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Earthworm population dynamics in traditional slash and burn cultivation in Mizoram, Northeast India

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Abstract

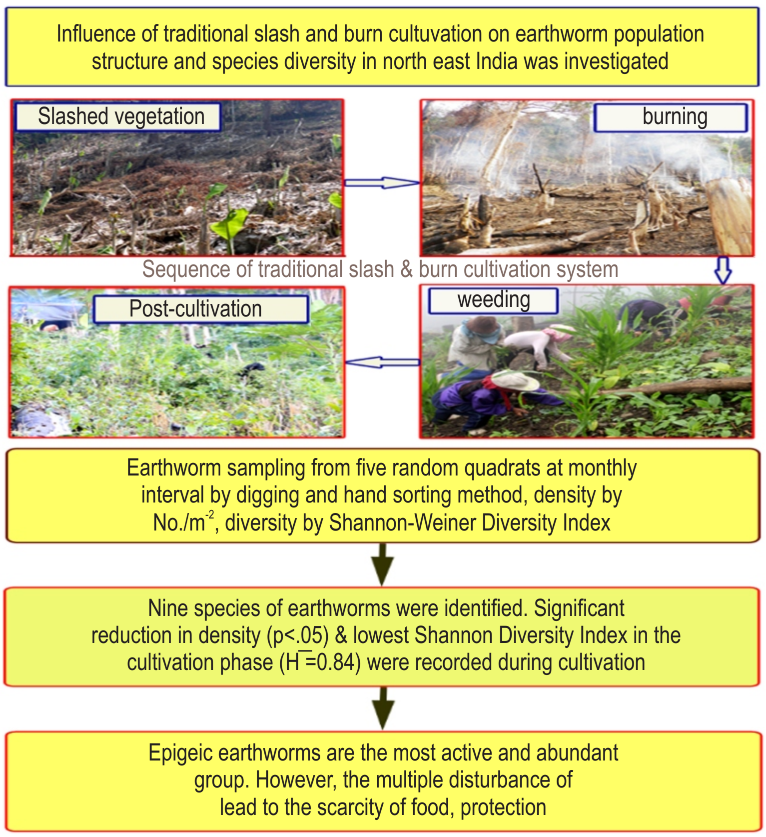
Aim: This paper describes the influence of traditional slash and burn (shifting) cultivation on earthworm population structure and species diversity.

Methodology: The study was conducted in a tropical hilly terrain natural forest in northeast India. The first year was taken as pre–cultivation phase. During second-year traditional slash and burn cultivation was carried out with rice (*Oryza sativa*) as the main crop, where local weeding practice using had hoe was done thrice. The land was left fallow in the third year. Earthworms were sampled from five random quadrats at monthly interval by digging and hand sorting method.

Results: Nine species of earthworms belonging to three families were identified, out of which three epigeic species (*P. excavatus, P. macintoshi* and *A. alexandri*) were not recorded during the cultivation phase. There was a significant (p<.05) reduction in earthworm density during the cultivation phase. *M. houletti* was the most dominant species in terms of density, while *D. nepalensis* was the most versatile in seasonal distribution. Shannon Index of diversity was lowest in the cultivation phase ($\bar{H}$=0.84, 1-D=0.46) as compared to pre-cultivation ($\bar{H}$=1.67, 1-D=0.76) and post-cultivation ($\bar{H}$=1.67, 1-D=0.77).

Interpretation: The reason for negative effect of traditional slash and burn cultivation on earthworm population density and diversity could be due to multiple weeding practices resulting in the disturbance of surface soil that directly or indirectly affects earthworms.

