НОВЫЕ МЕТОДЫ И РЕЗУЛЬТАТЫ ИССЛЕДОВАНИЙ ЛАНДШАФТОВ В ЕВРОПЕ, ЦЕНТРАЛЬНОЙ АЗИИ И СИБИРИ

Монография в 5 томах

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This monograph shall inform you about up to date methodologies and recent results in landscape research. It is intended as a guide for researchers, teachers, students, decision makers, stakeholders interested in the topic of landscape science and related disciplines. It provides information basis for decision makers at various levels, from local up to international decision bodies, representing the top level of landscape science in a very short form.

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Chapter I/35: UNDERSTANDING THE INTERACTIONS OF NEMATODES WITH SOIL DURING LANDSCAPE REDISTRIBUTION PROCESSES

Глава I/35: Понимание взаимодействия нематод с почвой в процессе перераспределения ландшафтов

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ABSTRACT. For the first time, water-borne mechanisms of physical redistribution of nematodes were tested under laboratory conditions using soil columns and a novel hydraulic test. Nematode mobilization from saturated soils generating runoff with minimal sediment entrainment (clear runoff) was different from events generating turbid runoff as a consequence of soil disaggregation, dispersal, entrainment and transport (sediment associated). A storm event simulating only clear runoff transported 7.5% of the soil nematode population, which was augmented to include sediment associated processes causing an additional 3.5% export. These two mechanisms were further tested under continuous export for two hours resulting in ~33% nematode redistribution, owing to the combination of water and disaggregation preventing the capability of individuals to use body shape to resist transport. This study encourages a quantification of population density thresholds for survival following redistribution to fully assess the vulnerability and resilience of soil biota and the wider ecosystem to erosive events.

Резюме. Для понимания взаимодействия нематод с почвой в процессе ландшафтного перераспределения впервые в лабораторных условиях с помощью почвенных колонок и нового гидравлического испытания были арбитрированы водные механизмы физического перераспределения нематод. Мобилизация нематод из насыщенных почв, образующих сток с минимальным уносом отложений (чистый сток), отличалась от событий, порождающих мутный сток в результате дезагрегирования, рассеивания, уноса и переноса почв (связанный с осадками). Штормовое событие, имитирующее только чистый сток, транспортировало 7,5% популяции почвенных нематод, которое было дополнено связанными с осадками процессами, приведшими к дополнительному экспорту величиной 3,5%. Эти два механизма были далее испытаны в условиях непрерывного экспорта в течение двух часов, что привело к перераспределению ~ 33% нематод, благодаря сочетанию воды и дезагрегации. Сочетание стока воды и дезагрегации уменьшило способность нематод использовать форму тела в качестве способа противодействия транспорту и перераспределению. Это исследование позволяет определить пороговые значения плотности населения для выживания после перераспределения ландшафтов с целью полной оценки уязвимости и устойчивости почвенной биоты и более широкой экосистемы к эрозионным явлениям.

KEYWORDS: climate change, erosion, landscape processes, soil biota, soil fauna

ключевые слова: изменение климата, эрозия, ландшафтные процессы, почвенная фауна, почвенная биота

INTRODUCTION

The significance for soil biota and the services they provide of accelerated soil erosion in agro-ecosystems is poorly understood [1]. Soil functioning may be changed both on and off site by redistribution of soil biota [2]. Recently, numerous publications [3-7] have outlined key ecosystem services provided by soil biota and highlighted soil processes critical for continued system function. Nematodes are diverse multicellular organisms serving important roles for ecosystem functioning including decomposition, nutrient cycling and parasitism [8-9]. Nematode sensitivity to environmental change provide insights into ecosystem quality and extent of soil disturbance [10-11]. In terrestrial systems, 95% of nematode assemblages inhabit the top 10-15 cm of soil [12]. They reside in or between...
soil aggregates according to their body size, feeding habits and access to resources but they also, possess the ability to move e.g. towards their food source [10]. Thus, the distribution of nematodes is inherently associated with the number and arrangement of pore spaces which is the soil structure, and degree of aggregation. Two texture related factors may influence nematode mobility from soil: (i) soil erodibility, and (ii) nematode population available for export. MacMillan et al. (2009) observed greater dispersal from clay soils compared to sandy soils due to the presence of stable aggregates and larger macropores within the clay matrix creating more, less tortuous dispersal routes [13]. Runoff water has been suggested as the main mechanism of nematode transport [14-16]. However, the relationship between mobility and soil-water flow is not fully understood [17] with previous literature focusing upon tropical regions and primarily plant parasitic nematodes (PPN) [13-15, 18]. PPN juveniles can escape adverse conditions, such as fast water flow, by actively moving into aggregates or towards narrow pores inhibiting their transport [17]. Redistribution of a subset of species may cause multi-trophic implications, in turn leading to erosion induced restructuring and modifications of soil habitats and their quality.

