Earthworm activities in cassava and egusi melon fields in the transitional zone of Benin: linking farmers' perceptions with field studies

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Abstract

Farmers' perceptions of earthworm activities were studied in the transitional zone of Benin and linked to scientific explanations of earthworm casting activities. Earthworm activity was assessed in farmers' fields with three different cassava cultivars and in a field experiment with three different egusi melon species. The experiment included plots with cowpea and maize. The study also comprised group discussions and a survey with 91 individual farmers. All farmers were aware of earthworms, but there were significant gender differences in terms of perception of earthworms. The presence of earthworm casts is used by farmers as an indicator of soil fertility and of good conditions for crop growth. Cast production over a period of two months was highest in fields with maize, followed by cowpea, cassava and egusi melon. Farmers' ranking of earthworm abundance showed a pattern almost the opposite of our assessment, with cassava and egusi melon fields being ranked highest and those with maize and cowpea lowest. We suggest that farmer's criteria are context-dependent, with earthworm casting activity being relevant when judging whether a field can be intensively cropped again. Casts showed significantly higher plant nutrient contents than the topsoil. Nevertheless, the amount of nutrients recycled in casts is relatively low. Farmer involvement in the research activity increased their interest in earthworms.

Additional keywords: cast enrichment, local ideas, science-based explanation, soil fertility, surface cast

Introduction

Until recently, scientists have underestimated the knowledge of African farmers about soil fertility and crop management, e.g., with respect to intercropping to minimize risks (Norman, 1974; Igbozurike, 1978; Richards, 1985), soil and water conservation to improve crop production (Reij *et al.*, 1996), or the precision and details given by local people when classifying their soils (Birmingham, 2003; Oudwater & Martin, 2003; Saïdou *et al.*, 2004). This knowledge can be considered a mixture of beliefs and practical experience. It is not always clear whether local ideas about soil–crop interactions should be regarded as beliefs, and treated interpretively, or whether they are to be understood as empirically based explanatory understandings comparable with accounts offered by science. One approach is to pick and choose, emphasizing the bits of local knowledge compatible with science, and ignoring the rest. An alternative approach is to link these local ideas to a science-based explanatory framework.

A diagnostic study carried out in the Atacora region and the transitional zone of Benin revealed a range of alternative local practices of soil and crop management. Informants claimed that these practices restore soil fertility and enhance crop production (Saïdou *et al.*, 2004). Farmers suggested that cassava (*Manihot esculenta*) and egusi melon (*Citrullus* spp. and *Lagenaria* spp.) in the rotation improve the soil when it has become degraded. Farmers argued that under cassava and egusi melon the soil is better protected against solar radiation. As a consequence of shading, soil temperature is lower and soil moisture retention higher. Both factors promote earthworm activity (Hauser, 1993; Henrot & Brussaard, 1997). However, it is not clear whether farmers see this connection. Farmers perceive earthworms as indicators of soil fertility, not as organisms creating or maintaining soil fertility (Ortiz *et al.*, 1999). Earthworms can positively affect both chemical and physical soil quality, by increasing initial decomposition and mineralization of nutrients; by returning basic cations to the topsoil, thereby preventing leaching; by regulating soil hydraulic properties; and by maintaining or enhancing soil structure through burrows and casts, which simultaneously protect organic matter against further degradation. The direct effect of earthworms on nutrient mineralization (and hence on increased plant productivity) is generally considered less important than their impact as soil ecosystem engineers (Lavelle *et al.*, 2001).

Below we describe a study linking farmers' perceptions of the role of cassava and egusi melon in maintaining or restoring soil fertility, analysing the potential role of earthworms as reflected in casting activity, cast and topsoil nutrient contents, and amounts of nutrients deposited in surface casts. The study is based on four objectives: (1) to understand farmers' perceptions of earthworms, (2) to relate these perceptions to scientific explanation, (3) to set up joint research to link both forms of knowledge, and (4) to use this joint research as a route to improve soil and crop management practices.

