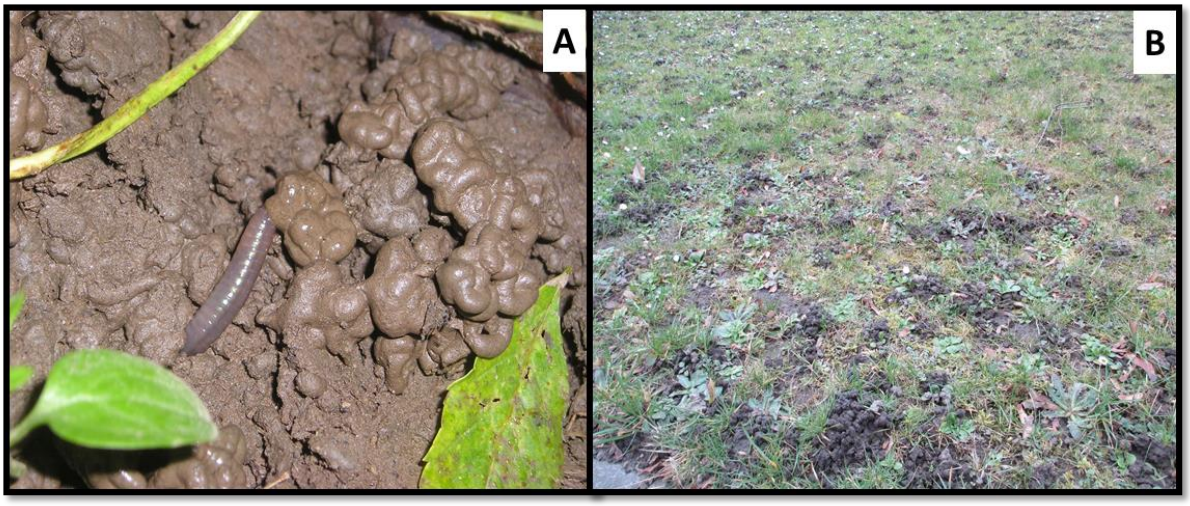

Fig. 1A. After feeding on a mixture of organic matter and fine sediment, earthworms egest casts on the soil surface. **Fig. 1B**. After ingestion of OM and fine-sediment, casts are egested across the soil surface. This makes them vulnerable to disintegration by impacting raindrops, whereupon the loose sediment can be mobilised by surface runoff.

Casts are fragile, especially when fresh, and their exposure on the soil surface (Fig. 1B) renders them susceptible to disintegration and dispersal by erosive processes, such as impacting raindrops and surface runoff. As cast production is both a natural and ongoing process, from the perspective of fully vegetated surfaces, it could represent an important sediment detachment mechanism, as traditionally, erosion has always been presumed to be low due to limited sediment supply. Moreover, as casts are often enriched in fine-sediment and associated nutrients, the mobilisation and off-site removal of this material could account for a large proportion of agricultural runoff. The implications of this on water quality could be severe, particularly if contributing areas are located immediately upslope or adjacent to ditches and streams. Despite this likelihood, however, the contribution of earthworm casts to agricultural runoff has not been fully established owing to difficulties in accurately measuring the movement and fate of such material at the relevant spatial and temporal scales.

Purpose of the STSM

Results from previous work looking at the role of earthworm casts have provided tantalising glimpses of the importance of this relatively understudied transfer mechanism. However, certain results also highlighted a possible uncertainty with the tracing technique in its original form, which threw the reliability of all results into question. The purpose of this collaborative STSM between Basel and Exeter Universities, therefore, is to reduce these uncertainties, and so confirm the reliability of existing, and future data arising from subsequent tracing experiments. The motivation behind this research aligns very well with the aim of WG2; namely, to increase knowledge of water and sediment transport connectivity mechanisms across a range of relevant spatial and temporal scales.

