Chapter 2

Abundance and Diversity of Earthworms in Managed and Non-Managed Fallow Lands of Calakmul Reserve of Campeche, Mexico

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Abstract

In Mexico, the best preserved tropical rain forest is found in Calakmul Reserve, where fallow land management has been established. Fallow lands are developed as a consequence of a successional vegetation process after clearing the primary vegetation and milpa production. Forty-nine sites were studied, where 17 were managed fallow lands, 24 non-managed fallow lands, and 8 tropical rain forests. Earthworms were collected at the end of the raining season, and four monoliths of 25 × 25 × 30 cm were developed per site according to the TSBF method. We observed how *Zapatadrilus siboney*, a native species was dominant in managed and non-managed fallow lands. Earthworm's total biomass and density were not significantly different between the managed and non-managed fallow lands. Earthworm's species richness was significantly low in non-managed fallow lands. We observed a strong correlation between earthworm density and richness with the age of the fallow lands (r^2: 0.9 and 0.7; $p < 0.05$, respectively). The management type of the fallow land seems to affect earthworm biomasses (r^2: 0.56; $p < 0.05$).

Keywords: Calakmul reserve, *Zapatadrilus siboney*, managed and non-managed fallow lands

1. Introduction

Calakmul is one of the most important biosphere reserves, where it is possible to find primary tropical rain forests, secondary vegetation, and managed lands. It has an extension of

723,185 ha, where 65% can be potentially managed (Esparza-Olguin, personal communication). Among the managed areas, fallow lands are developed as a consequence of a successional vegetation process after clearing the primary vegetation and milpa production. Fallow land management is developed by the reserve inhabitants, where wood, herbs, fruits, vegetal carbon, or honey is extracted or collected; even though it is an ancient practice, there is no information about the effects of this management over soil conditions. Earthworms constitute 60–90% of soil macroinvertebrate biomass [1], and they are considered as soil quality indicators [2]; they can inform about the degree of perturbation that can be taken place within a terrestrial ecosystem. In natural system, native earthworms are dominant [3], while exotic earthworms can inhabit managed systems due to their width range of tolerance to different pH and temperature conditions [3]. Earthworms provide soil ecosystem services such as infiltration, and they participate in soil organic matter dynamics and green house mitigation [4]. The objective of this study was to describe earthworm's communities among managed and non-managed fallow lands, in Calakmul Reserve.

2. Material and methods

Calakmul Reserve is located at 18°37′02″N and 89°33′00″W. The mean annual precipitation is 1076 mm with the mean temperature of 22.5°C. It is possible to find abundant karst outcroppings which characterize the shallow soils of the Calakmul region [5]. Forty-nine plots among nine communal settlements (ejidos) of Calakmul Reserve were selected. Within the fallow lands, 17 were managed and 24 were non-managed; fallow lands were successional vegetation belonging to evergreen tropical rain forest or subcaducifolius rain forests. Eight tropical rain forests were also sampled. Earthworms were collected at the end of the raining season, according to the TSBF method [6], where four monoliths of 25 × 25 × 30 cm per plot were done. Earthworms were preserved in 94% alcohol for further identification in the laboratory of soil of El Colegio de la Frontera Sur, Unidad Campeche. Data was normalized, and ANOVA were performed in order to observe significant differences between managed and non-managed fallow lands; also Pearson correlation was developed among variables. A canonical analysis was performed with data of managed and non-managed fallow lands from the subcaducifolius rain forest; as environmental variables, we used fallow land age, density and richness of plants, and type of management (extraction of vegetal carbon, forestall management, and apiculture); and as species variables, we used earthworm biomass, density, and richness.