Key words: Earthworms, Epigeic species, Mizoram, Slash and burn cultivation, Soil, Weeding



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Introduction

Earthworms are the most significant group of soil macrofauna in temperate as well as tropical soils for their beneficial effects being relevant predominantly in agricultural and allied sciences. They play a critical role in maintaining soil quality, fertility and productivity (Bhadauria *et al.,* 2009). Various soil management options can have a dramatic effect on earthworm community structure (Decaens *et al.,* 2004). Burning natural forest for cultivation temporarily increases the availability of soil nutrients through rapid mineralization, addition of nutrient-rich ash and change in soil pH, and can further result in long-term nutrient losses due to increased erosion and leaching, in addition to volatile losses during combustion (Sommer *et al.,* 2004). Therefore, modification of natural habitat for agricultural purpose may harm population density, species diversity, richness and activities of earthworm communities (Ponge *et al.,* 2013).

India is one of the richest host of tropical earthworms with 590 species (Julka *et al.,* 2009) and notable quantity of investigation has been conducted on earthworm ecology, however, only sporadic reports are available on earthworm diversity and population structure with respect to land use system including Blanchart and Julka (1997). Despite the availability of numerous literatures on the impact of slash and burn (shifting) cultivation on soil attributes and vegetation in different areas of the world (Gafur *et al.,* 2003; Lawrence *et al.,* 2005; Diekmann *et al.,* 2007; Are *et al.,* 2009), information on slash and burn (shifting) cultivation with special reference to earthworms is scanty. Few reports related to various land-use systems and earthworm community structure is available from the northeast region of India (Mishra and Ramakrishnan, 1988; Bhadauria and Ramakrishnan,1989; Darlong and Alfred, 1991; Chaudhuri and Nath, 2011; Dey and Chaudhuri, 2014; Jamatia and Chaudhuri, 2017; Zodinpuii *et al.,* 2019). However, these previous works did not deal with the detailed earthworm community dynamics during traditional slash and burn cultivation systems.

The slash and burn cultivation system is the main mode of agriculture in tribal-dominated Mizoram state. Information on the influence of traditional slash and burn cultivation on earthworm diversity and density is meagre, hence, the present study was conducted to evaluate earthworm community structure and species diversity in such type of land use system.

Materials and Methods

Study area: The study was conducted for three years (2013 to 2015) at an experimental plot of one acre of natural forest at Khawrihnim (23°36'58" N and 92°38'04" E, 950 m above sea level), located in Mamit district, Mizoram in northeast India. The landscape is steep with a slope percentage that ranges from 55% to 80%. The dominant vegetation of this area includes tree species like *Ficus prostrate, Saurauia punduana, Macaranga indica*, etc., wild banana (*Musa paradisiacavar. sylvestris*) and climbers. The forest is a tropical semi-evergreen rainforest and receives annual rainfall of about 2500 mm. The soil is of acidic (pH 4.5 to 6.7) nature. The study period was divided into three phases, viz., Pre-cultivation phase (first year), Cultivation phase (second year) during which traditional slash and burn cultivation system was practiced, and Post-cultivation phase (third year).

Traditional slash and burn cultivation (locally called shifting cultivation) involves slashing of vegetation in December/January, followed by burning of dried vegetation in March and sowing of seeds in April/May. Multiple cropping is practiced with about 20 different kinds of crops, with rice (*Oryza sativa*) as the main crop. Weeding is usually carried out three times a year, where weeds are pulled-out along with roots and upper fertile soil is roughly semi-tilled with a hand hoe.

Earthworm sampling: Earthworm samples were collected from five random sites, located at least 20 m apart at monthly interval. At each sampling point, blocks of soil (25cm x 25 cm x 20 cm) was dug out, earthworms were collected by hand sorting method (Anderson and Ingram 1993), fixed overnight in 4% formalin and preserved in 70% alcohol for further study. Variation in seasonal earthworm population was determined from average monthly data obtained from five random samplings in each month. Density was determined as number of individuals per square meter. The taxonomic study was done on adult specimens at Research and Instrumentation Centre, Pachhunga University College by thorough morphological and anatomical examinations using Optika Stereomicroscope (SZN-4) and earthworm monographs (Stephenson, 1923; Gates, 1972; Julka, 1988).

