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Diversity of Soil Surface Invertebrates in Cultivated and Uncultivated Fields in Coastal Savanna Zone of Ghana

A.N.M. Pappoe, F.A. Armah and H.K. Akotoye
Department of Environmental Science, School of Biological Sciences,
University of Cape Coast, Ghana

Abstract: Understanding how communities of important soil invertebrates vary with land use may lead to the development of more sustainable land-use strategies. Diversity of soil surface invertebrates in the University of Cape Coast Teaching and Research Farm (UCCTRF) and the University of Cape Coast Nature Reserve (UCCNR) was investigated over a 21-days period. The two locations span a gradient in agricultural land-use intensity. Ten pitfall traps were sunk into the soil in either community and inspected at 3-day intervals. Three hundred and fifty-four soil invertebrates were identified into 3 phyla, 6 classes, 9 orders and 14 species in the UCCTRF. Five hundred and eighty-six soil invertebrates were identified into 3 phyla, 8 classes, 11 orders and 21 species in the UCCNR. Termite (*Kalotermis* sp.) was most abundant in both communities, 112 and 343 individuals were encountered in UCCTRF and UCCNR respectively. The UCCTRF was more diverse than UCCNR with respective Simpson's and Shannon-Wiener indices of 4.909 and 1.8429 and 2.6390 and 1.4808. The cultivated soil had fewer numbers of soil invertebrates than the uncultivated natural soil.

Key words: University of Cape Coast Teaching and Research Farm, University of Cape Coast Nature Reserve, pitfall traps, Simpson's index, Shannon-Wiener index

INTRODUCTION

Invertebrates comprise approximately 95% of the kingdom Animalia (*Posthethwait et al.*, 1991). They may be found in almost all habitats, ranging from aquatic, arboreal to terrestrial. Soil organisms are influenced by many factors including climate, vegetation and the physical and chemical characteristics of the soil. According to Brady and Weil (1999) cultivated fields are generally lower than undisturbed native lands in numbers and biomass of soil organisms, especially the fauna. Habitat diversity also plays a role in the landscape on species richness and on the stability of soil faunal communities (Devictor and Jiguet, 2007). Varied roles such as mixing, loosening and aerating are performed by many organisms associated with soils, including worms, insects and mites (Engelmann, 1961; Ober and Hayes, 2008; Sileshi and Mafongoya, 2006). Other invertebrates, namely, centipedes, millipedes and molluscs influence the integrity of their habitat. Soil invertebrates play important role in soil formation. According to Wallwork (1982) millipedes feed on plant detritus and assist in decomposition of organic matter whilst centipedes are primarily decomposers whose decomposed bodies add organic matter to the soil. Termites and ants contribute to soil ecology by constructing

Corresponding Author: Alexander Nii Moi Pappoe, Department of Environmental Science, School of Biological Sciences, University of Cape Coast, Ghana

numerous galleries in the soil, transporting large amounts of organic material from surface to underground chambers thereby significantly facilitating nutrient cycling (Schaefer and Whitford, 1981). Therefore, soil surface invertebrates are considered as indicators of soil quality (Blair *et al.*, 1996). According to Mafongoya *et al.* (2006) soil poor in carbon are indigent in biological activity and in the fertility that this activity imparts. Soil nitrogen turnover-the nitrogen-supplying power of the soil-is lower whenever microbial populations are diminished and there are consequently fewer invertebrates such as earthworms, ground-dwelling beetles and non-parasitic nematodes. Among the soil biota essential in soil processes in cultivated systems, probably the most important ones are the so-called ecosystem engineers, e.g., termites, earthworms and some ants and the litter transformers including millipedes, some beetles and many other soil-dwelling invertebrates (Sileshi and Mafongoya, 2005). The negative effects of landscape homogenization and agriculture intensification on biodiversity are recognized and have been studied at many spatial scales on plants, invertebrates and vertebrates (Benton *et al.*, 2003; Stoate *et al.*, 2001).