Aim: To address recognised knowledge gaps [1], we conducted two laboratory experiments to ascertain the mechanisms leading to the biotic redistribution of soil nematodes associated with runoff and soil erosion events in agro-ecosystems. This study aimed to establish whether the infiltration of rainwater is the onset of nematode mobility or dispersal in conjunction with the disaggregation of soil particles, dispersal, entrainment and transport downslope under intense runoff erosion.

MATERIALS AND METHODS
Fifty-eight soil cores (i.d.= 5.1 cm, length 15 cm) were taken within a 9 m² plot in the margin of a sandy loam field (lat 56.4788, long -3.1131), typical of agro-ecosystems in east central Scotland. A simple column test was used with two pressure treatments creating different hydraulic heads and flow rates. The subsequent runoff was either clear with minimal entrainment (low head) or turbid as a consequence of soil disaggregation (high head) (Figure 1).

Experiment 1: Eight soil cores per pressure treatment were wrapped with a fine mesh to prevent loss of soil and biota during 24 h saturation. A rubber stopper with a 6 mm diameter hole was fitted to the base of each core allowing upward flow of water. Mesh between the soil and rubber stopper prevented soil
entering the tubing. The core was secured vertically on a retort stand (Figure 1). A water tank connected to mains supply ensured the applied head remained constant. Water freely flowed from the tank down through the tubing providing an upward flux through the soil. The low head for clear runoff was 0.32 m and the high head for turbid runoff was 0.78 m. After one litre of runoff (m$^3$) was collected, flow time was recorded (s) and the flow rate (F) and saturated hydraulic conductivity (Ks) for each replicate calculated using Equation 1, where dx is the length of soil in the core (m).

$$ F = \frac{\text{Volume of Runoff}}{\text{Area of Core} \times \text{Flow Time}} = -K_s \frac{dy}{dx} \quad (1) $$

The collected runoff was weighed, sealed with anti-bacterial cling-film and stored at 4°C for three days to allow particles to settle. For turbid samples, the clear supernatant was decanted and a subsample of sediment weighed and oven dried at 105°C for 24 hours to determine sediment yield. The particle size of this sediment subsample was analysed using a Beckman Coulter LS 13 320 Laser Diffraction Particle Size Analyser (LDPSA, High Wycombe, UK). A correction for the loss in sediment removed for particle size analysis and sediment yield was added to nematode abundances. Live nematodes were extracted from the runoff using a modified Baermann funnel extraction [19]. A further either soil cores were utilised to calculate a baseline nematode abundance for this soil.

**Experiment 2:** Soil columns were subjected to sustained flow and both pressure treatments; clear followed by turbid. Each core was sampled at five one-litre intervals, with five replicates per treatment. Nematode extraction was undertaken immediately following each litre of runoff in the clear treatment until all 25 litres were collected. The pressure gradient was then altered to that required for turbid runoff and another 25 litres collected, weighed and stored before sediment yield analysis with nematode extraction conducted as before. Nematodes remaining in the soil column and overlying water were also extracted, allowing for an accurate estimate of the initial core abundance prior to experimentation.

**Data Analysis:** Experiment 1 was analysed by a Wilcoxon Rank Sum Test to assess differences in nematode counts between pressure treatments. For Experiment 2, a Generalised Linear Mixed Effects Model (GLMM) with quasi-Poisson errors tested the interactions between nematode counts, sediment yield and pressure treatments.