Data analysis: Data obtained from the experiments were used to determine Shannon's Diversity Index, Simpson's Index of Dominance, Menhinick's Species Richness Index and Pielou's Evenness Index with a software, Paleontological statistics (PAST) version 1.86b (Hammer *et al.,* 2001). The average of data obtained from five random samples in each month was utilized for calculating earthworm density (ind. m^{-2}) using Microsoft Office Excel. Significant differences in density between different cultivation phases and seasons were analyzed by ANOVA using Statistical Software package SPSS 20.

Results and Discussion

Nine species of earthworms representing five genera under three families were identified (Table 1). This comprised five species of family Megascolecidae, *viz. Perionyx excavatus* (Perrier), *P. macintoshi* (Stephenson), *Metaphire houlleti* (Perrier), *Amynthas alexandri* (Beddard) and *A. corticis* (Kinberg), two species each of Moniligastridae *i.e., Drawida nepalensis* (Michaelsen) and one *Drawida sp.,* and Octochaetidae i.e., *Eutyphoeus gigas* (Stephenson) and *E. assamensis* (Stephenson). This recorded number of species fits within the reported range of Edwards and Bohlen (1996), who reported that species diversity in a particular community generally ranges from 4-14 species. Prior to this study, five species of earthworms have been previously recorded from two agroforestry sites in Mizoram (Lalthanzara *et al.,* 2011). Interestingly, the conversion of natural forest to slash and burn cultivation system has resulted in the disappearance of three epigeic species of earthworms, viz. *P. excavatus, P. macintoshi* and *A. alexandri.* (Fig. 1).

All other earthworm species were recorded in the cultivation phase, but in reduced numbers. Due to burning effect as cocoons and diapause adults of these epigeic species are killed during burning and later, the semi-tilled surface soil during multiple weeding can completely disturb the surface dwellers by removing food sources, reducing soil moisture and surface cover that directly expose them to sunlight and their predators. Disappearance of native species, shifts in species composition and loss in species richness in slash and burn cultivation has been reported ealier (Dlamini and Haynes, 2004; Bhadauria *et al.,* 2009; Dash and Saxena, 2012). In line with our findings, Fragoso and Lavelle (1992) reported a dramatic decrease of epigeic and anecic earthworms due to loss of surface litter cover after conversion of rain forest to agricultural land in various tropical regions. Bhadauria and Ramakrishnan (2005) reported loss of two native species after the conversion of primary forest to slash and burn cultivation in northeast India.

Taking species-wise density and relative abundance into account, *M. houlleti* was the dominant species, with highest density (169.6 ind.m^{-2}), while *Drawida* sp. and *E. gigas* were frequent species at study site (Table 1). This could be due to epi-endogeic nature of *M. houlleti* and *Drawida* sp., and anecic nature of *E. gigas* a voiding soil surface disturbance by weeding practice. The report of Kale and Karmegam (2010) deviates from our results as they elucidated that *Lampito mauritii* was the most widely distributed earthworm species in different agro-ecosystems in India. Mean while, *P. excavatus* was rare in terms of population density (lowest density 32 ind.m^{-2}), relative abundance and frequency (Table 1), as it is an epigeic species,