One major challenge that faces invertebrates in cultivated fields is habitat modification by imposition of different management practices, including pesticide and fertilizer applications which affect their ecological roles (Sileshi and Mafongoya, 2005). Soil communities are so diverse in both size and numbers of species, yet little work has been done on them. Moreover, there is a large imbalance in the knowledge of tropical and temperate species (Brussard *et al.*, 1997). The research sought to identify, classify and investigate the diversity of soil surface invertebrates in the Teaching and Research Farm and Nature Reserve of the University of Cape Coast.

MATERIALS AND METHODS

The study was carried out in the University of Cape Coast Teaching and Research Farm (UCCTRF) and University of Cape Coast Nature Reserve (UCCNR) located at the Northern Campus. The entire study was carried out from August 2007 to May 2008. UCCTRF covers an area of 20 hectares and has been cultivated with vegetables. UCCNR is a thicket with a few isolated scattered trees. It covers an approximate area of 17.6 hectares. Both sites, located within $5°05^1$ N latitude and $1°07^1$ W longitude, form part of the coastal savannah zone of Ghana. Cape Coast is characterized by humid conditions. The relative humidity could range between 95 and 100% during the night. The annual mean temperature ranges between 25°C and 29°C. There are two seasonal rainfall patterns. The major season begins from April to June whilst the minor season begins from September to November. The annual rainfall ranges from 750 to 1000 mm (Agyarko *et al.*, 2006).

A 100×100 m plot was demarcated in each site and divided into hundred 10×10 m subplots. The pitfall method was used to trap soil surface invertebrates (Sutherland, 1996) in each of 10 randomly selected subplots. A glass jar, approximately 7 cm wide, filled with 250 mL of 70% ethanol was sunk into ground on each subplot. Two pieces of rock was placed at opposite sides of the jar to serve as a platform on which a cardboard was placed to prevent rain water from entering the trap. The traps were inspected at 3 day intervals for 21 days. The alcohol was topped up occasionally. Invertebrates which fixed in the alcohol were taken to the Zoology Museum of the University for Identification and classification.

Simpson's index ($D = 1/\Sigma p^2_i$, by Ricklefs (1996)) and Shannon-Wiener index ($H = -\Sigma p_i \log_e p_i$, In Ricklefs (1996)) were used to estimate the diversity of soil surface invertebrates in the two communities. The similarity of the sites was compared using the

Sorenson's similarity index ((2C/A+B)×100, In Molles (1999)). The means of the number of invertebrates were compared using the unpaired design of the Student's t-Test. General information on student's t-test is given in Appendix 1. Information on Shannon-Weiner and Simpsons' indices are given in appendix 2. Appendix 3 displays information on Sorenson's similarity index.

The Student's t-test is a statistical method that is used to ascertain if two sets of data differ significantly (Millard and Neerchal, 2001). The method assumes that the results follow the normal distribution (also called student's t-distribution) if the null hypothesis is true (MacBerthoues and Brown, 2002). This null hypothesis will usually stipulate that there is no significant difference between the means of the two data sets. The unpaired, or independent samples t-test is used when two separate independent and identically distributed samples are obtained, one from each of the two populations being compared (MacBerthoues and Brown, 2002). For the test to be applicable, the sample groups must be completely independent and it is best used when the sample size is too small to use more advanced methods. Before using this type of test, the sample data from the two samples were plotted to make sure that it had a reasonably normal distribution, or the student's t test will not be suitable. In the unpaired design of the student's t test, the statistical units underlying the two samples being compared are non-overlapping (Millard and Neerchal, 2001).

This test is only used when both:

- The two sample sizes (that is, the number, n, of participants of each group) are equal
- It can be assumed that the two distributions have the same variance

The t-statistic to test whether the means are different can be calculated as follows:

$$t = \frac{\overline{X}_1 - \overline{X}_2}{S_{x_1x_2} \cdot \sqrt{\frac{2}{n}}}$$

Where,

$$S_{X_1X_2} = \sqrt{\frac{S_{X1}^2 + S_{X2}^2}{2}}$$

where, $S_{X_1X_2}$ is the grand standard deviation (or pooled standard deviation), 1 = (UCCTRF), 2 = (UCCNR). The denominator of *t* is the standard error of the difference between two means (Millard and Neerchal, 2001). For significance testing, the degrees of freedom for this test are 2n-2 where n is the number of participants in each group.