Materials and methods

Study sites

The study was carried out in 2003 in farmers' fields at the villages Ouoghi Central and Ouoghi Gare (at a distance of 3 km from each other) in the transitional agro-ecological zone of Benin. Ouoghi Central is inhabited by indigenous Tchabè people (Yoruba subgroup) and Ouoghi Gare (a settlement located along a north-south railway line) by migrants from Atacora-Donga and Abomey plateau (Saïdou *et al.*, 2004). The area, located at 8°07' N and 2°33' E at an altitude of about 200 m a.s.l. is essentially dominated by tropical ferruginous soils (Dubroeucq, 1977) derived from Precambrian crystalline rocks (granite and gneiss), classified as Ferric Lixisol (Anon., 1990). The climate is Sudano-Guinean with a unimodal rainfall pattern. The average yearly rainfall and temperature are 1100 mm and 27.5 °C, respectively. The rainy season lasts from April to mid-November.

Survey approach

Farmers were full participants in the research rather than an object of study. After a diagnostic study, stakeholder learning groups (SLG) of 31 and 10 members in Ouoghi Central and Ouoghi Gare, respectively, were formed on a voluntary basis in February 2003. The groups consisted of youth and elders. The local extension agent played the role of facilitator. These SLGs served as a forum for interaction and knowledge exchange among farmers and between farmers and researchers. Tools used for knowledge exchange included photos, graphs and descriptions of biological processes (nutrient cycling through earthworm casts) in ecosystems. The purpose of forming such a SLG was to build farmers' capacity and strengthen their self-confidence. The groups were also important as client stakeholder groups for more relevant agro-scientific research.

In November 2003, a formal survey with individual farmers was carried out using an open-ended questionnaire including ranking exercises. In order to see whether the group to which respondents belonged affected their perceptions, the responses from native and migrant, male and female, and older and younger male farmers were analysed separately. In total, 91 persons (51 native and 40 migrant farmers) were interviewed. Farmers' perceptions of earthworms and surface casts in the field were assessed. Farmers were also asked to rank the different crops with regard to earthworm cast abundance.

Field studies

The two most important crops included in the field studies were cassava and egusi melon. Farmers' fields were used for the cassava study. For egusi melon a special field experiment was laid out, jointly managed by farmers and researchers. The emphasis in these studies was on earthworm activity as measured by surface cast production. Earthworm species were not identified. The field studies were carried out in 2003.

Cassava

The cassava in the study area is grown as a perennial: the crop is harvested in the second year or later. Three cultivars are being used: Odongbo (a local landrace), Bouaké (a fast growing cultivar introduced from Côte d'Ivoire), and Ben 86052 (an improved high-yielding cultivar introduced by IITA through the cassava project 'Projet de Développement des Racines et Tubercules). Cassava is always planted at 1 m × 1 m. Canopy diameter is therefore a proxy for the amount of soil cover and shading. Ben 86052 has a dense canopy (the mean value of canopy diameter is 1.2 m), whereas Bouaké and Odongbo have a more open canopy (mean canopy diameter 0.7 m for both cultivars).

The farmers' cassava fields were selected together with the SLG members in February 2003 after an exploratory tour in both villages. The main selection criteria, apart from similarity of soils (texture and colour) and cassava cultivars grown, were farmer's attendance at the SLG meetings, willingness not only to make available a small portion of the field for the on-farm field study but also to manage it as necessary and to participate in data collection.

Six farmers were selected for each of the three cultivars. Plots of 6 m × 5 m were delimited for each cultivar in the middle of each farmer's field to avoid edge effects. When harvested, the cassava crops were 6–18 months old. The trials were set up as a randomized block design with cassava cultivars as treatments.

Egusi melon

Egusi melon is an annual crop. Its growing period is 3–4 months and the crop is sown soon after the first rains. It covers the soil within 2 months after sowing. Egusi melon includes three species: *Citrullus colocynthis* (egusi baa), *C. lanatus* (egusi Côte d'Ivoire), and *Lagenaria siceraria* (egusi ugba).

The egusi experiment was of the randomized block design with four replications. Given local practices, farmers suggested to also include cowpea (local cultivar Tawa) and maize (cultivar TZB). Maize was selected for comparative reasons, cowpea for its ability to fix atmospheric nitrogen and thus improving soil fertility, which could affect earthworm activity. The experiment was started in April 2003. Plot size was 30 m^2 (6 m × 5 m). Egusi baa, egusi Côte d'Ivoire and cowpea were sown at a density of 62,500 plants ha^{-1} and egusi ugba and maize at 25,000 plants ha^{-1}. The difference in plant density among egusi melon species is based mainly on differences in growth habit.

