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Characterization of Earthworms (*Lumbriscus terestris*) Population Under Several Area of Shallots Cultivation

Karakterisasi Populasi Cacing Tanah (*Lumbriscus terestris*) *pada Beberapa Daerah Budidaya Bawang Merah*

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ABSTRAK

Secara umum permasalahan dalam pengembangan komoditas bawang merah masih menggunakan teknik usahatani biasa dan belum mempertimbangkan kesesuain lahan dan kondisi tanah serta aspect penanaman. Tujuan dari penelitian ini untuk mengklasifikasi beberapa karakteristik lahan terhadap penanaman bawang merah dan mengamati populasi cacing tanah berdasarkan kelas kesesuain lahan yang ditanami bawang merah. Metode yang digunakan adalah pendekatan evaluasi lahan dan pengamatan lapangan. Penelitian dilakukan selama musim penghujan pada tahun 2018 di tiga lokasi dengan tanah yang berbeda, yaitu gambut/Histosol (IST), tanah tertimbun Quartzipsamment diatas gambut (ENT), dan tanah Dystropept di lahan kering (EPT). Penelitian ini dihususkan pada musim hujan pada bulan Desember dan Januari dimana berlangsung program penanaman bawang merah. Sedangkan populasi cacing tanah diperoleh dengan menggali luasan 1 m2 kedalaman 20 cm di empat tempat pada masing-masing lokasi. Penghitungan cacing tanah dilakukan secara hand sorting. Hasil penelitian menunjukkan bahwa kelas kesesuaian lahan tertinggi pada lokasi EPT S3tr,rt,nr, sedangkan pada lokasi lainnya tidak sesuai. Pada lokasi IST tergolong N3fb dengan kendala adanya bahaya banjir saat musim hujan, sedangkan untuk lokasi ENT tergolong Nrt yaitu kendala tekstur kasar. Kelas kesesuaian lahan yang tinggi tidak identik dengan kepadatan populasi cacing tanah yang tinggi. Aspek budidaya yang mampu meningkatkan pH tanah mendekati netral serta aplikasi pestisida yang lebih rendah mempengaruhi populasi cacing tanah. Lokasi ENT yang memiliki pH tanah netral dan menggunakan pestisida lebih rendah memiliki populasi cacing tanah terbanyak. Kepadatan populasi cacing tanah dari tinggi ke rendah diperoleh ENT>IST>EPT atau 74>33>31 ekor/m2.

Kata kunci: kelas kesesuaian lahan, *Allium ascalonicum, Lumbriscus terrestris*

ABSTRACT

In General, the problem of shallot commodities development was still used common farming without considering land suitability and other specific soil condition including aspect cultivation. The objective of this study was to clasify several lands characteristics for shallots cultivation and to observe earthworm (*Lumbriscus terrestris*) population based on their land suitability classes. The methodology used was land evaluation approach and field observation. This study was performed during rainy season in 2018 at three locations with different soils, namely, peat soils/Histosol (IST), buried soil of Quartzipsamment above peat soils (ENT), and dry land of Dystropept (EPT). The population of earthworms is obtained by digging up an area of 1 m^2 with depth of 20 cm at in four places of location of study. The calculation of earthworms is conducted by hand sorting. The results showed that the highest land suitability class at EPT S3tr, rt, nr, while for other locations are not suitable. The location of IST is classified into N3fb with several limiting such as flooding hazard during rainy season, while for ENT location, classified into Nrt, limiting factor is rough texture. High suitability class is not identical with high earthworm population density. Cultivation aspect that is able to increase soil pH become neutral condition and lower pesticide application affect earthworm populations. ENT locations that have neutral soil pH with lower pesticides applcation have the highest earthworm populations. Earthworm population density from high to low involve ENT> IST> EPT or 74> 33> 31 tails/m^2.