RESULTS

Three hundred and fifty-four individuals of soil invertebrates were recorded in University of Cape Coast Teaching and Research Farm (UCCTRF). These were distributed among 3 phyla, 6 classes, 9 orders and 14 species (Table 1). Eight species of insects was identified of which termites (*Kalotermis* sp.) numbered 112 representing 32%. *Achatina fulica*, *Cryptops hortensis*, *Glomeris marginata* and *Tenebrio molitor* were represented by 1 individual each representing 0.3%. Five hundred and eighty-six individual soil invertebrates

Table 1: Composition and abundance of soil surface invertebrates in University of Cape Coast Teaching and Research Farm

Phylum	Class	Order	Species	Number
Mollusca	Gastropoda	Stylommatophora	*Achatina fulica*	1
Arthropoda	Insecta	Hemiptera	*Aethus flavicornis*	13
Arthropoda	Insecta	Coleoptera	*Aphodius rufipes*	10
Arthropoda	Chilopoda	Scolopendromopa	*Cryptops hortensis*	1
Arthropoda	Insecta	Hymenoptera	*Formica fusca*	16
Arthropoda	Diplopoda	Opisthandria	*Glomeris marginata*	1
Arthropoda	Insecta	Isoptera	*Kalotermis* sp.	112
Arthropoda	Insecta	Hymenoptera	*Lasius niger*	40
Mollusca	Gastropoda	Stylommatophora	*Lamellaxis gracillis*	3
Annelida	Oligochaeta	-	*Lumbricus terrestris*	4
Arthropoda	Insecta	Orthoptera	*Melanogryllus desertus*	73
Arthropoda	Insecta	Hymenoptera	*Myrmica rubra*	74
Arthropoda	Arachnida	Aranae	*Pissaura* sp.	5
Arthropoda	Insecta	Coleoptera	*Tenebrio molitor*	1
Total				354

Table 2: Composition and abundance of soil surface invertebrates in University of Cape Coast Nature Reserve

Phylum	Class	Order	Species	Number
Mollusca	Gastropoda	Stylommatophora	*Achatina fulica*	1
Arthropoda	Insecta	Coleoptera	*Acheta* sp.	20
Arthropoda	Insecta	Hemiptera	*aethus flavicornis*	1
Arthropoda	Oligochaeta	-	*Allolobophora* sp.	2
Arthropoda	Insecta	Hymenoptera	*Camponatus* sp.	4
Arthropoda	Insecta	Homoptera	*Coramus* sp.	2
Arthropoda	Chilopoda	Scolopendromopa	*Cryptops hortensis*	1
Arthropoda	Insecta	Dictyoptera	*Ectobius* sp.	2
Mollusca	Insecta	Hymenoptera	*Formica fusca*	16
Annelida	Diplopoda	Opisthandria	*Glomeris marginata*	1
Arthropoda	Insecta	Orthoptera	*Kalotermis* sp.	343
Arthropoda	Insecta	Hymenoptera	*Lasius niger*	30
Annelida	Oligochaeta	-	*Lumbricus terrestris*	2
Arthropoda	Arachnida	Araneae	*Lycosa rubra*	2
Arthropoda	Insecta	Orthoptera	*Melanogryllus desertus*	73
Arthropoda	Insecta	Hymenoptera	*Myrmica rubra*	74
Arthropoda	Symphyla	-	*Oniscus* sp.	3
Arthropoda	Thysanura	-	*Petrobius* sp.	1
Arthropoda	Arachnida	Araneae	*Pisaura* sp.	6
Arthropoda	Diplopoda	Opisthandria	*Scolopendra* sp.	1
Arthropoda	Insecta	Coleoptera	*Tenebrio molitor*	1
Total				586

were recorded in the University of Cape Coast Nature Reserve (UCCNR) made up of 3 phyla, 8 classes, 11 orders and 21 species (Table 2). Eighteen arthropod species, 2 annelid species and one mollusc species were identified. Two species were found only in the UCCTRF, namely, *Aphodius rufipes* and *Lamellaxis gracillis.* Nine species were encountered only in UCCNR. These were *Acheta* sp., *Allolobophora* sp., *Camponata* sp., *Coramus* sp., *Ectobius* sp., *Lycosa rubida*, *Oniscus* sp., *Petrobius* sp. and *Scolopendra* sp. The Simpson's diversity index for UCCTRF and UCCNR was 4.909 and 2.6390, respectively. The Shannon-Wiener index was 1.8429 and 1.4808 for UCCTRF and UCCNR, respectively. The Sorenson's similarity index was 68.57%.

