The Simulated Experimental Design and Study of the Synergistic Treatment of Chicken Manure and Traditional Chinese Medicine Residues on Earthworm Growth and Soil Quality

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Abstract. Annelids conspicuously exert influence upon soil physicochemical attributes through their alimentary, burrowing, and excretion endeavors, thereby imparting ramifications upon soil erosion phenomena. Nevertheless, comprehension of the particular repercussions stemming from annelid activities vis-à-vis soil erosion remains circumscribed. The primary objective of this investigation was to scrutinize the synergistic ramifications of gallinaceous fecal matter and remnants of traditional Chinese medicinal substances on annelid proliferation and soil characteristics within a simulated experiment. In order to gauge the impact of annelid activities upon soil hydric distribution, runoff velocity, and soil erosion, a laboratory-simulated precipitation experiment was executed across three incline gradients (5 degrees, 10 degrees, and 15 degrees), featuring a uniform precipitation intensity of 80 mm/h and a 60-minute precipitation duration post-runoff initiation. Findings evinced that annelids significantly heightened soil hydric infiltration and retention. In tanks inhabited by annelids, the increments in soil hydric retention were 93%, 51%, and 70% more elevated than those in control plots at incline gradients of 5 degrees, 10 degrees, and 15 degrees, respectively. Comparatively, earthworm activities led to a 70% reduction in runoff rate at a 5-degree slope, a 13% reduction at 10 degrees, and a 39% reduction at 15 degrees. However, soil erosion rates increased by 42% and 46% at slope gradients of 10 degrees and 15 degrees, respectively. Earthworms, through their feeding and burrowing activities, not only enhanced soil water infiltration but also mitigated surface runoff while contributing to increased soil erosion. This research proffers invaluable perspicacity regarding the influence of subterranean fauna on the vicissitudes of soil erosion processes, furnishing empirical evidence amenable for assimilation into extant soil erosion simulation paradigms or as a substratum for the construction of nascent models.

1 Introduction

Acknowledged as "biotic geomorphologists," oligochaete annelids wield a conspicuous sway over soil constitution, physicochemical attributes, biotic multiplicity, and fecundity by virtue of their alimentary, subterranean, and excretory endeavors. This study aims to comprehensively investigate the synergistic effects of chicken manure and residues from traditional Chinese medicine on earthworm growth and soil quality using the META simulated experiment design [1]. The creation of burrows and casting by earthworms leads to the formation of numerous continuous macropores in the soil profile, resulting in significant alterations to soil aggregation, porosity, and surface microtopography. These changes, in turn, impact soil water infiltration and soil erosion. Notably, the characteristics of earthworm burrows, including diameter, tortuosity, and interconnectivity, play a crucial role in influencing soil water movement. By means of their alimentary, subterranean, and excretory endeavors, lumbricid annelids augment soil hydric permeation, diminish superficial runoff, and alleviate soil attrition [2-3].

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Precipitation and aqueous flux stand as paramount instigators of soil attrition, notably discernible in the interconnection between attrition apex and runoff zenith amid circumstances of elevated and perpetual vigor. Given the surging recurrence of heightened precipitation extremes attributed to climatic metamorphosis, the peril and intensity of soil attrition may heighten. Effective soil erosion mitigation involves reducing runoff velocity, increasing infiltration capacity, and maintaining soil cover and surface roughness.

The primary aqueous saturation level emerges as a pivotal determinant in governing runoff during moderate and feeble-intensity tempests, wielding sway over the runoff attrition resilience of the substrate. As elucidated by *Li et al.*, biotic geomorphologists, specifically lumbricid excretory undertakings, manifestly influence soil attrition, particularly in consolidated substrates. Nevertheless, divergent assertions persist, as posited by Schneider et al., articulating that annelids, by virtue of their subterranean endeavors, amplify vertical hydric conveyance, modify substrate hydric content dispersion, and curtail superficial runoff and substrate attrition.