Keywords: land suitability classes, *Allium ascalonicum*, *Lumbriscus terrestris*

INTRODUCTION

In Central Kalimantan, shallot has been cultivated since 2013 (Firmansyah and Anto, 2013). Generally, the development of shallot was caried out at locations based on the willingness of farmers when they accept shallot development programme established by government, so that, it has not been cultivated based on criteria refering to crop requirements. Even, the farming of shallots was carried out during the off-session or during rainy season, when many farmers did not grow this commodity in Java. One of several important factors that should be taken into account for farming activities is land suitability and other related factors that influence crop growth. This study was then conducted in order to obtain further information about land condition under areas of shallot cultivation. Therefore, the resulting analysis can then be used as recommendation for optimum cultivation. The land condition for crop growth of shallot with high inputs of organic fertilizers, inorganic fertilizers and pesticides may affect earthworm populations, in the soils. Although earthworms (*Lumbriscus terestris*) have a relatively wide distribution in terms of various land cover involving forest areas, gardens, bare lands, rice fields areas, organic and inorganic agriculture as well (Firmansyah *et al*, 2017; Qudratullah *et al*, 2013; Jayanthi *et al*., 2014). Nutrient availability in the soils affects number of earthworms, the application of compost up to 30 tons/ha, almost 1,077 tails/2 m^2 can be found compared 309 tails/2 m^2 with control treatment (Firmansyah and Atikah, 2019). Soil types that can support the life of earthworms are also found to be very broad ranging from mineral to peat soils (Dwiastuti *et al.*, 2018; Maftu'ah *et al.*, 2005). Specifically, for earthworms found on river banks of Kahayan river and Barito river in Central Kalimantan, shows that shallow ground water surface with rough texture are not suitable for earthworm habitats (Firmansyah *et al*., 2014).

The increase of earthworm population density is dominantly affected by soil biological processes, ecosystem health, improved water management and degraded soil, and balance of greenhouse gases as well (Supriati *et al.,* 2011; Mayilswami and Reid, 2010; Dewi and Senge, 2015). The objectives of this study was to classify land suitability to three soil ecosystems used shallots development in Palangka Raya, while at the same time observing the earthworm populations as bio-indicators of land quality.

Many studies have shown that the use of inorganic fertilizers and excessive pesticides will adversely affect earthworms. Earthworm populations exposed by high levels of inorganic fertilizers and pesticides will decrease (Yulipriyanto, 2009). However, rainfall and physical properties of soil have more influence to biomass of earthworm compared to chemical factors (Lalthanzara *et al.,* (2011). This study was the conducted to to clasify several lands characteristics for shallots cultivation and to observe earthworm population based on their land suitability. The resulting information can then be used to cultivate land based their suitability for shallot farming with soil macro-fauna support. Therefore, the objective of this study was to clasify several lands characteristics for shallots cultivation and to observe earthworm (*Lumbriscus terrestris*) population based on their land suitability classes

MATERIALS AND METHODS

The study was conducted during rainy season in 2018. Administratively, location of study have been choosen involving Sabangau district for peat soils (IST or Haplohemist); Jekan Raya District for mineral soils above peat soils (ENT or Quartzipsamment above Haplohemist), and Bukit Batu district for dryland mineral soils (EPT or Dystropept). Theses locations are located in Palangka Raya, Central Kalimantan Province with each geographical coordinate i.e. IST (-02^o 17' 20''S; -113^o 53' 48''E); ENT (-02^o 14' 08''S; -113^o 52' 52''E); and EPT (-02^o 00' 12''S; -113^o 43' 28''E). For the last 2 years, each land areas has been utlized for shallot farming. Therfore, these site locations were selected based on dominant areas for shallot cultivation.

The observation of earthworms was carried out in the morning to noon at area of 1 m^2 with a depth of 20 cm. The earthworms samples were collected at 4 locations proportionally in which each of the locations in beds and mounds. Earthworms are collected by hand sorting to calculate, wet weight, dry weight and water content. Calculation of earthworm population density using the formula of Suin (2014) where Population Density = Number of individual earthworms/Soil volume

The temperature data is collected before obtaining earthworms, in the morning and noon include temperature and air humidity (1 meter above ground level) and for soil sample, it was measured 20 cm in depth. Physical soil sample was obtained at the depth of 0-20 cm using a ring sample to analyze bulk density (BD), KAT (B/V), Porosity, MAT. Soil chemical properties that were analyzed involve pH H2O, organic C, Total N, K, Na, Ca, Mg exchangeable, base saturation, CEC, Al exchangeable, H exchangeable, and Texture (Sand, silt, clay).