**Figure 2** – Mean nematode export with standard error bars for clear and turbid treatment in Experiment 1 [left]. Mean sediment yield and mean cumulative nematode export with standard error bars over 10 litres of runoff [right]. Arrow indicates change in treatment from clear to turbid. Note high error in first litre of runoff due to one core having an irregularly high abundance of nematodes residing near the surface.

All statistical analyses were conducted using R [20].
RESULTS AND DISCUSSION

Experiment 1: Due to disaggregation within the soil column, a threefold increase in nematode export occurred in the turbid treatment ($p=0.009$, Figure 2). However, water alone as a mechanism transported up to 7.5% of the community resident in the soil core during a 25-minute event with a flow rate of $4.61 \times 10^{-4}$ ms$^{-1}$ with minimal sediment displacement. We suggest that the success of the turbid treatment was due not only to the movement of soil particles but a combination with water to redistribute up to 10.8% of the population during a 1-minute event with a flow rate of $1.62 \times 10^{-3}$ ms$^{-1}$.

Experiment 2: As the clear treatment was conducted prior to the turbid treatment, nematode transport during the first five litres will decrease the population available for later transport. A GLMM quasi-Poisson model found that nematode transport in the turbid treatment (mean flow rate of $9.9 \times 10^{-3}$ ms$^{-1}$) was greater ($p \leq 0.001$) than in the clear treatment (mean flow rate of $5.9 \times 10^{-4}$ ms$^{-1}$). Sediment yield was found to be an effective predictor of increasing nematode export ($p=0.002$) further suggesting that the action of both water and disaggregation encourages biota redistribution. However, as before, the mechanism of the water alone should not be disregarded as up to 46.5% of the nematode community was transported in the clear treatment. A mean of 72% of nematodes remained in soil cores following both treatments, owing to their capability of adhering to soil particles preventing dispersal. Similarly, Fujimoto et al. (2009) observed around 90% of their sample remained, and concluded this was due to the ability of individuals to alter their shape with pore spaces to avoid dispersal [17] though at a slower flow rate of $2.57 \times 10^{-4}$ ms$^{-1}$ than used in this study. We suggest changes to pore tortuosity may limit water flow through pores where individuals were residing. Further research is required to confirm whether community-specific dispersal strategies affect the capability for redistribution via runoff erosion. Selective redistribution of species may have multi-trophic implications, including above-belowground interactions and genetic diversity within the wider landscape that impact on soil health, function and resilience. Therefore, future work can inform preventative strategies to reduce the ability of runoff erosion, and importantly the management of pathogenic infestations within agricultural landscapes.

CONCLUSIONS

1. There was substantial transport of nematodes from soil associated with water and sediment movement.
2. A distinction was observed between nematode mobilisation associated with saturated soils compared with events that generated turbid runoff as a consequence of soil disaggregation, dispersal, entrainment and transport (sediment associated).
3. A combination of water runoff and disaggregation reduced the capability of nematodes to use body shape as a way of resisting transport and redistribution.
4. Further research is needed to understand differences in transport between species and the impact of nematode transport on landscape processes.

REFERENCES

Chapter I/36: ANALYSING REGIONAL-SCALE PATTERNS OF C3 AND C4 VEGETATION IN THE INNER MONGOLIA STEPPE THROUGH GRAZER WOOL CARBON ISOTOPE COMPOSITION

Глава I/36: Анализ регионально-масштабных характеристик C3 и C4 растений в степи внутренней Монголии через изотопный состав углерода шерсти пасущихся животных

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ABSTRACT. The Eurasian steppe is the world’s largest contiguous terrestrial biome. Its vegetation is mainly composed of herbaceous species applying either C3 or C4 photosynthesis. The spatial pattern of C3/C4 contributions to aboveground biomass and its variation over time can be estimated from the carbon isotope composition of wool samples. This method exploits the fact that grazers’ foraging activity integrates over their grazing grounds and wool isotope composition integrates over the wool growth period, buffering small-scale spatial (km) and temporal (yr) variation. Wool can be collected easily and samples of old material can often be dated for reconstruction of time series. The theoretical background and the details of the methodology are explained and illustrated with studies from Inner Mongolia grasslands. These works reveal pronounced variation of C3/C4 proportions in space and time.