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The Diversity of Terrestrial Earthworm in Agricultural Land and Adjacent areas, Uttaradit Province, Thailand

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Abstract The diversity of terrestrial earthworms was studied in 4 sub-districts of Uttaradit Province namely; Numrid, Kungtapao, Pasao, and Hadkruad. The earthworms and soil samples were collected in 6 land types consisted of rice field, vegetable plantation, Crop plantation, Orchard, Grove, and Residential area. Results showed that 24 earthworm species in 5 families were founded. *Pontoscolex corethrurus* was the only one of the family GLOSSOSCOLECIDAE. We founded 15 species of the family MEGASCOLECIDAE, 3 species of the family MONILIGASTRIDAE, 4 species of the family OCTOCHAETIDAE, and 1 species of ALMIDAE. Of these, 10 were supposed to be new species. The most diversity of earthworm species was found in the Pasao sub-district (21 species). The highly abundant species were *M. posthuma, M. peguana,* and *M. houlleti* respectively. The population density of earthworms was significantly different in June and August; highly in vegetable plantation areas followed by residential areas respectively.

Keywords: earthworm; diversity; agricultural land

Introduction

The foods from plants or animals are products in Agriculture. The good yield and productivity from agricultural products for public health should come from the good soil. Fertile soils are a crucial element of food security, providing the basic foundation of agroecosystems (Johnston *et al.*, 2015). An extensive quantity of chemical pesticides and fertilizers has been used to boost up crop yield from agricultural land which resulted in good yield and productivity. The modern agricultural practice has caused a steep fall in the number and biodiversity associated with cropland ecosystem and has also produced ill effect to the human through the food chain (Singh, 2018). Earthworms are known as macro soil fauna that can maintain the soil fertile. It is a key important to maintain good soil properties for plants, such as soil physical, soil chemical, and soil biological properties. The land that has abundant of earthworms were plant nutrient-rich content which is easily available for the plants (Edwards, 2004). Crops grown in earthworm inhabited in soil to increase yields from 25% to over 300% than in

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earthworm-free soil (Edwards and Bohlen, 1996). Soil organisms, including earthworms, are a key component of terrestrial ecosystems. The provisioning of ecosystem functions by earthworms depends on the abundance, biomass, and ecological group of the earthworm species, and soil properties such as pH and soil carbon influence earthworm diversity (Phillips, 2019). Management practices which optimize soil environmental conditions also stimulate earthworm biomass production (Lavelle *et al.*, 2006). Earthworm diversity is reduced in habitats with more intensive anthropogenic interventions. The conversion of natural forests into different land uses has reduced earthworm diversity which can substantially affect soil health and ecosystem functions. The population and diversity of earthworm species vary across land habitats and sensitive to change in land use (Mulia *et al.*, 2021). The earthworm diversity in Thailand has little been reported especially in agricultural land use. Uttaradit Province is located in the lower north of Thailand about 483 from Bangkok, at 17°37′23″N and 100°5′45″E cover area of 7,838 square kilometers. The land for agriculture was 25.48% of this 54.51% used for rice production, 25.24 % for crop production, 12.32 % for trees and orchards, 1% for vegetables and ornamental plants, and 6.91% for other activities. The project is presented the information about these conditions for future study and land management to benefit both farmers and environment friendly.

Materials and methods

The study was conducted in 4 sub-districts of Uttaradit Province, namely; Numrid, Kungtapao, Pasao, and Hadkruad. The study sites are divided into 6 different land-use types. There consists of rice fields, vegetable plantations, crop plantations, orchards, groves, and residential areas, every 3 replications, 4 times in 2013, June, August, September, and December. Earthworm and soil samples were collected from the areas that are suitable for earthworm living such as more litter cover, or more earthworm cast presented. The samples were collected from the site in 1x1m. and 30 cm. depth. The earthworm samples were collected by digging and hand sorting method. All specimens were knocked in 70 % of ethanol then transfer to 10% formalin for long-term storage. To avoid the effects from formalin, unless than a week the samples have to transfer to 70% ethanol before identification, by using keys of Gates (1972), and Sims and Easton (1972), and others were available. The soil samples (500 g) were taken to measure pH, moisture. Soil pH was determined in a water suspension at a 2:5 soil: water ratio. Soil moisture was determined by the percent of the weight of fresh soil sample after dried at105 °C for 24 hours (Buurman *et al.*, 1996). Soil temperature was measured at site sampling by using a digital thermometer. The environmental data of soil factors were analyzed using ANOVA. To comparing among variables, we used a