DISCUSSION

The method employed in this study did not afford us the opportunity to test hypotheses on the impact of specific cultivation methods on earthworm communities. However, it gives ample evidence of the ecological significance of decomposer assemblages in natural as well as cultivated areas. Soil invertebrates-soil interplay is very important for ecosystem functioning. Whereas the soil serves as a suitable habitat for the invertebrates, these organisms in turn cause bioturbation which modifies the texture and structure of the soil by incorporating organic matter into the soil (Zech, 1993). Earthworms are an important component of the invertebrate community in most soils, both in terms of their contribution to overall below ground biomass and in terms of their effects on soil biogeochemical cycles (Smith *et al*., 2008; Ghafoor *et al*., 2008). Soil structure, gas dynamics, water flow and C and N turnover and stabilization may be altered by the presence and community structure of earthworms (Llausas *et al*., 2009). The University of Cape Coast Nature Reserve (UCCNR) contained more species (21) than UCCTRF (14). Forest systems are frequently accounted to have greater numbers of earthworm species compared to cultivated agricultural land because these systems tend to be more complex and have more niches which allow persistence of a greater number of species with variable ecologies (Smith *et al*., 2008; Llausas *et al*., 2009; Ghafoor *et al*., 2008).

It has been argued that communities which receive little or no disturbance abounds in species compared to those that experience harsh conditions that often result from pesticide and fertilizer applications and changes in texture and structure (Sheals, 1969; Smith *et al*., 2008; Ghafoor *et al*., 2008). Lagerlöf *et al*. (2002) found lower numbers of earthworms in an uncultivated field than in an adjacent intensively cultivated agricultural field, while Scheu (1992) found lower earthworm numbers and biomass in an 11-year old-field compared to a 2 and 50 year old-field. Conversely, it has been found that earthworm populations rebounded following 2 years abandonment from agriculture and densities and biomass were similar in 4 and 10 year fallows (Pizl, 1992).

Arthropoda recorded the highest number of species in both communities. This is consistent with the fact that the phylum is the most successful and largest group of invertebrates (Posthethwait *et al*., 1991).

Formica fusca, *Myrmica rubra* and *Lasius niger* were species of insect found in UCCTRF whilst the same species, in addition to *Camponatus* sp. were identified in UCCNR. *Kalotermis* sp. was most abundant arthropod in both communities. UCCTRF and UCCNR recorded 112 and 343 individuals, respectively. These differences may be attributed to the fact that there were abundant plant materials on the floor of UCCNR than UCCTRF. Three groups of termites have been identified according to feeding habits. These include litter, wood and humus consumers (Zech, 1993). All these can be categorized according to habitat into two, namely, epigeal and hypogeal. Whereas termitaria were observed in UCCNR none was encountered in UCCTRF. This implies that termites in UCCTRF were hypogeal. The low number of termites in UCCTRF might have arisen as a result of management practices including pesticides application. Crickets were the second abundant species. UCCTRF and UCCNR recorded 1 species (*Melanogryllus desertus*) with 71 individuals and 2 species (*Melanogryllus desertus* and *Acheta* sp.) with 73 individuals, respectively. *Achatina fulica*, *Crytops hortensis* and *Glomeris marginata* were the least abundant species represented by 1 individual.

CONCLUSION

The UCCTRF was more diverse than UCCNR. The respective Simpson's and Shannon-Wiener indices were 4.909 and 1.8429 at UCCTRF and 2.6390 and 1.4808 at UCCNR. Sorenson's similarity index portrayed considerable similarity (68.57%) between the two communities. The differences in the number of individuals of the species were not significant (p>0.05). The fact that the communities were within 2 km radius within the coastal savannah zone may account for this observation. The results confirm the fact that cultivated fields are generally lower than undisturbed native lands in numbers of soil organisms.