3. Results

We found six earthworm morphospecies belonging to the Acanthodrilidae family; most of the individuals were juveniles. Among adults we identified one native species *Zapatadrilus siboney* and one peregrine species *Dichogaster crawi*, where *Zapatadrilus siboney* was dominant

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in managed and non-managed fallow lands. Only two ecological earthworm categories were found in this study: endogeics and epigeics. Earthworm's biomass and density (**Figures 1** and **2**) were not significantly different between managed and non-managed fallow lands, but earthworm species richness was significantly different (**Figure 3**); fallow lands without management had the lowest earthworm's species number (**Figure 3**). Regarding the age of the fallow lands, we observed a significant correlation between age of the fallow land and abundance and richness of earthworms (r^2: 0.9, 0.7; $p \leq 0.05$, respectively), independently of the management and the type of vegetation (evergreen tropical rain forest or subcaducifolius rain forest). Vegetation structure between tropical rain forests and managed or non-managed old fallow lands (≥25 years) was not significantly different, but the vegetation composition of the tropical rain forest was significantly different, i.e., tropical rain forest had tree species with the hardest wood trunk compared with those found in non-managed fallow lands and managed fallow lands (**Table 1**). After the canonical analysis developed with data of fallow lands from the subcaducifolius fallow lands, we observed with 99% of inertia explained how earthworm density is strongly correlated with the age of the fallow land (r^2: 0.7; $p < 0.05$) and lightly correlated with vegetation richness (r^2: 0.4; $p < 0.05$, **Figure 4**). Earthworm biomass seems to be affected by the type of fallow land management (r^2: 0.56; $p < 0.05$).

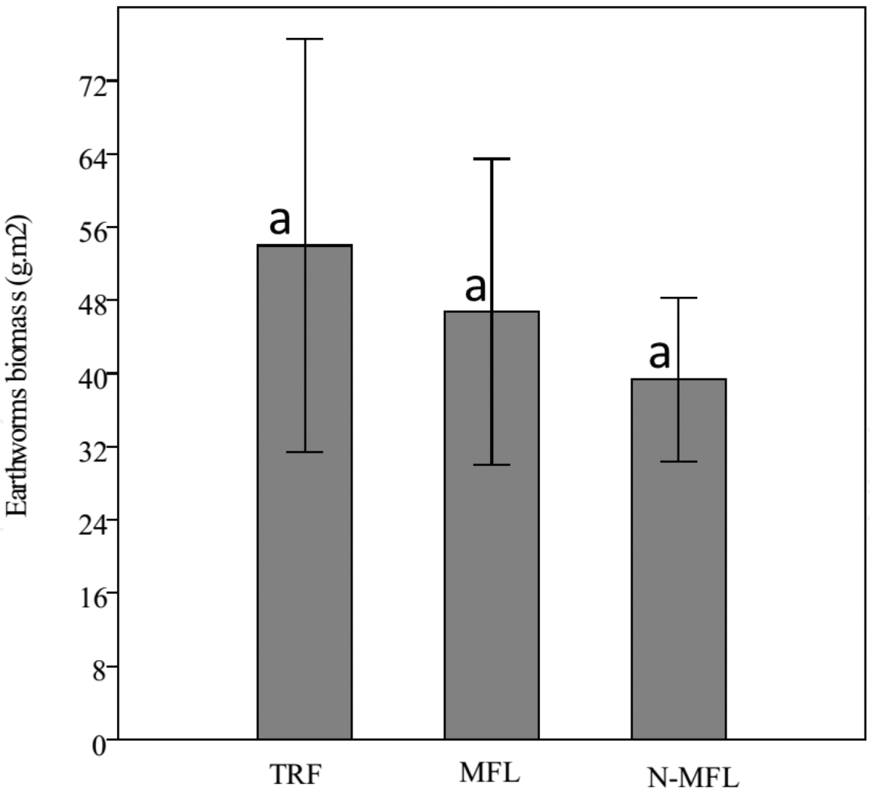

Figure 1. Earthworm biomass ($g.m^2$) in different land uses. Managed fallow land (MFL), non-managed fallow lands (NMFL), and tropical rain forest (TRF).