Randomized Complete Block Design (RCBD) (Treatment=land uses, Block=sub-district), followed by Duncan's Multiple Range Test (DMRT) at the P = 0.05 confidence level. Evenness and Shannon-Wiener index (Krebs, 1985) were used to compare the diversity of earthworms among sites. Differences in earthworm density and species abundance among land-use types were analyzed with ANOVA. The Pearson correlation was employed to find the relationship among soil parameters.

Results

Earthworm species diversity

There are 25 species in five families were found in this study. The most abundant was the family Megascolecidae. There are 15 species, consists of *Amynthas longiculiculatas*, *Amynthas alexandrii*, *Amynthas alexandrii-group*, *Amynthas* sp.1, *Amynthas* sp.2, *Metaphire anomala*, *Metaphire bahli*, *Metaphire houlleti*, *Metaphire peguana*, *Metaphire posthuman*, *Metaphire planata*, *Metaphire* sp.1, *Metaphire* sp.2, *Metaphire* sp.3, and *Polypheretima elongata*, followed by 4 species of the family Octochaetidae consists of *Dichogaster affinis*, *Dichogaster bolaui*, *Dichogaster* sp.1, and *Dichogaster* sp.2, three members of the family Moniligastridae such as *Drawida* sp.1, 2, and 3, and finally *Pontoscolex corethrurus* only species of the family Glossoscolecidae and *Glyphidrilus* sp. of the family Almidae. The highest diversity was found in Numrid (H'=2.28) followed by Kungtapao (H'=2.27), Hadkruad (H'=2.13) and Pasao (H'=2.04) respectively. While the species richness was found in Pasao (21 species). The highest population abundant was *Metaphire posthuma* (29.17%) about 1 by 3 apart of total and also distributed in all areas (Table 1).

The highest of earthworm populations were found in residential areas (755 individuals), followed by vegetable planting areas (684 individuals), and rice fields (650 individuals), while the lowest were 210 individuals in cropping areas. Ten of these suggested being new species such as, *Amynthas* sp.1,2 *Metaphire* sp.1,2,3 *Dichogaster* sp.1,2, and *Drawida* sp.1,2,3. When we looking for the diversity among different land uses types the results were shows. The most diversity was found in the grove types (H'=2.36) followed by orchard types(H'=2.26), and crop types(H'=2.12), while the lowest species diversity was found in vegetable types (H'=1.53). In contrast, vegetable land uses had high spices richness (18 species), but cropping lands was the lowest of species richness (12 species). Earthworm species that had high distribution in all land uses types were *M. posthuman*, *Metaphire peguana*, *M. houlleti*, *Amynthas alexandrii*, *Metaphire* sp.1 *Metaphire* sp.2 and *M. planata* respectively. Almost of land uses were dominated by the member of genus *Metaphire* excepted in rice field areas were dominated by *Glyphidrilus* sp. and the member of genus *Metaphire*. Whereas, earthworms that very site-specific species which presented in one habitat such as *Amynthas* sp.2 presented in the orchard, *Metaphire* sp.3 presented in cropping areas, *Dichogaster* sp.1 in residential areas, *Dichogaster* sp.2 presented in cropping land, and *Glyphidrilus* sp. presented in Rice field. The data shows in Table 2.