Measurement of earthworm surface casting

The granular (most common) and tubular earthworm casts that accumulated on the soil surface were counted and collected in four 0.5 m × 0.5 m sub-plots delimited randomly in each plot of the cassava fields and the egusi melon experiment. The production rate of casts was assessed over the months of June and July 2003. Between 15 July and 15 August the cassava fields were weeded. Cassava cropping continued until the end of October. Surface casts were counted every two weeks. For reasons of comparability between the studies we only report cast production over 2 months (June–July 2003). After counting, casts were collected, air-dried and subsequently oven-dried at 40 °C to a constant weight. The dried casts were passed through a 2-mm sieve to separate them from plant material and stones, and then weighed. At the end of the 2-month period the sieved cast samples were bulked per plot and analysed for their nutrient contents.

Nutrient contents of the underlying topsoil (0–10 cm depth) were also determined. The soil samples were taken in November for cassava and in August for egusi melon. Chemical analyses were done in the Laboratory of Soil Sciences of the Faculté des Sciences Agronomiques of the University of Abomey-Calavi and in the Laboratoire des Sciences du Sol, Eau et Environnement of Benin National Research Institute. Topsoil samples and casts were analysed for pH($CaCl_2$) (1:2.5 v/v soil solution), total N (Kjeldahl digestion in a mixture of H_2SO_4–selenium followed by distillation and titration), available P (Bray 1), and exchangeable cations (extracted with 1 N ammonium acetate at pH 7). K was determined by flame photometer, and Ca and Mg by Atomic Absorption Spectrophotometry.

Statistical analysis

The data were analysed using the statistical programme SAS version 8.1. Soil and cast chemical properties and amount of nutrients deposited were subjected to analysis of variance, and means were separated using Student Newman-Keuls test. $Log^{10}(x + 1)$ transformation was used for the number of casts per unit area and the cumulative cast mass in order to satisfy the conditions of normality and homogeneity of variances. Nutrient enrichment in the casts was calculated by dividing cast nutrient content by nutrient content of the underlying topsoil (Hauser & Asawalam, 1998; Norgrove & Hauser, 2000). Differences between the distribution of responses were determined by the χ^2-test. As informants were not allowed to give more than one answer per question, the answers given reflect farmers' conceptions of the most important role (and not the variety of roles) that earthworms play.

Results

Farmers' perception and knowledge on earthworms

The local name for earthworm is *idjèlè* or soil eater. Almost all farmers were knowledgeable about earthworms. Earthworm casts are considered vitamins (*ora* or *udja*), i.e., fertilizer, because they are richer than the topsoil. The farmers considered the presence of surface casts as soil fertility indicator (Table 1). Several farmers reported the importance of earthworms for litter decomposition. A few farmers perceived earthworms as root herbivores or a cause of human foot infection. Three categories of farmer perceptions of the role of earthworms can be distinguished: (1) positive (soil fertility indicator or improver, litter decomposer and plant residues burrower), (2) negative (root herbivore and source of infection), and (3) indifferent (no opinion). Gender differences in perception were statistically significant ($P = 0.01$). Female farmers appeared to be less knowledgeable or less confident of the role of earthworms than male farmers.

The ranking farmers made of the intensity of earthworm casting activity in cassava, egusi melon, maize and cowpea fields is presented in Table 2. Most native farmers (except young males) ranked earthworm activity highest in cassava fields, whereas migrant farmers ranked it highest in fields of egusi melon. Maize fields were ranked lowest by both native and migrant farmers.

Earthworm surface cast biomass and distribution

Two types of earthworm casts were found: small granular and tubular ones. The granu-

Table 1. (a) Relative distribution of responses of social groups of native and migrant farmers on the role of earthworms. (b) Results of statistical analysis.