Rainfall data used in this study is over a 10-year period, for Sabangau and Jekan Raya areas taken from the BP3K Kalampangan in Sabangau district because the coveraged areas is within radius of 3 km. Rainfall data is available for 2008 to 2017. Another location in Bukit Batu district used rainfall data from BP3K Tangkiling for the years of 2009 to 2018. This rainfall data was used to classify climate types based on Schmidt and Ferguson and Oldeman climate type and also to determine land suitability class of shallots.

Determination of land suitability class for shallot use crop requirement criteria for shallot (Ritung *et al*., 2011). Land suitability classification was conducted at sub-class level.

RESULTS AND DISSCUSSION

Agricultural Input on The location

The cultivation of vegetables that has a short life is conducted several times in a one year period. Generally, planting vegetables with different types of plants is performed three times or more. Based on interviews with farmers who manage the lands, it was found that the use of organic fertilizer include chicken manure, lime and inorganic fertilizer of NPK 16:16:16 (Table 1). The pesticides used in study areas involve herbicides, fungicides, bactericides, insecticides, nematicides (Table 2). Pesticide residues that are retained in the soil directly affect earthworm population. The high input of dossage was applied to overcome low soil fertility.

Characteristics of the Location

The condition of monthly average rainfall based on the last 10 years in both locations, IST and ENT located in Sabangau district was 2,927 mm/year, while for location of EPT in Bukit Batu district reached 2,862 mm/year. The annual average rainfall for 10 years in Bukit Batu district is 2,927 mm/year and Sabangau district is 2,867 mm/year. Number of rainy days in Sabangau district was 160 days, while in Bukit Batu district 137 days (Figure 1 and 2).

Based on Schmidt and Ferguson rainfall system, the location of Bukit Batu has wet month throughout the year, whereas in Sabangau, it also has no dry month but this location has 11 wet months so that these locations is categorized as very wet rainfall types. Based on Oldeman climate type, Sabangau has 7 consecutive wet months and Bukit Batu has 8 consecutive wet months, so that both of these locations are classified as B rainfall type.

The condition of air temperature was 30.2-40.1^{o}C, while for soil temperature is 31.2-40.6^{o}C. Air humidity ranges from 43.3-76%, while for soil moisture is 37.0-86.9% (Table 3). Morning air temperature is lower than daytime. On the aother hand, morning soil temperature at ENT and EPT, comparing to daytime.

The soil characteristics was very different within each location. In location of IST, bulk density is very low, but it has very high soil water content up to 319.59% and based on weight and high porosity that reach 82.70, it indicates that the soil is filled with water. Other locations show that ENT which is sandy soil (Table 5) piled on peat soil is more dense according to BD of KAT and porosity compared tothe EPT, namely soil with sandy clay loam texture in dry land. Whereas based on groundwater level, the two locations of IST and ENT are located on swampland with a groundwater level of 33-75 cm, while EPT is a typology of dry land with groundwater level reach 308 cm (Table 4).

Table 1. Input of fertilizer for vegetable farming during a year at site location

Ecosystem	Organic fertilizer (ton/ha)	Lime (ton/ha)	Urea (kg/ha)	SP-36 (ton/ha)	KCl (kg/ha)	NPK 16:16:16 (ton/ha)?
IST	15	7.5	0	3.0	0	3.0
ENT	24	10	0	0,5	0,3	2,5
EPT	15	5	0	4.5	2.0	1.6

Table 2. Pesticide application for during a year at site location

Ecosystem	Use of Pesticides Based on Active Ingredients				
	Herbicide	Fungicide	Insekticides	Baktericides	Nematicides
IST	Parakuat diklorida	Tembaga oksi sulfat, Propineb, azoksistrobin, difenokonazol	Deltametrin, Metomil	Streptomisin sulfat	Karbofuran
ENT	-	Propineb, Mankozeb	Deltametrin, Metomil	-	-
EPT	Parakuat diklorida	Propineb, Mankozeb, azoksistrobin, difenokonazol	Deltametrin, Metomil, Prefenofos	Streptomisin sulfat	Karbofuran