Table 1. The species diversity of earthworm in different areas (sub-districts)

		Areas(sub-district)					
	Family/species	**Numrid**	**Kungtapao**	**Pasao**	**Hadkruad**	**Total**	**%**
	Glossoscolecidae						
1	*Pontoscolex corethrurus*	3	75	33	11	122	4.06
	Megascolecidae						
2	*Amynthas longiculiculatas*	0	0	6	6	12	0.40
3	*Amynthas alexandrii*	60	50	47	39	196	6.52
4	*Amynthas alexandrii-grouן*	4	4	0	4	12	0.40
5	*Amynthas sp.1*	3	0	0	0	3	0.10
6	*Amynthas sp.2*	0	0	2	0	2	0.07
7	*Metaphire anomala*	54	12	35	11	112	3.73
8	*Metaphire bahli*	0	2	2	0	4	0.13
9	*Metaphire houlleti*	44	52	82	51	229	7.62
10	*Metaphire peguana*	169	133	65	90	457	15.20
11	*Metaphire posthuma*	103	241	359	174	877	29.17
12	*Metaphire planata*	30	46	32	14	122	4.06
13	*Metaphire sp.1*	15	40	28	100	183	6.09
14	*Metaphire sp.2*	113	31	13	8	165	5.49
15	*Metaphire sp.3*	9	0	1	1	11	0.37
16	*Polypheretima elongata*	22	14	16	12	64	2.13
	Octochetidae						
17	*Dichogaster affinis*	1	0	2	10	13	0.43
18	*Dichogaster bolaui*	0	5	3	0	8	0.27
19	*Dichogaster sp.1*	0	0	3	0	3	0.10
20	*Dichogaster sp.2*	0	0	0	4	4	0.13
	Moniligastridae						
22	*Drawida sp.1*	13	6	4	0	23	0.77
23	*Drawida sp.2*	0	31	5	5	41	1.36
24	*Drawida sp.3*	5	11	14	0	30	1.00
	Almidae						
25	*Glyphidrilus sp.*	88	45	40	140	313	10.41
	Species number	17	17	21	17	3006	100
	Population number	736	798	792	680		
	Species diversity	2.28	2.27	2.04	2.13		
	Evenness index	0.80	0.80	0.67	0.75		

Table 2. The diversity of earthworm in different land uses

		Type of land use					
	Family/species	**Rice**	**Vegetable**	**Crop**	**Orchard**	**Grove**	**Residence**
	Glossoscolecidae						
1	*Pontoscolex corethrurus*	0	5	0	93	19	5
	Megascolecidae						
2	*Amynthas longiculiculatas*	0	6	0	3	0	3
3	*Amynthas alexandrii*	30	36	36	23	26	45
4	*Amynthas alexandrii*-group	5	4	0	0	3	0
5	*Amynthas* sp.1	0	0	0	2	1	0
6	*Amynthas* sp.2	0	0	0	2	0	0
7	*Metaphire anomala*	0	17	4	29	38	24
8	*Metaphire bahli*	0	3	1	0	0	0
9	*Metaphire houlleti*	32	37	23	33	35	69
10	*Metaphire peguana*	56	47	32	99	25	198
11	*Metaphire posthuma*	25	436	20	82	21	293
12	*Metaphire planata*	13	30	45	11	3	20
13	*Metaphire* sp1	81	13	24	11	28	26
14	*Metaphire* sp2	57	17	5	27	20	39
15	*Metaphire* sp3	0	0	10	0	0	1
16	*Polypheretima elongata*	4	13	0	19	10	18
	Octochetidae						
17	*Dichogaster affinis*	2	6	0	1	0	4
18	*Dichogaster bolaui*	5	3	0	0	0	0
19	*Dichogaster* sp1	0	0	0	0	0	3
20	*Dichogaster* sp2	0	0	4	0	0	0
	Moniligastridae						
22	*Drawida* sp1	0	1	5	12	3	2
23	*Drawida* sp2	9	7	0	20	3	2
24	*Drawida* sp3	18	2	0	2	5	3
	Almidae						
25	*Glyphidrilus* sp.	313	0	0	0	0	0
	Species number	14	18	12	17	15	17
	Population number	650	684	210	469	240	755
	Species diversity	1.81	1.53	2.12	2.26	2.36	1.85
	Evenness index	0.13	0.08	0.18	0.13	0.16	0.11