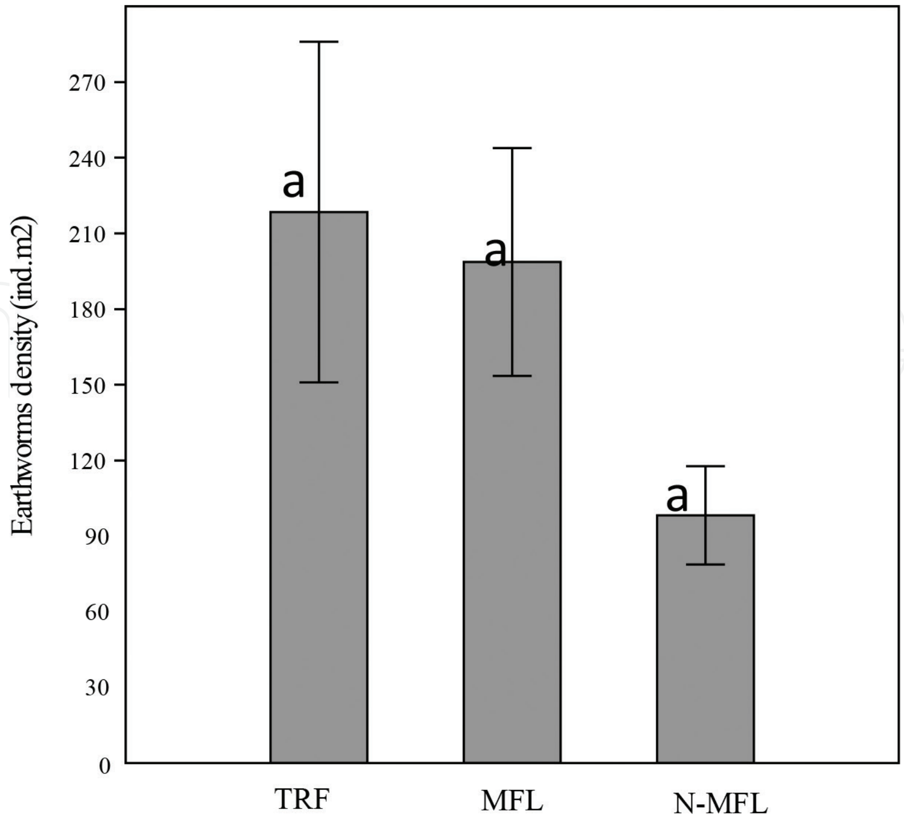

Figure 2. Earthworm density (ind.m^2) in different land uses. Managed fallow land (MFL), non-managed fallow lands (NMFL), and tropical rain forest (TRF).

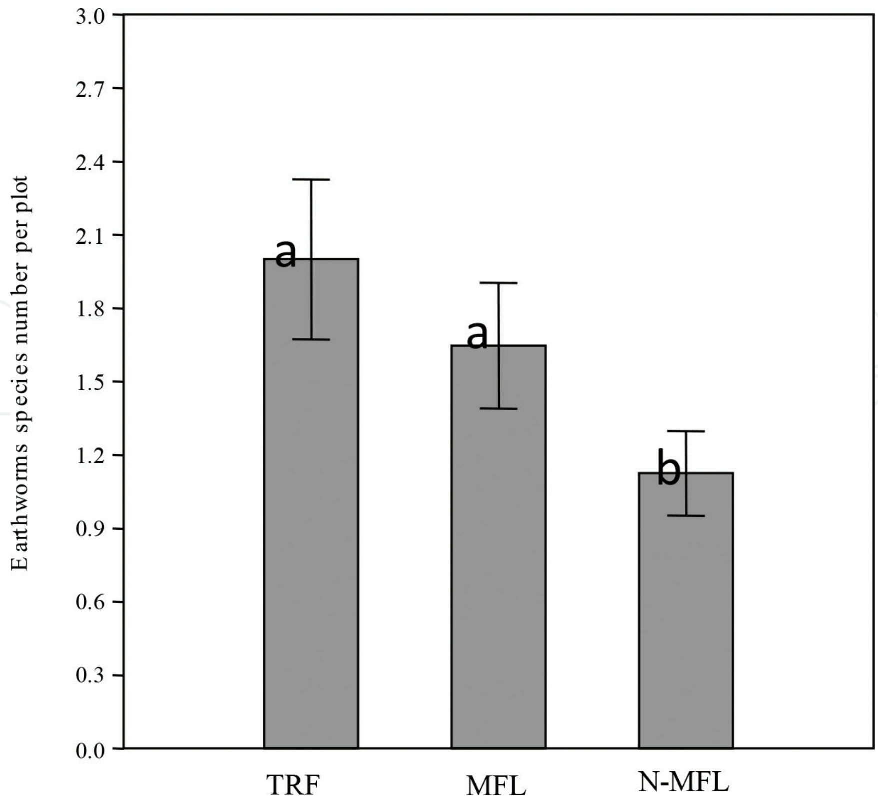

Figure 3. Earthworm richness in different land uses. Managed fallow land (MFL), non-managed fallow lands (NMFL), and tropical rain forest (TRF).