In spite of myriad investigations delving into the correlation between annelids and substrate attrition, the inquiry into whether annelids foster or debilitate substrate attrition remains nebulous. This research endeavors to rectify this lacuna by quantitatively assessing the repercussions of annelid endeavors on runoff and substrate attrition across diverse incline gradients [4].

In this research, we focused on the prominent local anecic earthworm species, Metaphire guillelmi, due to its remarkable adaptability to arid conditions and widespread presence in China. These earthworms, characterized by their rapid growth until sexual maturity, primarily inhabit semi-permanent, vertical burrows while actively foraging for organic litter on the soil surface. Our experimental setup involved the cultivation of alfalfa on loess soil in tanks, with the subsequent introduction of earthworms into the soil. To assess the impact of earthworm activities, we executed laboratory-simulated precipitation trials at incline declinations of 5 degrees, 10 degrees, and 15 degrees. The paramount objectives of the investigation were twofold: (1) to measure the impact of annelid endeavors on substrate aqueous content profile dispersion, runoff, and substrate attrition velocities amid diverse incline gradients, and (2) to explicate the modalities through which annelids contribute to substrate depletion [5].

2 Methodology and data

2.1 Methods and materials

Employing a lateral-spurt emulative mechanism proficient in dispensing precipitation at intensities spanning from ~30 mm/h to ~150 mm/h, the predominant aim of the experiment was to meticulously duplicate the dimensions, dispersal, and ultimate swiftness of indigenous rain globules, as delineated by Raman et al. The proficiency of this emulative system in reiterating veritable raindrop circumstances has been firmly substantiated.

In this specific study, a constant rainfall intensity of ~80 mm/h, representative of intense storms in sub-humid climate regions of China, was chosen. The duration of rainfall following runoff generation was set at ~60 minutes. This experimental design aimed to explore the synergistic effects of chicken manure and traditional Chinese medicine residues on simulated earthworm growth and soil quality.

The substrate employed in the investigation was procured from Xibo Village (34° N, 108° E; elevation ~500 m) of Yanglin City, a locality subjected to an average yearly downpour of roughly ~637 mm, predominantly transpiring in torrential tempests spanning from July to October. Disrupted substrate, gathered from a profundity of 0-~50 cm in a barren terrain expanse, underwent desiccation through natural aeration and underwent sieving with a ~2 mm mesh to eliminate undesirable vegetation and diminutive rocks.

According to the FAO/UNESCO classification system, it falls under the category of cumulic anthrosol. This soil was selected for its representativeness and relevance to the investigation of the synergistic effects of chicken manure and traditional Chinese medicine residues on simulated earthworm growth and soil quality.

The soil tanks used to simulate rainfall were constructed with sheet steel, measuring 2 meters in length, 0.5 meters in width, and 1.0 meter in depth. To achieve the targeted soil bulk density of 1.35 g/cm^3, mirroring field conditions, a meticulous layered packing method, as detailed by Chen et al. (2021), was employed. Each tank was filled with soil up to a height of 90 cm, resulting in a total soil volume of 0.9 m^3 per tank.

To monitor Soil Water Content (SWC) at depths of ~10-90 cm, a PR2-6 probe from Delta-T Device Ltd, Cambridge, UK, was utilized. Trio conduits, each measuring 100 cm in length and possessing an approximate diameter of ~3 cm, were affixed within every soil reservoir for this specific objective. Subsequent to the introduction of soil, twelve arrays of lucerne were cultivated, with an inter-row interval of roughly ~15 cm, correspondingly oriented with the transverse dimension of the reservoirs. The reservoirs underwent exposure to indigenous precipitation and exterior solar irradiance, while the lucerne underwent manipulation adhering to conventional agricultural methodologies for nearly a twelve-month span before instigating the emulated rainfall undertaking.

Owing to labor-intensive requisites and fiscal confines, an aggregate of six substrate reservoirs were primed for this empirical undertaking. Tertiles of declination (5 degrees, 10 degrees, and 15 degrees) were instituted, culminating in the formulation of an individual reservoir incorporating lumbricid annelids and another devoid of lumbricid annelids for each degree of declination. This experimental setup was specifically devised to investigate the collaborative impact of chicken manure and traditional Chinese medicine residues on simulated earthworm growth and soil quality.