The significantly different earthworm densities were found in different land uses at different times. But non-significantly differences among the area sites(sub-district) were found. The average earthworm density was reported to be high in August followed by June October and December respectively. The earthworm density was highly significant found in August. The highest was 29.92 ind./m^2 in vegetable plantation, and followed by 29.75 ind./m^2 in residential areas. The lowest was 9.67 ind./m^2 in cropping areas. A significant difference was found in June. The highest was found in residential areas (21.33 ind./m^2), and followed by vegetable and orchard (18.83, 18.17 ind./m^2) respectively. The earthworm density showed non-significantly different in October and December, slightly in vegetable and residence areas were found. The earthworm density ununiform were found among area sites(sub-district). Namrid had high recorded in August (23.00 ind./m^2) as same as Kungtapao had found in 19.50 ind./m^2. Pasao had high prevalent in October (17.61 ind./m^2) whereas, Hadkruad was high density of 15.00 ind./m^2 in June (Table 3).

Table 3. The average of earthworm density (ind./m^2) and distribution by land use and area sites in 2013

Land uses(T)/ Area sites(B)	June	August	October	December
T1= Rice	9.75± 9.02^{abc}	11.50±12.62^{b}	13.25±17.55	1.33±4.62
T2=Vegetable	18.83±12.5^{a}	29.92±25.18^{a}	20.08±19.24	2.00±4.75
T3=Crop	6.00±11.56^{c}	9.67±9.84^{b}	7.92±5.65	0.17±0.58
T4=Orchard	18.17±14.43^{ab}	15.67±7.74^{b}	15.42±12.43	2.17±5.73
T5=Grove	6.58±7.06^{bc}	11.58±12.35^{b}	4.33±4.75	0.00±0.0
T6=Residence	21.33±21.96^{a}	29.75±13.05^{a}	19.67±21.39	0.42±1.00
B1=Numrid	10.39±9.14	23.00±18.07	8.44±5.76	0.39±0.92
B2=Kungtapao	16.33±14.73	19.50±15.52	15.44±11.92	1.11±4.71
B3=Pasao	12.06±19.11	16.11±16.51	17.61±18.81	0.72±2.42
B4=Hadkruad	15.00±13.87	13.44±15.46	12.28±20.79	1.83±4.85
CV(%)	101.94	79.98	110.62	359.74
Sig.Treatment	*	**	ns	ns
Sig. Block	ns	ns	ns	ns

ns, *, **, =non-significant, significant at $P < 0.05$ and $P < 0.01$, respectively
Mean in the columns followed by different letter are significantly different at P = 0.05

Table 4. The soil temperature (◦C) factor in different land uses, area sites, and months

Land uses(T)/ Area sites(B)	June	August	October	December
T1= Rice	31.38±1.00	28.19±1.05b	27.08±0.87	24.29±1.45
T2=Vegetable	31.46±1.27	29.54±2.20a	27.25±0.87	23.83±1.15
T3=Crop	31.63±1.38	29.71±2.29a	27.71±0.72	24.58±1.22
T4=Orchard	31.29±1.29	29.63±2.14a	27.25±0.92	24.71±0.58
T5=Grove	31.33±1.72	29.54±1.96a	27.46±0.81	24.88±0.74
T6=Residence	31.67±1.19	29.58±2.29a	27.38±0.71	25.00±0.71
B1=Numrid	30.42±0.52c	30.35±1.22b	27.03±0.53bc	24.28±0.99
B2=Kungtapao	31.03±0.47b	28.06±0.66c	26.94±0.70c	24.83±0.59
B3=Pasao	33.39±0.63a	27.28±0.71d	27.47±0.61b	24.69±1.10
B4=Hadkruad	31.00±0.73b	31.78±1.11a	27.97±0.96a	24.39±1.41
CV(%)	1.91	2.79	2.62	4.17
Sig.Treatment	ns	**	ns	ns
Sig. Block	**	**	**	ns

ns, **, =non-significant, significant at $P < 0.01$, respectively
Mean in the columns followed by different letter are significantly different at P = 0.05