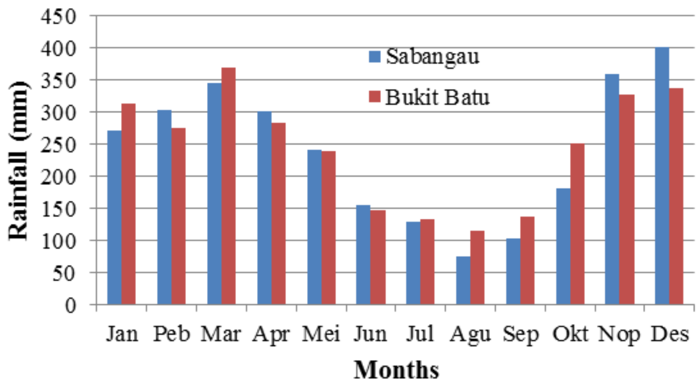

Figure 1. Monthly average rainfall for 10 years in location of study

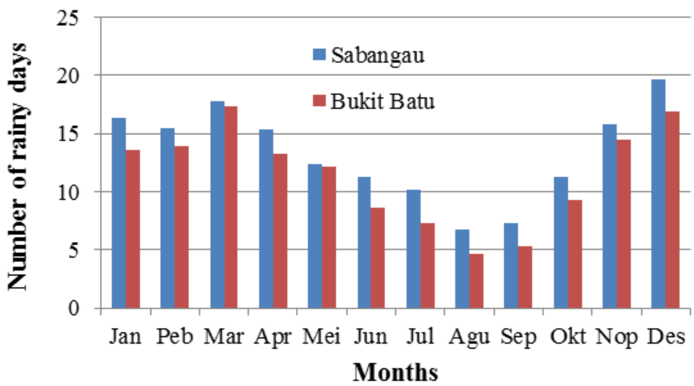

Figure 2. Average monthly rainy day for 10 years in location of study

Table 3. Characteristics of temperature, humidity and soil at location of study

Ecosystem	Morning (pk 09.00 WIB)				Day (pk 12.00 WIB)			
	T (°C)		RH (%)		T (°C)		RH (%)	
	Air	Soil	Air	Soil	Air	Soil	Air	Soil
IST	30,4	31,2	76,0	86,9	33,0	34,2	57,7	76,3
ENT	30,2	39,4	70,5	80,0	33,0	38,9	55,5	37,0
EPT	32	40,1	52,7	68,7	40,1	40,6	43,3	32,8

Table 4. Characteristics of soil physics at location of study

Ecosystems	BD (g/cc)	KAT-B (%)	KAT-V (%)	Porosity (%)	MAT (cm)
IST	0,46	319,59	146,18	82,70	74,50
ENT	1,31	29,46	38,23	50,68	33,25
EPT	1,08	80,62	86,47	59.34	307,50

Note: BD= Bulk Density, KAT-B= Water content; Soil-weight, KAT-V= soil water content-volume, MAT= ground water

Table 5. Characteristics of earthworms at location of study per 1 m^2 and individual

Soils	Per 1 m^2			Per Individual			KA
	Total Number (tails)	BB (g)	BK (g)	Total number (tails)	BB (g)	BK (g)	(%)
IST	33,00	27,63	4,875	1	0,81054	0,142	469,47
ENT	73,75	42,50	9,750	1	0,61014	0,137	345,86
EPT	30,75	21,23	4,125	1	0,71287	0,141	415,62

Earthworms Population

The highest earthworm population condition was found in location of ENT with a total number of 74 earthworm/m2, followed by IST, 33 tails/m2and EPT, 31 tails/m2 (Table 5). Based on earthworm density score (Bierman, 2007), the density score at all study areas is 4 and this indicate that the condition is good, because earthworms are found in large numbers between 31-250 tails/m2.