Description of the Work

This STSM specifically focused on refining an existing technique for labelling earthworm casts with [low-level] radioactive material. Labelling was undertaken by submerging small groups of intact, air-dried casts into a known activity of either caesium-137 (^{137}Cs) or cobalt-60 (^{60}Co) mixed with a known volume of water. This relatively simple approach exploits a characteristic of ^{137}Cs and ^{60}Co, inasmuch as both radionuclides rapidly and strongly sorb to fine particles; thereby effectively 'labelling' casts with a substance that can be used to trace the movement of the dispersed sediment. During previous work, an assumption was made that the activity concentration per gram of sediment (i.e. Bq g^{-1}) in any give group of casts would not exceed the activity concentration of the radionuclide solution (i.e. Bq ml^{-1}).

Once labelled, deployed and eroded, sediment recovery rates can thereafter be estimated by calculating the difference between the measured activity of the recovered sediment (Bq g^{-1}) against the initial activity of the group of casts (in Bq g^{-1}). In order to obtain accurate information on labelled sediment recovery, however, the initial group inventory, and in particular, the initial activity concentration per gram of sediment, must be known. The original assumption initially proved satisfactory, inasmuch as the activity of the recovered sediment never exceeded the original concentration of the radionuclide solution. However, results from one trial experiment using caesium did exceed the original activity concentration; indicating that the initial group inventory was higher than previously assumed. This not only rendered the original assumption unsafe, but it also raised questions about the reliability of previous data. Before this research can proceed, therefore, it is vital that more information about the sorption characteristics of earthworm casts is obtained, so that initial inventories can be determined more accurately.

Methods & Preliminary Results

Information on the sorption characteristics of intact sediment-based structures, such as earthworm casts, is limited. Consequently, a series of comparable experiments was devised and performed in an attempt to quantify the process. Three aliquots were prepared with each aliquot consisting of 500 ml of deionised water, plus the addition of sufficient ^{137}Cs material to give initial activity concentrations of 0.25, 0.5 and 1.0 Bq ml^{-1}. A similar approach was undertaken for ^{60}Co, giving a further three aliquots at the same activity concentrations as above. Cast preparation involved air-drying and sorting individual casts into groups, with each group consisting of 5 similarly-sized structures collectively representing ca. 40 g of sediment (av. 39.88 g) (Fig 2A). Three groups of casts were allocated to each aliquot and each group was immersed separately into the radionuclide / water solution for 280 s to ensure complete infiltration. Before casts were immersed, however, the initial activity of 100 ml of each aliquot was sub-sampled and subjected to radiometric analysis using a High Purity Germanium (HPGe) gamma spectrometer. After mixing each sub-sample back into its respective aliquot, the first group of casts was evenly distributed across a small mesh tray and fully submerged into its respective solution for the above time-period (Fig. 2B).