Soil factors and earthworm populations

Soil factors consist of soil temperature, soil moisture, and soil pH. The soil temperatures in collected sites were significantly different by areas, land uses, and months. The highly significant difference in soil temperature was founded in August as the lowest temperature presented in rice field areas (28.19 ◦C). When comparing among areas(sub-district) and months, highly significant were founded in every month, except in December was non-significant differed. The highest temperature in June was 33.39◦C in

Pasao, whereas in August and October revealed the highest temperature of 31.78°C and 27.97°C, respectively in Hadkruad (Table 4).

The soil moisture among land uses was highly significantly different. The rice field had the highest soil moisture around the year. Moreover, highly soil moisture was founded in different land uses as follows, in June presented in the vegetable plantation, in August presented in the orchards, in October presented in the forest, and in December was highly soil moisture which found in the vegetable plantation (Table 5).

Table 5. The soil moisture (%) factor in different land uses, areas, and months

Land uses(T)/Area site(B)	June	August	October	December
T1= Rice	75.38±8.51a	81.42±7.44a	46.60±12.17a	41.57±21.42a
T2=Vegetable	63.78±6.48b	64.2±9.84bc	33.50±7.66b	41.19±15.36a
T3=Crop	57.38±11.82bcd	59.12±11.53cd	28.83±2.94ab	21.36±4.02b
T4=Orchard	58.33±6.29bc	68.15±15.81b	28.45±3.59ab	24.7±7.53b
T5=Grove	51.75±5.50cd	54.50±15.41d	31.83±5.40ab	21.82±3.20b
T6=Residence	50.18±11.26d	55.92±16.99d	27.02±5.85c	26.64±6.45b
B1=Numrid	55.42±14.24	48.96±19.15c	29.85±5.40b	26.27±8.13
B2=Kungtapao	59.23±14.49	62.35±11.70b	31.91±10.66b	26.10±8.26
B3=Pasao	62.45±10.19	69.47±6.50a	32.29±5.56b	33.61±19.33
B4=Hadkruad	60.76±6.72	74.76±9.87a	36.76±13.10a	32.21±16.82
CV(%)	14.17	13.85	20.2	38.57
Sig.Treatment	**	**	**	**
Sig. Block	ns	**	*	ns

ns, *, **, =non-significant, significant at $P < 0.05$ and $P < 0.01$, respectively
Mean in the columns followed by different letter are significantly different at $P = 0.05$

The soil pH among land uses was highly significantly different in June and August, significantly different in December, and non-significant different in October. The soil pH in study sites showed acidity to mild acid, between 5.54 in rice fields and 6.78 in residential areas in August. The lower soil pH was found in rice fields while highly soil pH was presented in residential areas (Table 6).

Table 6. The soil pH factor in different land uses, areas, and months

Land uses(T)/ Area site(B)	June	August	October	December
T1= Rice	5.54±0.65b	6.07±0.55b	6.20±0.52	6.16±0.39b
T2=Vegetable	5.90±0.52b	6.14±0.50b	6.39±0.65	6.35±0.33ab
T3=Crop	6.36±0.54a	6.38±0.38ab	6.37±0.52	6.54±0.26a
T4=Orchard	6.40±0.52a	6.14±0.64b	6.10±0.62	6.48±0.32ab
T5=Grove	6.77±0.38a	6.38±0.54ab	6.34±0.53	6.53±0.26a
T6=Residence	6.62±0.39a	6.78±0.39a	6.59±0.72	6.68±0.61a
B1=Numrid	6.07±0.72	6.28±0.61	6.40±0.62	6.50±0.50
B2=Kungtapao	6.30±0.59	6.39±0.57	6.17±0.65	6.30±0.36
B3=Pasao	6.34±0.61	6.45±0.51	6.61±0.43	6.53±0.28
B4=Hadkruad	6.35±0.68	6.14±0.49	6.15±0.59	6.49±0.42
CV(%)	8.06	7.99	9.11	5.83
Sig.Treatment	**	**	ns	*
Sig. Block	ns	ns	ns	ns