This study provides baseline data on the diversity of soil surface invertebrates in the University of Cape Coast Nature Reserve (UCCNR) and University of Cape Coast Teaching and Research Farm (UCCTRF) in Ghana and gives ample evidence of the ecological significance of decomposer assemblages in natural as well as cultivated areas. It shows that management practices should aim to enhance decomposer communities in order to safeguard the productivity and sustainable use of the University of Cape Coast Nature Reserve (UCCNR).

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APPENDIX

Appendix 1: Two-Sample t-test for invertebrates in UCCTRF and UCCNR

	N	Mean	SD	SE mean
UCCTRF	23	15.4	30.2	6.3
UCCNR	23	25.5	72.4	15

Difference = mu UCCTRF -mu UCCNR
Estimate for difference: -10.1
95% CI for difference: (-43.0, 22.9)
T-test of difference = 0 (vs not =): t-value = -0.62 p-value = 0.540 df = 44
Both use Pooled SD = 55.4

Appendix 2: Simpson's and Shannon-Wiener indices of UCCTRF and UCCNR

University	pi (UCCTRF)	$\log_e$ (pi)	pi ($\log_e$pi)	pi sq
UCCTRF				
1	0.00282486	-5.8693	-0.0166	8E-06
13	0.03672316	-3.3043	-0.1213	0.00135
10	0.02824859	-3.5667	-0.1008	0.0008
1	0.00282486	-5.8693	-0.0166	8E-06
16	0.04519774	-3.0967	-0.1400	0.00204
1	0.00282486	-5.8693	-0.0166	8E-06
112	0.31638418	-1.1508	-0.3641	0.1001
40	0.11299435	-2.1804	-0.2464	0.01277
3	0.00847458	-4.7707	-0.0404	7.2E-05
4	0.01129944	-4.4830	-0.0507	0.00013
73	0.20621469	-1.5788	-0.3256	0.04252
74	0.20903955	-1.5652	-0.3272	0.0437
5	0.01412429	-4.2599	-0.0602	0.0002
1	0.00282486	-5.8693	-0.0166	8E-06
354			-1.8429	0.20371
				4.90896
UCCNR				
1	0.00170648	-6.3733	-0.0109	2.9121E-06
1	0.00170648	-6.3733	-0.0109	2.9121E-06
1	0.00170648	-6.3733	-0.0109	2.9121E-06
16	0.02730375	-3.6007	-0.0983	0.00074549
1	0.00170648	-6.3733	-0.0109	2.9121E-06
343	0.58532423	-0.5356	-0.3135	0.34260446
30	0.05119454	-2.9721	-0.1522	0.00262088
2	0.00341297	-5.6802	-0.0194	1.1648E-05
70	0.11945392	-2.1248	-0.2538	0.01426924

Appendix 2: Continued

University	pi (UCCTRF)	$\log_e$ (pi)	pi ($\log_e$pi)	pi sq
77	0.13139932	-2.0295	-0.2667	0.01726578
6	0.01023891	-4.5816	-0.0469	0.00010484
1	0.00170648	-6.3733	-0.0109	2.9121E-06
20	0.03412969	-3.3776	-0.1153	0.00116484
2	0.00341297	-5.6802	-0.0194	1.1648E-05
4	0.00682594	-4.987	-0.034	4.6593E-05
2	0.00341297	-5.6802	-0.0194	1.1648E-05
2	0.00341297	-5.6802	-0.0194	1.1648E-05
2	0.00341297	-5.6802	-0.0194	1.1648E-05
3	0.00511945	-5.2747	-0.027	2.6209E-05
1	0.00170648	-6.3733	-0.0109	2.9121E-06
1	0.00170648	-6.3733	-0.0109	2.9121E-06
586			-1.4808	0.37892695
				2.63903106

Appendix 3: Sorenson's similarity index of UCCTRF and UCCNR

Number of species common to UCCTRF and UCCNR	12
Number of species in UCCTRF	14
Number of species in UCCNR	21

$$\text{Sorenson's index} = \frac{2C}{A+B} \times 100\% = \frac{2\times 12}{14+21} \times 100\% = 68.5714\%$$

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