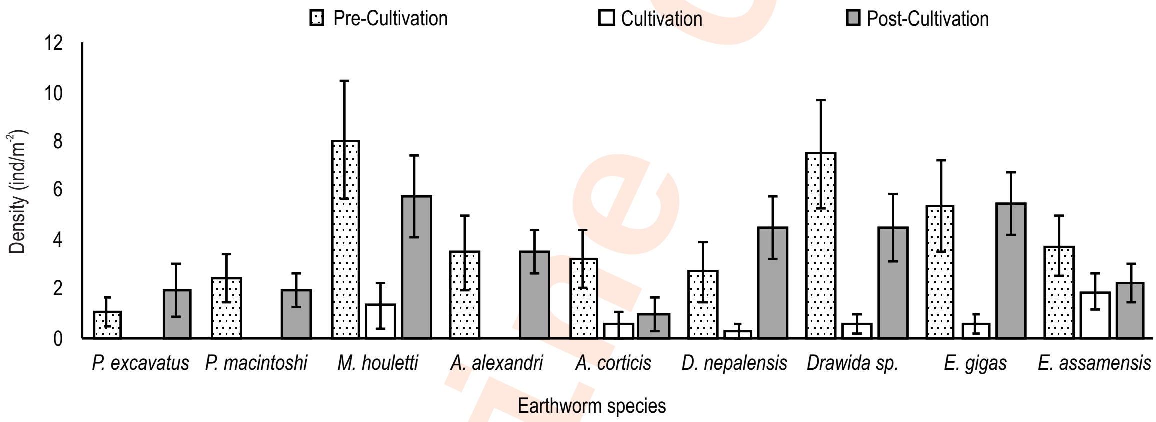

Fig. 1: Species-wise density (ind.m^{-2}) of earthworms in three cultivation phases (2013-2015).

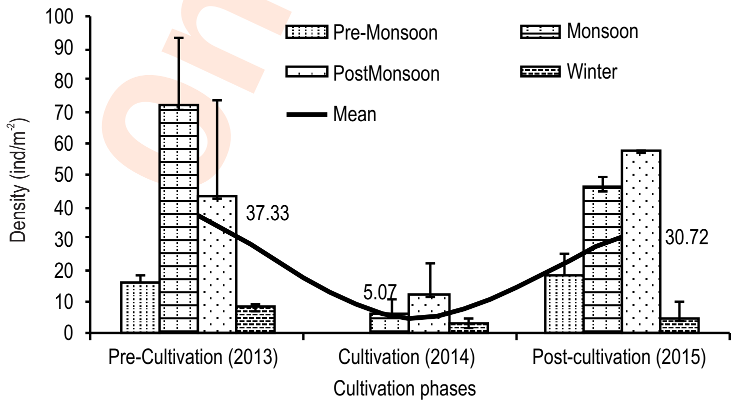

Fig. 2: Seasonal variation of earthworm density (ind. m^{-2}) in three cultivation phases (2013-2015).

Table 1: Earthworm species composition and species wise population status (2013-2015)

Family, Genus and Species	Density (ind.m^{-2}) Mean±SE	Relative abundance (%)	Frequency (%)
Megascolecidae			
Perionyx excavatus Perrier	0.94±0.39	3.92	17.65
Perionyx macintoshi Stephenson	1.41±0.43	5.88	29.41
Metaphire houlleti Perrier	4.99±1.12	20.78	47.06
Amynthas alexandri Beddard	2.26±0.64	9.41	35.29
Amynthas corticis Kinberg	1.60±0.53	6.67	26.47
Moniligastridae			
Drawida nepalensis Michaelsen	2.35±0.62	9.80	38.24
Drawida sp.	4.14±0.99	17.25	52.94
Octochaetidae			
Eutyphoeus gigas Stephenson	3.67±0.83	15.29	52.94
Eutyphoeus assamensis Stephenson	2.64±0.55	10.98	50.00

Table 2: Diversity indices of earthworm community during three cultivation phases (2013-2015)

	Cultivation Phases		
Indices	**Pre-Cultivation (2013)**	**Cultivation (2014)**	**Post-Cultivation (2015)**
Shannon diversity index (Ĥ)	1.67	0.84	1.67
Simpson's index of dominance (1-D)	0.76	0.46	0.77
Menhinick species richness index (R)	1.41	1.05	1.41
Pielou's Evenness index (J')	0.91	0.67	0.94

adversely affected by weeding activities during cultivation practices.