Plot no.	Ejido name	Vegetation type	M	Age	Plant species	Zs
1	Álvaro Obregón	Fallow land SCP	Non	20	Ly, Lg, Bs, Tp, Ht, Ey, Gf	No
2	Álvaro Obregón	Fallow land SCP	With	20	Bs, Ly, Tp, Ds, Ei, Lg, Ne	No
3	Álvaro Obregón	Fallow land SCP	With	15	Bs, Ly, Tp, Ds, Ei, Lg, Ne	x
4	Álvaro Obregón	Fallow land SCP	With	12	Bs, Ly, Tp, Ds, Ei, Lg, Ne	x
5	Álvaro Obregón	Fallow land SCP	Non	15	Ly, Lg, Bs, Tp, Ht, Ey, Gf	x
6	Álvaro Obregón	Fallow land SCP	With	20	Bs, Ly, Tp, Ds, Ei, Lg, Ne	x
7	Álvaro Obregón	Fallow land SCP	With	15	Bs, Ly, Tp, Ds, Ei, Lg, Ne	x
8	Álvaro Obregón	Fallow land SCP	Non	20	Ly, Lg, Bs, Tp, Ht, Ey, Gf	x
9	Álvaro Obregón	Fallow land SCP	With	25	Bs, Ly, Tp, Ds, Ei, Lg, Ne	No
10	Álvaro Obregón	Fallow land SCP	Non	15	Ly, Lg, Bs, Tp, Ht, Ey, Gf	No
11	Km 120	Fallow land SCP	With	19	Lg, Bs, Ey, Ca, Ly, Gf, Tp, Ns	x
12	Km 120	Fallow land SCP	Non	15	Ly, Lg, Bs, Tp, Ht, Ey, Gf	x
13	Km 120	Fallow land SCP	With	17	Lg, Bs, Ey, Ca, Ly, Gf, Tp, Ns	x
14	Km 120	Fallow land SCP	Non	17	Ly, Lg, Bs, Tp, Ht, Ey, Gf	x
15	Km 120	Fallow land SCP	With	18	Lg, Bs, Ey, Ca, Ly, Gf, Tp, Ns	x
16	Km 120	Fallow land SCP	With	18	Lg, Bs, Ey, Ca, Ly, Gf, Tp, Ns	x
17	Km 120	Fallow land SCP	With	17	Lg, Bs, Ey, Ca, Ly, Gf, Tp, Ns	x
18	Km 120	Fallow land SCP	Non	18	Ly, Lg, Bs, Tp, Ht, Ey, Gf	x
19	Km 120	Fallow land SCP	Non	19	Ly, Lg, Bs, Tp, Ht, Ey, Gf	x
20	Km 120	Fallow land SCP	With	19	Bs, Ly, Tp, Ds, Ei, Lg, Ne	x
21	Km 120	Fallow land SCP	Non	17	Ly, Lg, Bs, Tp, Ht, Ey, Gf	x
22	Pueblo de Morelia	Fallow land SCP	With	17	Bs, Ly, Tp, Ds, Ei, Lg, Ne	x
23	Pueblo de Morelia	Fallow land SCP	With	18	Bs, Ly, Tp, Ds, Ei, Lg, Ne	x
24	Pueblo de Morelia	Fallow land SCP	With	19	Bs, Ly, Tp, Ds, Ei, Lg, Ne	x
25	Pueblo de Morelia	Fallow land SCP	With	19	Bs, Ly, Tp, Ds, Ei, Lg, Ne	x
26	Pueblo de Morelia	TRF SCP	Non	>25	Ly, Ey, Tp, Dl, Kf, Bs, Ba, Mz	x
27	Km 120	TRF SCP	Non	>25	Ly, Ey, Tp, Dl, Kf, Bs, Ba, Mz	x
28	Km 120	TRF SCP	Non	>25	Ly, Ey, Tp, Dl, Kf, Bs, Ba, Mz	x
29	Puebo de Morelia	TRF SCP	Non	>25	Ly, Ey, Tp, Dl, Kf, Bs, Ba, Mz	x
30	Ley de Fomento	Fallow land EG	Non		Ca, Lg, Ll, Ns, Mz, Bt, Mb	x
31	Ley de Fomento	TRF EG	Non		Ps, Ss, Ei, Py, Mp	x
32	Ley de Fomento	Fallow land EG	Non	12	Ca, Ns, Pp, Bs, Lg, Tp, Gc	x
33	Ley de Fomento	Fallow land EG	Non		Ca, Lg, Ll, Ns, Mz, Bt, Mb	x
34	Centauro del Norte	Fallow land EG	Non	30	Ca, Lg, Ll, Ns, Mz, Bt, Mb	x
35	Centauro del Norte	Fallow land EG	Non	20	Ca, Lg, Ll, Ns, Mz, Bt, Mb	x
36	Centauro del Norte	Fallow land EG	Non	12	Ca, Lg, Ll, Ns, Mz, Bt, Mb	x
37	Centauro del norte	TRF EG	Non		Ps, Ss, Ei, Py, Mp	x
38	Narciso Mendoza	Fallow land EG	Non		Ca, Lg, Ll, Ns, Mz, Bt, Mb	x