2.2 The data analysis

The rate of substrate attrition, the velocity of aqueous runoff, and the density of particles in the effluent were determined through the utilization of the ensuing triad of mathematical expressions:

$$E_r = \frac{W}{A*T} \tag{1}$$

$$R = \frac{D}{T} = \frac{V}{A*T} * 10^3 \tag{2}$$

$$SC = \frac{W}{V} * 10^{-3} = \frac{E_r}{R} \tag{3}$$

In the paradigm of our inquiry, where E symbolizes the substrate attrition rate (quantified in g/m²/min), R signifies the pace of aqueous runoff (in mm/min), SC denotes sediment concentration within the runoff (in kg/m³), W corresponds to the desiccated sediment output (measured in grams), A embodies the planar projection of soil declivities [equivalent to declivity area * cos(5 degrees, 10 degrees, or 15 degrees), respectively, in m²], T designates the sampling interlude (fixed at 2 min), D signifies runoff profundity (in millimeters), and V stands for the volume of the runoff sample (quantified in m³), we systematically incorporated these parameters into the design of the simulated experiment. This integration aimed to explore the collaborative impacts of chicken manure and traditional Chinese medicine residues on earthworm growth and soil quality.

During the quantification of substrate hydric profiles, every conduit experienced four gaugings during each incidence. The computed mean values of the trio of conduits within each reservoir were subsequently ascertained to epitomize the comprehensive values. Posteriorly, the mean and standard deviation values were employed for scrutinizing the impact of lumbricid annelids on substrate dampness profiles. The substrate hydric retention within the 90 cm substrate profile was computed utilizing the stipulated mathematical expression. This methodology played a crucial role in comprehending the effects of the collaborative treatment, incorporating chicken manure and traditional Chinese medicine residues, on both earthworm growth and soil quality in our simulated experiments.

3 Results and Discussion

Integrating the influence of gallinaceous excrement and ancestral Oriental healing remnants on simulated oligochaete proliferation and terrestrial fertility, we delved into the repercussions of annelid behaviors on superficial outflow.

A superficial outpouring manifested in all half-dozen reservoirs when subjected to a precipitation intensity of 80 mm/h, with no discernible dissimilarity identified in the commencement epoch of effluent between treatments incorporating and excluding lumbricid annelids. For declivities of 5 degrees, 10 degrees, and 15 degrees, the reservoirs subjected to lumbricid annelids demonstrated median effluent velocities of about 0.3, 0.7, and 0.5 mm/min, respectively (perceive Figure 1a–c and Tabular Summary 1). Conversely, the control regimen exhibited velocities of approximately 0.9, 0.8, and 0.8 mm/min, respectively (Figure 1a–c and Table 1). In comparison to the control regimens, the inclusion of lumbricid annelids resulted in a reduction of the median effluent velocity by 70%, 13%, and 39% under declivities of 5 degrees, 10 degrees, and 15 degrees, respectively. The reservoir incorporating lumbricid annelids at a 10-degree declivity registered the acme median effluent velocity, while in the control plots, the utmost median effluent velocity occurred in the reservoir with a 5-degree declivity. Under the declivities of 5 degrees, 10 degrees, and 15 degrees, the botanical covering in the reservoirs subjected to lumbricid annelids was 74%, 63%, and 67%, respectively, whereas the corresponding values for the control regimen were 57%, 68%, and 58% [6].