(a) Role of earthworms	Native farmers			Migrant farmers			Total [1]	
	Older [2] men	Young men	Women	Older men	Young men	Women	Men	Women
	(n=18) [3]	(n=20)	(n=13)	(n=14)	(n=16)	(n=10)	(n= 68)	(n=23)
	(%)							
Positive effect								
Soil fertility indicator	28	60	23	57	44	30	47	26
Contribute to litter decomposition	17	10	8	7	6	10	10	9
Bury plant residues	11	5	0	7	12	0	9	0
Negative effect								
Destroy crop roots	11	5	8	14	25	20	13	13
Cause infection	6	10	15	7	6	10	7	13
No opinion	28	10	46	7	6	30	13	39

(b) Results of statistical analysis

Level [4] of significance determined with χ^2-test

	χ^2-value	*P*-level
Native vs. migrant farmers	2.941	0.230
Older vs. young men	1.612	0.447
Men vs. women	8.971	0.011

1 Total for men is the sum of responses of older and young men belonging to native and migrant farmers, and total for women is the sum of responses of native and migrant women.
2 Men of 50 years and older; the rest is classified as young men.
3 Number of respondents.
4 Level of statistical significance was tested by grouping farmers' responses into (1) positive effect, (2) negative effect, and (3) no opinion.

Table 2. Ranking order of the intensity of earthworm casting activity in different crops. Ranking of casting activity based on the relative importance as perceived by older men, young men and women of native and migrant farmers. Ranking scale 1–4 (1 = highest; 4 = lowest).

Crop	Native farmers			Migrant farmers		
	Older[1] men (n=18)[2]	Young men (n=20)	Women (n=13)	Older men (n=14)	Young men (n=16)	Women (n=10)
Cassava	1	3	1	2	2	2
Egusi melon	2	1	2	1	1	1
Maize	4	4	4	4	4	4
Cowpea	3	2	2	3	3	2

[1] Men of 50 years and older; the rest is classified as young men.
[2] n = number of respondents.

Table 3. Mean values (± standard error) of numbers of earthworm casts and cast weight in the period June–July 2003 in cassava fields and in plots of egusi melon, cowpea and maize. Values were $\log^{10}(x + 1)$ transformed before statistical analysis; original values in parentheses.

	Number of casts (m^{-2})		Cast weight ($t\ ha^{-1}$)	
Extensive cassava fields				
Cv. Odongbo	1.6 ± 0.07 b[1]	(38.6)	0.7 ± 0.08	(3.8)
Cv. Bouaké	1.9 ± 0.08 a	(78.4)	0.8 ± 0.05	(5.9)
Cv. Ben 86052	2.0 ± 0.14 a	(126.8)	0.9 ± 0.10	(8.3)
P > F	0.04		0.14	
Egusi–cowpea–maize plots				
Egusi baa	1.6 ± 0.05	(44.5)	0.7 ± 0.03 b	(4.2)
Egusi ugba	1.8 ± 0.07	(61.6)	0.8 ± 0.01 ab	(5.9)
Egusi Côte d'Ivoire	1.8 ± 0.08	(63.2)	0.9 ± 0.05 ab	(6.7)
Maize	2.0 ± 0.08	(93.5)	1.1 ± 0.05 a	(10.5)
Cowpea	1.8 ± 0.20	(74.8)	1.0 ± 0.10 a	(8.5)
P > F	0.26		0.01	

[1] Means within the same column, followed by the same letter are not statistically different ($P > 0.05$; Newman–Keuls test).

Table 4. Chemical analyses of topsoil (0–10 cm) and earthworm casts from extensive cassava fields and egusi melon, maize and cowpea plots.