Plot no.	Ejido name	Vegetation type	M	Age	Plant species	Zs
39	Narciso Mendoza	TRF EG	Non		Ps, Ss, Ei, Py, Mp	x
40	Narciso Mendoza	Fallow land EG	Non	10	Ca, Ns, Pp, Bs, Lg, Tp, Gc	x
41	Narciso Mendoza	Fallow land EG	Non	30	Ca, Lg, Ll, Ns, Mz, Bt, Mb	x
42	Unidad de Trabajo	Fallow land EG	Non		Ca, Lg, Ll, Ns, Mz, Bt, Mb	x
43	Unidad de Trabajo	TRF EG	Non		Ps, Ss, Ei, Py, Mp	x
44	Unidad de Trabajo	Fallow land EG	Non		Ca, Lg, Ll, Ns, Mz, Bt, Mb	x
45	Unidad de Trabajo	Fallow land EG	Non		Ca, Lg, Ll, Ns, Mz, Bt, Mb	x
46	Conhuas	Fallow land EG	Non	7	Ca, Ns, Pp, Bs, Lg, Tp, Gc	x
47	Conhuas	Fallow land EG	Non	20	Ca, Lg, Ll, Ns, Mz, Bt, Mb	x
48	Conhuas	TRF EG	Non		Ps, Ss, Ei, Py, Mp	x
49	Nuevo Becal	Fallow land EG	Non		Ca, Lg, Ll, Ns, Mz, Bt, Mb	x

Ejido: communal settlement where owners can or cannot sell the land. M, management; fallow land SCP, subcaducifolius forest; TRF SCP, tropical rain forest with subcaducifolius characteristics; fallow land EG, fallow land with almost evergreen characteristics (subperennifolius); TRF EG, tropical rain forest with subperennifolius characteristics. Plant species combinations according to vegetation type: Ca, Ns, Pp, Bs, Lg, Tp, Gc, *Croton arboreus*, *Nectandra salicifolia*, *Piscidia piscipula*, *Bursera simaruba*, *Lonchocarpus guatemalensis*, *Bursera simaruba*, *Nectandra salicifolia*, *Thouinia paucidentata*, *Guettarda combssi*; Ps, Ss, Ei, Py, Mp, *Pouteria reticulata*, *Sideroxylon salicifolium*, *Eugenia ibarrae*, *Piper yucatanense*, *Murraya paniculata*; Lg, Bs, Ey, Ca, Ly, Gf, Tp, Ns, *Lonchocarpus guatemalensis*, *Bursera simaruba*, *Esenbeckia yaaxhokob*, *Croton arboreus*, *Lonchocarpus yucatanensis*, *Gymnopodium floribundum*, *Thouinia paucidentata*, *Nectandra salicifolia*; Bs, Ly, Tp, Ds, Ei, Lg, Ne, *Bursera simaruba*, *Lonchocarpus yucatanensis*, *Thouinia paucidentata*, *Diospyros salicifolia*, *Eugenia ibarrae*, *Lonchocarpus guatemalensis*, *Neomillspaughia emarginata*; Ly, Lg, Bs, Tp, Ht, Ey, Gf, *Lonchocarpus yucatanensis*, *Lonchocarpus guatemalensis*, *Bursera simaruba*, *Thouinia paucidentata*, *Hampea trilobata*, *Esenbeckia yaaxhokob*, *Gymnopodium floribundum*; Ly, Ey, Tp, Dl, Kf, Bs, Ba, Mz, *Lonchocarpus yucatanensis*, *Esenbeckia yaaxhokob*, *Thouinia paucidentata*, *Drypetes lateriflora*, *Krugiodendron ferreum*, *Bursera simaruba*, *Brosimum alicastrum*, *Manilkara zapota*.