Table 1. The median effluent velocity, particulate density, and substrate attrition rate were gauged amid declivities of 5 degrees, 10 degrees, and 15 degrees in reservoirs possessing and devoid of lumbricid annelids

		Slope		
		5ºC	10ºC	15ºC
Mean runoff rate	With earthworm	0.28	0.65	0.46
	Without earthworm	0.92	0.75	0.75
Mean sediment concentration	With earthworm	2.5	12.8	8.5
	Without earthworm	2.3	6.4	3.8
Mean soil erosion rate	With earthworm	0.71	5.96	3.83
	Without earthworm	1.42	4.21	2.63

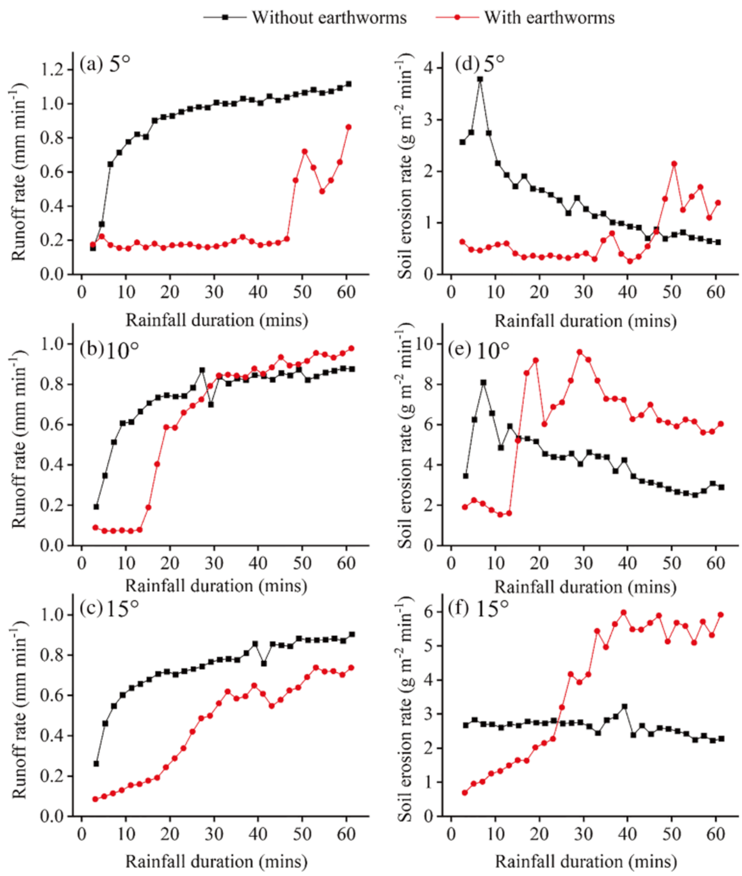

Fig. 1. Oscillations in the pace of aqueous runoff (a–c) and substrate attrition rate (d–f) were discerned during the precipitation episode, typified by an intensity of 80 mm/h, across declivities of 5 degrees (a and d), 10 degrees (b and e), and 15 degrees (c and f).

3.1 Examining the collaborative treatment involving chicken manure and traditional Chinese medicine residues on simulated earthworm growth and soil quality

While the operations of lumbricid annelids contributed to a reduction in the effluent velocity, there was an evident escalation in the median sediment concentrations within the effluent (consult Figure 2). The median sediment concentrations in reservoirs with lumbricid annelids at declivities of 5 degrees, 10 degrees, and 15 degrees were roughly ~3, 13, and 8 kg/m³, correspondingly. These magnitudes were ~9%, 100%, and 124% higher than those in the control plots (~2.3, 6.4, and 3.8 kg/m³, respectively) (Table 1). The median sediment concentrations reached their zenith at a declivity of 10 degrees and attained their nadir at a declivity of 5 degrees, irrespective of the presence of lumbricid annelids (Figure 2). In reservoirs devoid of lumbricid annelids, sediment concentrations dwindled during precipitation and ultimately stabilized. Conversely, in reservoirs with lumbricid annelids, sediment concentrations remained relatively constant during the precipitation progression, with the exception of a brief interlude (20 minutes post-runoff inception) in the reservoir with a 10-degree declivity (Figure 2) [7].