One-Way ANOVA indicated significant variation in density of *P. macintoshi* [$F_{(2,33)}$= 3.475, p=.043], *M. houlleti* [$F_{(2,33)}$= 3.802, p=.033], *A. alexandri* [$F_{(2,33)}$= 4.000, p=.028], *D. nepalensis* [$F_{(2,33)}$= 4.527, p=.019], *Drawida* sp. [$F_{(2,33)}$= 5.576, p=.009] and *E. gigas* [$F_{(2,33)}$= 4.730, p=.016] between different cultivation phases, signifying the negative impacts of cultivation on these earthworm species. A similar observation was reported by Dlamini and Haynes (2004) who studied the influence of agricultural land on earthworm communities in South Africa.The effect of season and cultivation phase on the density of earthworms was analyzed byTwo-way ANOVA. Although cultivation phase [$F_{(2,22)}$ = 7.440, p = .003] and season [$F_{(3,22)}$ = 7.639, p = .001] influenced the density of earthworms, but no significant influenced of combined effects of season and cultivation on the density of earthworms was noticed [$F_{(6,22)}$=1.862, p=.133]. This is unanticipated; however, the coincidence of the earthworm's favorable environmental condition (i.e. rainy season) and the cultivation peak activity (i.e. weeding) could be attributed for this statistically not-significant combined effect of season and cultivation on density.

In total, 255 individuals of earthworms were collected throughout the study period. The mean density of earthworms during pre-cultivation, cultivation and post-cultivation phases were 37.33, 5.07 and 30.72 respectively (Fig. 2), indicating significant reduction in density of earthworms during cultivation phase [$F_{(2,33)}$= 5.140, p = .012]. Nunes *et al.* (2006) reported a decrease in abundance and diversity after the conversion of pasture to crop cultivation in Brazil. Similarly, a significantly low density of earthworms in agricultural land was reported by Kalu *et al.* (2015) as compared to forest and grassland in Nepal. Significant reduction in density of earthworms during the cultivation phase as compared to pre-cultivation and post-cultivation may be attributed to semi-tilled surface soil, loss of nutrients, moisture and surface litter as a result of weeding. In line with our result, Jordan *et al.* (2000) had reported reduced earthworm density due to depletion of organic matter and nutrients. A gradual increase in population density of earthworms (30.72 ind. m^{-2}) in the post-cultivation phase may be attributed to availability of nutrients, more retention of moisture and no soil disturbance.

A comparison of diversity indices of earthworm community in three phases of cultivation is given in Table 2. Shannon Index of Diversity was low in cultivation phase (0.84) as compared to pre-cultivation/natural forest (1.67) and fallow/post-cultivation phase (1.67). Species richness and evenness of earthworms were drastically reduced in the cultivation phase as compared to pre-cultivation and post-cultivation phases. This may be attributed to the negative impact of habitat disturbance, removal of surface litters and weeding practices during the cultivation phase. Similarly, Dash and Saxena (2012) reported loss of earthworm species richness due

Table 3: Diversity indices of earthworm community in different climatic seasons (2013-2015)

	Seasons			
Indices	**Pre-Monsoon**	**Monsoon**	**Post-Monsoon**	**Winter**
Shannon diversity index (Ĥ)	1.80	2.09	2.05	0.99
Simpson's index of dominance (1-D)	0.82	0.86	0.85	0.60
Menhinick species richness index (R)	1.24	0.72	1.24	0.80
Pielou's Evenness (J')	0.93	0.95	0.93	0.90

Table 4: Correlation of temperature and moisture content of soil with average earthworm density and cultivation phase-wise density (ind. m^{-2}). n = number of observations, r represents Pearson correlation coefficient and P represents significance probability