Table 1. Presence of *Zapatadrilus siboney* (Zs) along the studied sites.

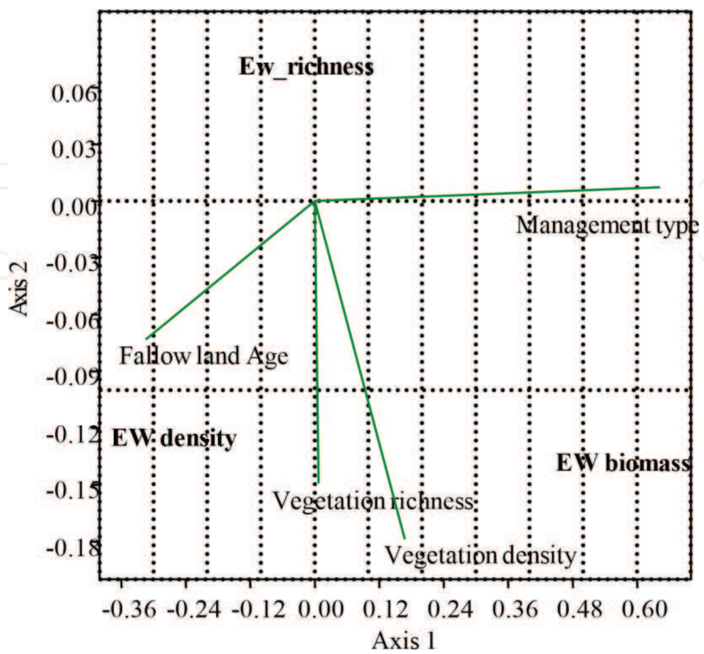

Figure 4. Earthworm community and vegetation characteristics (abundance and richness) among managed and non-managed fallow lands of subcaducifolius forests in Calakmul reserve, after a canonical analysis (99.7% of inertia explained at first axis $p < 0.05$).

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4. Discussion

Fallow land management in Calakmul has been spread among the inhabitants of the reserve; this economical practice allows them to obtain resources (mainly economical) without damaging the environment. In this study we observed that the management of the fallow land doesn't produce an effect over earthworm communities, while the age of the fallow land is more important. The age of fallow lands informs about the plant composition, where an important succession process has been taken place within 25–30 years (>vegetation cover, >diversity, >organic matter in the soil), and earthworms respond to this process. *Zapatadrilus siboney*, endogeic species found in Cuba and north and center of Mexico, has been spread in Calakmul [7, 8] where forest and fallow lands are present. In Mexico, 102 earthworm species have been described, with 51 natives and 51 exotics; in Campeche, only 8 native species and 3 exotics have been found [8]; native species are confined to undisturbed systems. Native species, as being less tolerant to different ranges of temperature and pH [3], can be useful as indicators of soil quality [2]; in this study, *Zapatadrilus siboney* as native species was not affected by the fallow land management, which suggests us that this management can be used in other parts of Mexico where forest vegetation wants to be preserved. Earthworms, as ecosystem engineers [9], have an important role in edaphic processes [10, 11], and more studies are required in tropics, in order to study the relationship between native species and their role in soil quality enhancement.

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