In this exploration, both the presence of lumbricid annelids and the declivity were identified as factors influencing substrate attrition. The median substrate attrition rates in lumbricid annelid-treated plots at declivities of 10 degrees and 15 degrees were approximately 6 and 4 g/m²/min, respectively, signifying an augmentation of about 42% and 46% compared to the values observed in the control plots (~4 and 3 g/m²/min, respectively) (Figure 1e, f and Table 1). However, at a declivity of 5 degrees, the median erosion rate in the lumbricid annelid treatment was only about 0.8 g/m²/min, which was 50% lower than that of the control treatment (about 1.4 g/m²/min) (Figure 2d and Table 1). Despite the initially inferior mean erosion rate in the lumbricid annelid treatment at the 5-degree declivity, it progressively intensified with the precipitation process and surpassed the control plot around the 46th minute. This trend endured at the 10-degree and 15-degree declivities (Figure 1e, f). Significantly, the points of "surpass" (17 and 25 minutes) occurred appreciably earlier than that for the 5-degree declivity. The median erosion rate reached its zenith at the declivity of 10 degrees and was minimized at the declivity of 5 degrees, regardless of the presence of lumbricid annelids.

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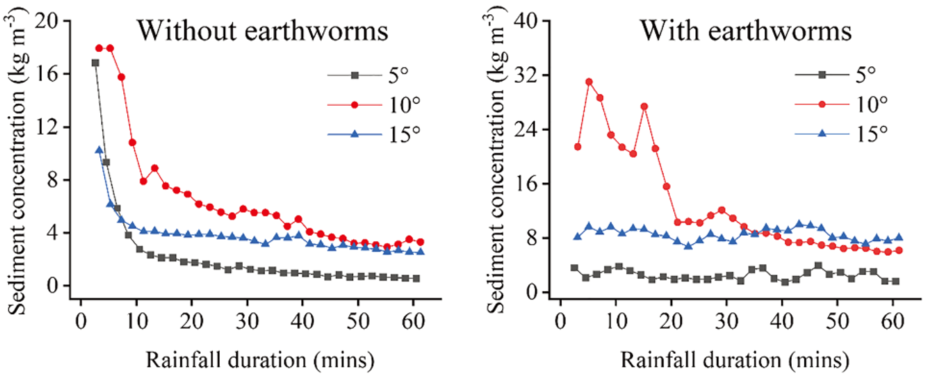

Fig. 2. Alterations in sediment denseness were scrutinized amid precipitation of 80 millimeters per hour, utilizing bi-minute gaps, traversing inclinations of 5, 10, and 15 degrees in reservoirs, inclusive of and exclusive of lumbricids

3.2 Synthesizing the investigation into the concomitant impacts of poultry excreta and ancient Oriental medicinal remnants on simulated oligochaete proliferation and terrestrial health

The evaluation of substrate hydric content (SHC) and substrate hydric retention (SHR) within the profundity scope of 0-~90 cm endeavored to scrutinize the repercussions of the cooperative intervention encompassing gallinaceous excrement and customary Chinese therapeutic remnants on emulated annelid proliferation and substrate caliber (consult Figure 3 and Table 2). Subsequent to the emulated precipitation, there transpired a conspicuous ($P < 0.05$) surge in SHC in contrast to pre-precipitation magnitudes, particularly within the 0–20 cm substrate stratum. Across the 24-hour interval post-precipitation emulation, substrate hydric content persisted in permeating into the more profound substrate strata (Figure 3). The combined influences of substrate hydric permeation, surface substrate desiccation, and lucerne aqueous assimilation resulted in a decrement in SHC within the 0-~30 cm substrate profile in the existence of lumbricid annelids, whereas the reduction was confined to the 0-~20 cm profundity in reservoirs devoid of lumbricid annelids (Figure 3).