ns, *, **, =non-significant, significant at $P < 0.05$ and $P < 0.01$, respectively
Mean in the columns followed by different letter are significantly different at $P = 0.05$

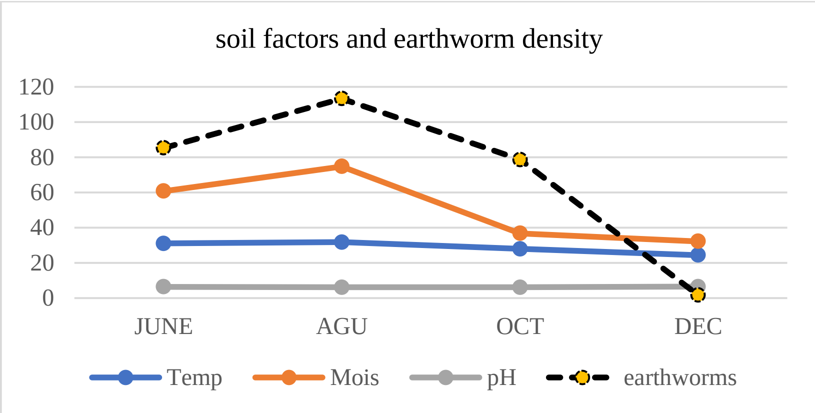

Figure 1. Soil factors and earthworm population dynamic

The earthworm populations involved with soil factors especially soil moisture which gave the earthworm population increased when the soil had more moisture (from June to August) as seen in Figure 1. Whereas the soil moisture decreased from August to October and December that caused earthworm populations to decline. However, soil temperature might affect earthworm populations. For example, soil temperature and earthworm populations showed positive correlations in June and October but negative correlations in August and December. The soil pH showed negative correlations with earthworm populations.

The earthworm dynamic showed that populations of earthworm increased from June to the highest in August and decreased in October and lowest in December, excepted earthworm populations in Orchard was higher density than in June, and decreased in August through December (Figure 2).