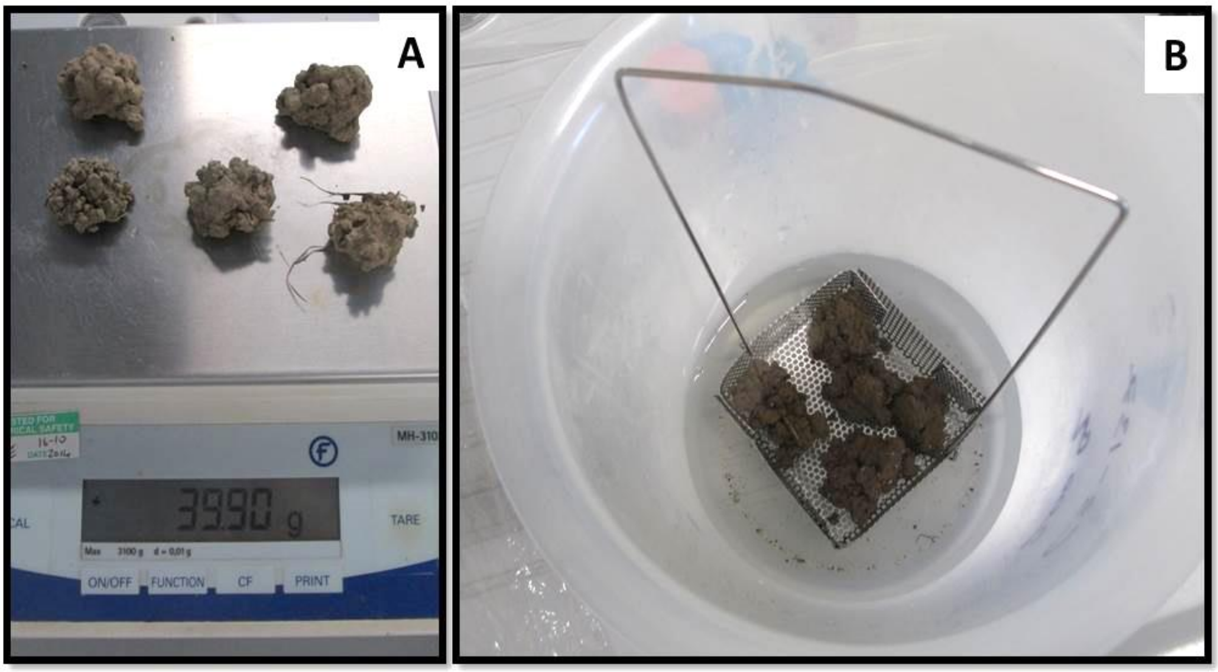

Fig. 2A. Similarly-sized casts were sorted into small groups and weighed. **Fig. 2B**. Each group of casts was labelled by immersion into the radionuclide / water solution for 280 s.

After allowing casts to drip-drain for ca. 10 s, 100 ml of the remaining solution was sub-sampled and again subjected to gamma analysis. This step-wise procedure of sub-sampling and analysis of the solution, followed by cast immersion, followed again by sub-sampling and analysis of the remaining solution was repeated until the three groups of casts had each been systematically immersed and the activity remaining in solution was measured each time. In this manner, the reduction in activity concentration of each solution after the immersion of casts could be systematically tracked, and the 'missing' inventory firmly attributed to a particular group of earthworm casts. The reduction in activity after immersion was used to calculate the amount of inventory that was sorbed to that particular group of casts (expressed in Bq per group mass). The sorbed inventory (Bq) was then divided by the total group mass (g) to derive an equivalent activity concentration per gram of sediment (Bq g^{-1}). This value was then divided by the activity concentration of the initial solution to determine whether the amount sorbed was proportionally higher (enriched), lower (depleted), or similar to the original concentration. For the nine groups of casts sorbed with ^{60}Co at activity concentrations ranging from 0.25-1.0 Bq ml^{-1}, they collectively recorded an average enrichment ratio which was 1.1 times greater than the initial activity concentration of the radionuclide solutions. This finding supports the original assumption that ^{60}Co-activity per gram of sediment will sorb to a group of casts at an activity that is generally proportional to the original concentration. For the nine groups of casts sorbed with ^{137}Cs, however, the average concentration per gram of sediment was almost double the available initial activity concentration. It is possible, therefore, that the erroneous Cs data from one trial erosion experiment may have been higher than predicted, simply because the initial cast inventory was higher than expected.

Contribution to the Action ES1306 Aims

Earthworms frequently account for a large proportion of the soil biota on agricultural land and particularly on permanent grassland. Given the large spatial scales over which earthworms are distributed, the ongoing process of casts production leading to sediment detachment is likely to be occurring over very large areas and possibly even 'fuelling' a relatively undocumented field- to catchment-scale sediment transfer mechanism. I am confident that this work will pave the way for future collaborations with the Geography Department at Exeter University and hopefully generate a number of publications.

Confirmation by the host institution of the successful execution of the STSM;

Notification confirming the successful execution of the STSM is attached in a separate file.

Authorization to post the report on the Action website

I give my authorisation to post this report on the COST Action ES1306 website

Dr. Phil Greenwood,
Basel, Switzerland.