Fields / plots	pH ($CaCl_2$)		Total N (g kg^{-1})		P-Bray I (mg kg^{-1})		Exchangeable kations (cmol kg^{-1})					
							K^+		Ca^{2+}		Mg^{2+}	
	Soil	Casts	Soil	Casts	Soil	Casts	Soil	Casts	Soil	Casts	Soil	Casts
Extensive cassava												
Cv. Odongbo	5.2±0.1	5.9±0.1 a [1]	1.0±0.1	1.7±0.1 a	27.7±2.2 a	29.3±4.3	0.4±0.04	0.6±0.1	1.1±0.2	1.9±0.2	1.0±0.1	1.8±0.2
Cv. Bouaké	5.4±0.1	5.9±0.1 a	0.8±0.2	1.0±0.1 b	15.5±3.3 b	27.7±2.4	0.2±0.1	0.5±0.1	1.1±0.2	1.8±0.3	0.8±0.1	1.9±0.2
Cv. Ben 86052	5.3±0.1	5.5±0.1 b	0.7±0.1	1.7±0.2 a	20.3±3.1 ab	17.4±3.4	0.3±0.1	0.6±0.1	0.8±0.1	2.2±0.2	1.0±0.2	1.9±0.1
$P > F$	0.38	0.002	0.61	0.02	0.04	0.09	0.11	0.75	0.42	0.48	0.78	0.93
Egusi–maize–cowpea												
Egusi baa	5.1±0.2	5.9±0.1 a	1.1±0.2	1.1±0.1	26.8±3.9	22.6±4.4	0.3±0.1	0.6±0.03	0.8±0.1 ab	1.1±0.03	0.7±0.03	1.1±0.1
Egusi ugba	4.8±0.1	5.3±0.2 b	1.0±0.1	1.2±0.1	21.9±2.1	32.0±1.8	0.3±0.04	0.4±0.1	0.6±0.1 b	0.9±0.1	0.5±0.1	0.9±0.1
Egusi Côte d'Ivoire	5.3±0.1	5.8±0.1 a	1.4±0.1	1.8±0.3	22.2±2.8	31.4±1.7	0.3±0.1	0.6±0.1	0.7±0.03 b	1.1±0.1	0.6±0.1	1.1±0.1
Maize	5.2±0.1	5.5±0.2 ab	1.2±0.1	1.5±0.1	23.9±3.4	28.9±1.1	0.3±0.1	0.5±0.04	0.7±0.1 b	1.1±0.2	0.6±0.1	1.1±0.2
Cowpea	5.1±0.1	5.6±0.1 ab	1.2±0.1	2.6±0.8	22.9±3.8	24.9±4.9	0.4±0.02	0.9±0.2	0.9±0.1 a	1.3±0.1	0.7±0.2	1.2±0.2
$P > F$	0.06	0.02	0.67	0.07	0.77	0.14	0.29	0.08	0.01	0.23	0.48	0.67

[1] Means per column, followed by the same letter are not statistically different ($P > 0.05$; Newman–Keuls test).

lar casts were most abundant and were found in all fields, whereas never more than two tubular casts were counted per field. For that reason, the latter have been bulked with the granular casts for chemical analysis.

The average number of casts per square metre and the total cast mass in the various fields are presented in Table 3. In both the cassava fields and in the egusi experiment cast number and cast mass were significantly correlated. The cast produced over a period of two months ranged from 3.8–8.3 t ha^{-1} for cassava fields. The numbers of casts were significantly higher in the fields with the cassava cultivars Ben 86052 and Bouaké than in the fields with the cultivar Odongbo. Cast mass was highest in the fields with Ben 86052, but differences with the other fields were not statistically significant. Quantities of 4.2–6.7 t ha^{-1} for egusi melon, 10.5 t ha^{-1} for maize and 8.5 t ha^{-1} for cowpea were recorded in the egusi experiment. Cast numbers followed the same pattern. Over the two months of study (June–July 2003) the ranking order found for cast mass was: maize > cowpea > cassava > egusi melon. This order was (almost) the reverse of the farmers' ranking order cassava = egusi melon > cowpea > maize.

Chemical properties of earthworm casts and underlying topsoil

In the cassava fields, nutrient contents (except P; not significantly different) and pH were significantly ($P < 0.001$) higher in the casts than in the underlying topsoil (Table 4). Cast enrichment was highest in the plots with the lowest topsoil fertility. In the cassava fields, the cast : topsoil ratios were 1.3–2.4 for total N, 1.5–2.5 for exchangeable K, 1.6–2.9 for exchangeable Ca and 1.9–2.4 for exchangeable Mg (Table 4). In the egusi experiment, nutrient contents (except N; $0.01 < P < 0.05$) and pH were significantly ($P < 0.001$) higher in the casts than in the underlying topsoil (Table 4). In the cowpea plots cast enrichment for total N and exchangeable K was somewhat higher than in the egusi and the maize plots. Total N and exchangeable K of the casts from the cowpea plots were 50–100% higher than in the casts from the egusi and maize plots, but the difference was not statistically significant (Table 4).