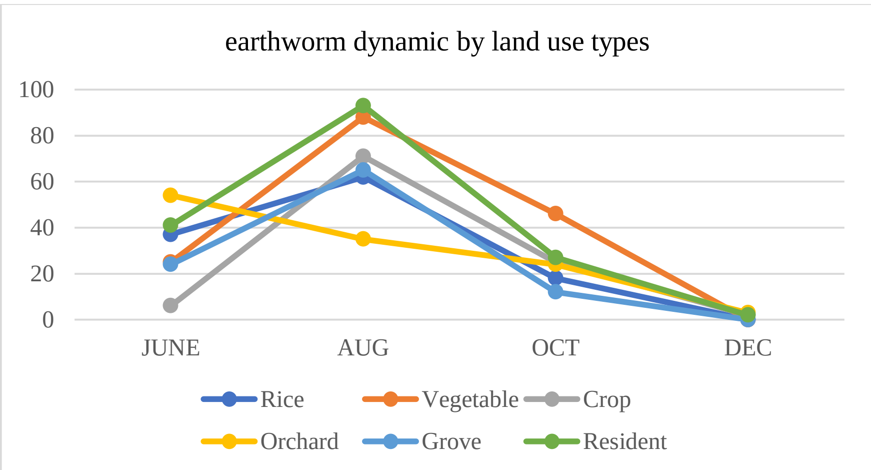

Figure 2. The dynamic of earthworm populations in different land use types

Discussion

Earthworm populations and diversity varies are greated by land-use types and times. The types of land use can affect to earthworm population by vegetation and land disturbance. The seasonal change around the year is caused the soil factors that affected earthworms. Their population are changed by correlated with soil factors, especially positive with the soil moisture. From the results, we found 25 species in five families in this study. This result is similar to Mulia *et al*. (2021) who studied in Vietnam. They also found that 25 different earthworm species. But other studies in Thailand have been reported, such as 27 species by Gate (1972); 13 species by Prasuk (2005); 37 species by Somniyam and Phatdiphanpreeda (2016). This is quite different from Edwards and Bohlen (1996) stated that the number of earthworm species ranges from 1 to 15 species in most habitats and most earthworm communities contain around 3-6 species. The highest of earthworm populations were found in residential areas followed by vegetable plantation areas, and rice fields while the lowest was in cropping areas. It was the same as Somniyam and Suwanwaree (2009); Somniyam and Phatdiphanpreeda (2016) found that high density in residential areas followed by agricultural lands and forests. The human activities around the residence area are food waste, water that may give the soil more moisture and also avoid them from predators. The vegetable planting area may give the soil moisture that suitable habitat for them. Soil preparations by the input of animal manure left of the vegetable residues which easily for decomposing are mostly greated for earthworm food. The most diversity was found in the grove types but cropping lands were the lowest of species richness, the same results were reported by Mulia *et al.* (2021) who stated that species richness had greater in natural forests than annual cropland. Moreover, Nunes *et al*. (2006) found that cropping had a negative effect on earthworm abundance and diversity; fewer individuals and species were found more in the cropping systems than in the pastures. Richard *et al.* (2008) suggested that both land-use intensity and land-use type are strong drivers of the abundance and composition of earthworm communities in agricultural ecosystems. In this study, availability of organic matter from the vegetative forest as the food resource for earthworms may causes high diversity in grove types. Earthworm populations are associated with plant species that provided the amount and quality of above-or belowground they produced (Marhan and Scheu, 2005). The quality of residue is also important. Shakir and Dindal (1997) stated that earthworms depended on the type of dominant vegetative cover in the site. But the history of land use and soil disturbance by heavy tillage for crop production may cause fewer earthworm species in this area. The size of the population depends on a wide range of factors, but most importantly, on the ready availability of organic matter that is the major food resource for earthworms (Lavelle *et* *al.*, 1999). Although the diversity of earthworm species varies greatly by site and habitats. Almost of land uses were dominated by the member of genus *Metaphire* excepted in rice field areas which were dominated by *Glyphidrilus* sp. The Southeast Asian earthworm fauna is dominated by species of Megascolecidae, Moniligastridae, and some Ocnerodrilidae. The most diverse and successful group of earthworm species in this region is the pheretimoid-related genera *Pheretima*, *Polypheretima*, *Metaphire*, and *Amynthas.* In both natural and disturbed ecosystems (Lavelle *et al.,*1999). While the *Glyphidrilus* sp. is presented only in rice fields because it is the semi-aquatic freshwater earthworm that lives in the semi-aquatic habitat between terrestrial and freshwater ecosystems. Earthworm activity in the tropics is also limited to certain seasons. The earthworm populations of earthworms increased from June reaching the highest in August and decline in October and lowest in December. This situation confirmed the report by Somniyam and Phatdiphanpreeda (2016), they found that high densities were discovered in the mid-rainy season, begin with the minimum in August and reaching a maximum in September, and then declining in October. The same results have been reported by many authors, such as Edwards and Bohlen (1996) stated that when the rain began, the population consisted of juvenile individuals. The mature earthworms were found one month later and predominated to the end of the wet season. Gerard (1967) stated that the distribution of each species changed considerably with the time of year. The activities of earthworms differ greatly between seasons and they are active in the spring and Autumn. Earthworms are active mainly in the 4-6 months of the rainy season between May and October (Tiwari *et al.*, 1992). The earthworm populations and their activities are linked closely with rainfall which caused soil condition moisture and then declines when the winter begins and disappeared in summer with less soil moisture. Water constitutes 75-90% of earthworm's bodyweight so the prevention of water loss is a major factor in earthworm survival. Earthworm activity also depends upon the adequate availability of soil moisture (Edward and Bohlen, 1996). In inconclusions, earthworm populations and diversity vary with land uses types and times. The agricultural land use can affect to earthworm populations by vegetation and land used practices, while the season changed around the year made their population changed by correlated with soil factors. So, left vegetative residues after harvesting and low practice in agricultural land are ideas for earthworm conservation for good to the farmers. Finally, *Metaphire posthuma is* the most abundant of all agricultural habitats. We recommend it for use for soil improvement in agricultural land (Figure 3, 4).