Soil property		**n = 34 Density (ind. m^{-2})**	**Pre-cultivation Phase n = 12 Density (ind.m^{-2})**	**Cultivation Phase n = 12 Density (ind. m^{-2})**	**Post-cultivation Phase n = 10 Density (ind. m^{-2})**
Temperature	r	.016	.234	-.107	.663*
	P	.930	.465	.740	.037
Moisture content	r	.474**	.402	.209	.672*
	P	.005	.195	.515	.033

to conversion of natural forest by shifting cultivation practices. Similarly, Crittenden *et al.* (2014) reported reduced earthworm species richness after land management. Bhadauria *et al.* (2000) were also of the opinion that extensive deterioration of natural forest has an adverse effect on earthworm diversity. They also reported that earthworm diversity at a particular region chiefly depends on the type of agricultural practice and perturbation (Bhadauria *et al.,* 2000). On the other hand, it was generally understood that earthworm diversity is mainly influenced by soil nutrients and rainfall patterns (Singh *et al.,* 2016). Shannon diversity index (Ĥ) of earthworm (0.84) at shifting cultivation site in Mizoram was lower as compared to 1.76 (mixed forest in Tripura) by Chaudhuri and Nath (2011), mixed fruit plantation in Tripura (1.57) by Dey and Chaudhuri (2014), mixed tree plantation semi arid lands of western India (1.58) by Suthar (2011) and forest in the Western Ghats (2.53) as reported by Blanchart and Julka (1997).

These data confirm the drastic effect of shifting cultivation on earthworm diversity. Species richness index (1.05), however, is much higher than that of rubber plantation (0.45) having a huge amount of in edible turf and human disturbances (Chaudhuri and Nath, 2011), mixed fruit (0.69) (Dey and Chaudhuri, 2014) and mixed tree plantation (0.74) (Suthar, 2011). This may be attributed to varying soil conditions and the difference in the type of crop plantation. In line with the result of this study, Chaudhuri and Nath (2011) also revealed that the community structure of earthworms depend on the type of land-use practices and clearance of natural vegetation and cultivation of crops in a particular land always have depleted macro-invertebrate communities with low diversity. They also observed that under agro ecosystems earthworm population disappeared due to disturbances.

The seasonal variation of earthworm density in each cultivation phase is presented in Fig. 2. No earthworms were sampled during pre-monsoon season at cultivation phase. This could be due to slashed and burned activity. While the density of earthworms gradually increased from pre-monsoon [11.38] to monsoon [41.60], and gradually decreased from monsoon to winter [5.6±1.45] via post-monsoon [33.92±13.52] season [$F_{(2,33)}$= 4.327, p=.012]. This population fluctuation trend follows the changes in season. Earthworm diversity indices of various seasons are given in Table 3. Shannon Diversity Index was highest in monsoon (2.09) followed by post-monsoon (2.05) and pre-monsoon (1.81), while it was lowest in winter (0.99). Seasonal fluctuations observed from the study, i.e., increased population density and diversity during the rainy season and decline in the dry season has been noted as a general trend by many workers (Lalthanzara and Ramanujam, 2014; Kumar *et al.,* 2018). The results of this study suggest that the seasonal dynamics of earthworm population is not affected by practicing slash and burn cultivation system.

Pearson correlation analysis showed a positive and significant correlation (p<.05) between earthworm density and moisture content of the soil in all three cultivation phases (Table 4). This is a universal observation as earthworms perform cutaneous respiration, moisture is an inevitable habitat component (Lalthanzara *et al.,* 2011). Although not statistically significant (p>.05), a positive correlation was observed between earthworm density and soil temperature, even in pre-cultivation and post-cultivation phases. A similar observation has been reported from agro-ecosystem by Lalthanzara *et al.* (2011).

The practice of traditional slash and burn cultivation systems has resulted in a decline of earthworm population density and diversity. The main reason for this adverse effect could be the disturbance of surface soil due to multiple weeding practices that led to the removal of soil surface cover, that led to the scarcity of food, loss of protection, the decline in moisture content, and frequent disturbance for the epigeic and epi-endogeic earthworms.

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Add-on Information

Authors' contribution: H. Lalthanzara: Design the experiment and supervise the work, write and finalise the MS; **Betsy Zodinpuii:** Perform the experiment, analyse the data and interpret the result, draft the MS.

Research content: The research contents is original and has not been published elsewhere

Ethical approval: Not Applicable.

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