Cast pH was significantly ($P < 0.05$) higher in the fields with the cassava cultivars Ben 86052 and Bouaké than in fields with Odongbo (Table 4). Total N in the casts was significantly higher in the fields with Ben 86052 and Odongbo. Between the cassava fields there were no statistically significant differences in P-Bray 1, and exchangeable K, Ca and Mg of the casts. Cast pH values were significantly ($P < 0.05$) higher in the egusi baa and egusi Côte d'Ivoire than in the egusi ugba plots (Table 4).

Amounts of nutrients recycled through casts

The amounts of nutrients recycled through casts are given in Table 5. Over the two-month period, the largest amounts of nutrients were recycled in the cowpea and maize fields, and the lowest amounts in the fields with cassava and egusi. In the Ben 86052 fields, significantly higher amounts of N and exchangeable Ca and Mg were recycled through casts compared with the Odongbo and Bouaké fields (Table 5).

Table 5. Amounts (means ± standard error) of nutrients deposited through surface casts in extensive cassava fields and egusi melon, maize and cowpea plots in the period June–July 2003.

	Total N	P-Bray 1	K^+	Ca^{2+}	Mg^{2+}
	(kg ha^{-1})				
(a) *Cassava*					
Cv. Odongbo	6.5 ± 1.3 b [1]	0.1 ± 0.0	0.8 ± 0.1	2.6 ± 0.4 b	1.5 ± 0.2 b
Cv. Bouaké	6.8 ± 0.6 b	0.2 ± 0.0	1.3 ± 0.2	4.0 ± 0.7 ab	2.7 ± 0.3 ab
Cv. Ben 86052	13.8 ± 2.2 a	0.2 ± 0.1	1.9 ± 0.4	7.2 ± 1.6 a	3.3 ± 0.4 aa
$P > F$	0.03	0.34	0.08	0.03	0.02
(b) *Egusi–maize–cowpea*					
Egusi baa	4.5 ± 0.7 b	0.1 ± 0.0 b	1.0 ± 0.1 c	1.8 ± 0.2	1.1 ± 0.2
Egusi ugba	7.1 ± 0.7 ab	0.2 ± 0.0 ab	0.9 ± 0.1 c	2.0 ± 0.1	1.4 ± 0.1
Egusi Côte d'Ivoire	11.9 ± 1.5 ab	0.2 ± 0.0 ab	1.5 ± 0.4 bc	3.0 ± 0.6	2.0 ± 0.5
Maize	15.9 ± 3.0 ab	0.3 ± 0.0 a	1.9 ± 0.3 ab	4.8 ± 1.4	3.1 ± 1.0
Cowpea	17.6 ± 5.8 a	0.2 ± 0.1 ab	2.4 ± 0.1 a	4.4 ± 1.0	2.6 ± 0.5
$P > F$	0.048	0.011	0.001	0.11	0.21

[1] Means per column, followed by the same letter are not statistically different ($P > 0.05$; Newman–Keuls test).

Discussion

Farmers' perceptions of earthworm casting activity

Farmers' perceptions and knowledge (or the confidence with which they expressed their knowledge) of earthworms and their casting activity was dependent on gender, but not on the distinction between native and migrant farmers (Table 1). Female farmers were less knowledgeable (or less confident) of the role of earthworms than male farmers. From a theoretical perspective the concept of not knowing (or not professing to know) has been problematical (Last, 1981). If earthworms are perceived as indicating fertile soils or indicating that the land can be intensively cropped again, then not knowing by women could refer to the fact that cropping decisions fall outside their socially recognized domain of competence. Having no opinion is then a significant phenomenon. Native and migrant farmers generally shared perceptions of earthworms, probably due to the nearness of the two villages, because interaction between both groups induces common habits and experiences. Most farmers considered cast abundance as an indicator of fertile soils. Beneficial effects of earthworms as mentioned by farmers were also reported by Ortiz *et al.* (1999) in a review of surveys conducted in Congo, India, Peru and Mexico. Birang *et al.* (2003) reported similar perceptions for farmers in southern Cameroon, who on the basis of the presence of earthworm casts determine whether or not the land is ready for cropping. In their study, high levels of surface casting were associated with a strong belief in positive effects of earthworms on yield. Some Cameroonian farmers also stated that earthworms cause crop damage. Henrot & Brussaard (1997) observed granular casts in a Nigerian ultisol that were produced by earthworms of the family Eudrilidae. These worms live close to roots, but we did not encounter reports that they actually cause root damage.