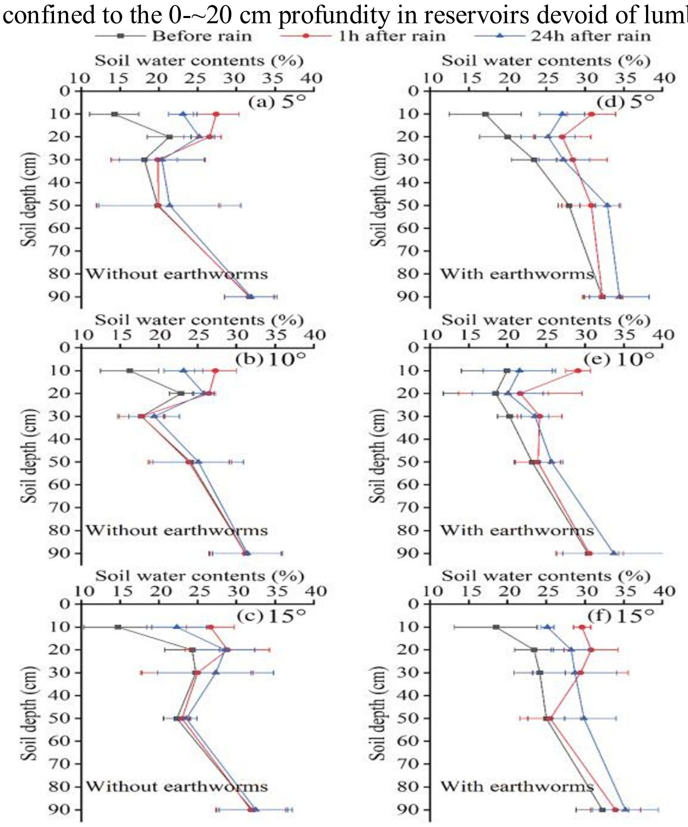

Fig. 3. Profiles of terrestrial hydrous content were scrutinized beneath declivitous inclinations of 5 degrees, 10 degrees, and 15 degrees at profundities of 10, 20, 30, 50, and 90 centimeters in reservoirs, encompassing conditions void (a–c) and inhabited by lumbricids (d–f)

In the reservoirs subjected to lumbricid annelids, substrate water infiltrated into the more profound substrate strata, and the elevation in substrate hydric content at depths of ~50-~90 cm was markedly ($P < 0.05$) superior to that in the control plots (Figure 3). Consequently, lumbricid annelids significantly potentiated substrate hydric permeation compared to the control plots. The increments in SHR for reservoirs with lumbricid annelids at declivities of 5 degrees, 10 degrees, and 15 degrees were 41.2, 24.0, and 34.9 mm, correspondingly. These magnitudes were 93%, 51%, and 70% higher than those documented in the control regimens (21.3, 15.9, and 20.5 mm). The utmost increment in SHR occurred at the 5-degree gradient, while the minimum was observed at the 10-degree gradient, regardless of the presence of lumbricid annelids.

4 Conclusion

In the context of our simulated experiment design investigating the collaborative treatment involving chicken manure and traditional Chinese medicine residues on earthworm growth and soil quality, earthworms, through their feeding, burrowing, and casting activities, played a pivotal role. They facilitated soil water infiltration, mitigated surface runoff, yet contributed to an increased sediment content in runoff, consequently elevating soil erosion. The interplay of earthworms and slope gradient significantly influenced soil erosion dynamics. Introducing earthworms resulted in a reduction in soil erosion rates at a slope gradient of 5 degrees but led to an increase in erosion rates at gradients of 10 and 15 degrees.

The subterranean excavation pursuits of lumbricid annelids, engendering substantial apertures from the substrate facade to the profound substrate stratum, not solely expedited substrate hydric permeation but also magnified substrate hydric retention (SHR), thus diminishing superficial effluent. Lumbricid annelids, via the disintegration of substrate and detritus, engendered copious clods on the substrate facade. These clods heightened substrate facade unevenness and transmuted microtopography. As precipitation commenced, desiccated clods functioned as moisture-absorbing substances, transforming into saturated clods that served as potential origins of substrate attrition. Throughout our investigation, all clods were disrupted, contributing to the reservoir of particulate matter during precipitation. This process complicated the dynamics of superficial effluent and attrition.

The revelations underscore the magnitude of recognizing the part played by lumbricid annelids in substrate attrition, especially under intense precipitation conditions. The exploration posits a necessity for heightened scrutiny of the repercussions of lumbricid annelids and other subterranean-dwelling fauna on attrition processes.

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