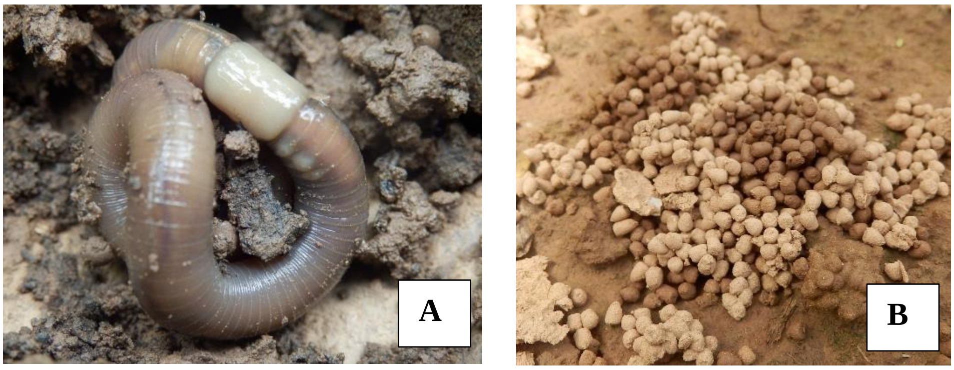

Figure 3. *Metaphire posthuma* (A) and their granular form of cast (B)

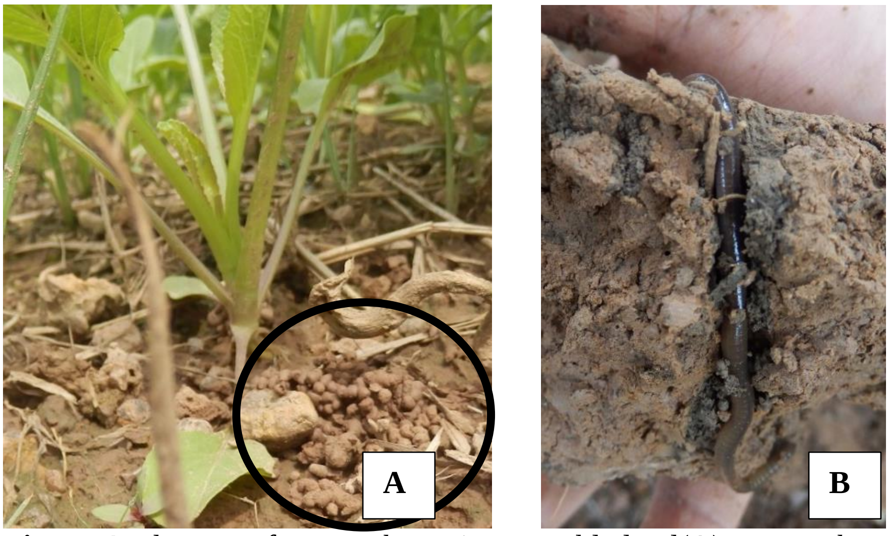

Figure 4. The cast of *M. posthuma* in vegetable land(A), *M. posthuma* and their borrow (B)

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