Linking farmers' perceptions with the results of field studies

Farmers associated earthworms with soil fertility. However, their ranking order of earthworm casting activity did not fit with our soil fertility assessment; in fact their ranking was (almost) the reverse of our assessment. The amounts of nutrients recycled through casts followed more or less the same patterns, although the amounts of N and K^+ recycled through casts in cowpea plots were higher than in maize plots. Maize, which had the highest cast mass production in two months, was consistently ranked lowest by farmers, and cowpea was ranked third. Egusi melon and cassava, two crops that are reported to improve the soil, were ranked highest, but cast mass was lowest.

Within the framework of our study we cannot just privilege scientific explanations and discard the farmers' ranking as another example of inadequate knowledge. Such an approach would not allow for the possibility that the scientists' concepts and approaches need to be critically evaluated and involves only an evaluation of the accuracy of local knowledge (Fairhead & Scoones, 2005). Our sampling was very much restricted in time (2 months in the egusi experiment) and may therefore have captured only a partial view of earthworm activities. But more importantly, the causal link between earthworm activity and soil fertility may be constructed differently from the farmers' perspective. Whereas scientists construct general causal links between earthworm activity and soil fertility, farmers likely have a more contextualized view. They 'overlook' earthworms in their cropping fields, because they use earthworm activity only to assess the status of degraded fields. In such fields cassava and egusi are planted, and the assessment of the degree of recovery (and hence the suitability for subsequent planting with higher-value crops) is based on earthworm activity. Farmers ranked casting intensity in fields with different crops mainly on the basis of soil cover by the plant canopies. Within that context the higher cast mass in fields planted with Ben 86052 than in the fields with the two other cassava cultivars fits with the idea expressed by farmers that shading (resulting in higher soil moisture and lower soil temperatures) enhances earthworm casting activity.

Farmers appeared to be aware of the higher nutrient content of the casts compared with the topsoil. The amount of nutrients recycled through casts was, however, relatively low. We therefore do not want to suggest that farmers should use casts as fertilizer. Using casts as fertilizer, which would be very labour-intensive, can only result in the recycling of poverty. Farmer's indication of earthworm casts as a kind of vitamin should not be interpreted as indicating knowledge of a causal role of earthworms in enhancing soil fertility. Equating nutrients with vitamins (or even translating *ora* or *udja* as vitamin) privileges soil chemical explanations of earthworm effects. Considering the amounts recycled in casts, it might well be more important to look at their role as soil ecosystem engineers (Lavelle *et al.*, 2001).

The contracts to experiment together with farmers were successful and provided a rich experience in terms of knowledge exchange for both researchers and farmers. Joint experimentation also gave farmers more self-confidence. In meetings they had the opportunity to explain their perceptions after which the researcher provided information and explanation from formal science. Scientists tried to take explanations by farmers seriously, while the input from science was taken seriously by farmers. Farmers' interest in the beneficial effects of earthworms was increased, which could be relevant when it comes to improving their soil fertility and cropping management practices.

Conclusions

Farmers in the transitional zone of Benin treat earthworms as an indicator of soil fertility. Farmers reported that earthworms play a role in litter decomposition. But some farmers thought that earthworms damage crop roots, a misconception that appears to relate to their observation of earthworms feeding on dead roots. Farmer's views on earthworm activity are context-dependent, using it to assess the recovery status of degraded fields.

The participatory approach was a rich experience for both researchers and farmers. Most farmers confessed that never before had they been involved in research on earthworms. Indeed, they saw the stakeholder learning group as a learning space where they had an opportunity to exchange knowledge with the researchers and also to learn from individual experiences about biological processes. It increased farmers' self-confidence.

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