The high density of earthworm populations in location of ENT can be caused by soil conditions with pH approaches neutral 7.1. While for other locations, they have acidic soil condition. However, in several locations such as IST and EPT, earthworms are still found, so that this indicates that earthworms have adaptation to soil acidity. Earthworms that are intolerant of acid will not be found and at several locations with acid soil environment, they can be found with low population (Siun, 2012). Neutral pH conditions are very suitable for earthworms. The decrease of soil pH and organic matter will affects the decrease in population (Puspitasari, 2016).

The high population of earthworms in location of ENT is caused by having a neutral soil pH and also cultivation techniques without the use of nematicides such as carbofuran which reacts directly in soil. In addition, this conditions also supported by shallow ground water levels so that soil moisture will support earthworm life. Tribrata et al, (2015) stated that the relative density of earthworms is lower in locations exposed to pesticides (mankozeb 0.035 mg / kg and propineb 0.014 mg / kg) than land not exposed to pesticides. Araneda et al. (2016) added that high carboxylesterase enzym (CbE) in earthworms is an indicator of pesticide exposure.

Based on the use of chemical fertilizers in study locations which ranged from 1.15 tons/ha/year to 3.5 tons/ha/year, itdoes not affect earthworm population, especially on mortality rate. The use of single or compound chemical fertilizers will have an impact on the death of earthworms 32% to 100% especially for using doses around 12-24 tons/ha (Shruthi et al., 2017). Even by not using urea at study locations, it will support optimum life for earthworms. Rai et al. (2014) added that the use of urea is harmful to earthworms (Esenia foetida) so tha the use of urea must be limited in orer to achieve optimum condition of environment.

The use of pesticides as shown at Table 2 has an influence to the population of earthworms, the use of pesticides at location of IST and EPT was quite large compared to other locations. The use of pesticides such as herbicides have different effects on the level of earthworm populations (Iordache and Borza, 2011). The herbicide type of Gardoprim Gold 500 SC is able to kill earthworms within 24 -72 hours after application. In contrast, the Helmstar 75 WG herbicide can still be tolerated with earthworms.

The location of EPT has the lowest population numbers due to several main things, namely application of lower organic fertilizer, and also condition of the deep planting water level. This can cause the scope of earthworms life to be relatively drier due to the lack of vertical seepage from the ground water level to surface, so that in some cases these conditions inhibit development of earthworms.

However, the presence of earthworms in study site, including endogaesis earthworms, is an indicator that cultivation of shallot is still managed environmentally. The existence of largest number of earthworms in location of ENT, can be categorized as the most environmentally friendly cultivation system compared to other locations. the presence of endogaesis earthworms is an indicator of environmentally friendly agriculture (Subowo and Purwani, 2013).

Table 6. Land characteristics for each location

Chemical/Physical Soil Properties	Unit	Value		
		IST	ENT	EPT
Temperature	^oC	26,2	26,2	26,4
Rainfall at growing	mm/2 months	673	673	651
Drainage		poor	poor	moderate
Texture	%	-	88,205	82,2
Sands	%	-	8,74	11,27
Silt	%	-	2,55	6,50
Clay	%	-	-	-
Rough materials	cm	50	33	307
Soil depth	cm	40	-	-
Peat tickness	cm	-	-	-
Peat insertion	-	Sapric+	-	-
Peat ripeness	cmol (+)/kg	72,5	4,68	14,03
CEC	%	30,22	103,315	49,99
Base saturation	-	4,68	7,11	5,53
pH H_2O	%	47,379	1,097	0,974
C organic	cm	0	-	-
Sulfidic depth	%	0	1	2
Slope	cm/th	<0,15	<0,15	< 0,15
Erossion hazard	-	F1	-	-
Inundation	%	-	-	-
Surface stoniness	%	-	-	-
Rock outcrops				

Land Suitability Classification

Land characteristics used to determine land suitability classes for off-season shallot development showed that there are several significantly differences, especially for the presence or absence of inundation (Table 6). At location of IST when the data was collected in January 2018 showed that floods had occurred two weeks earlier as high as 50 cm for two days. Flooding is an absolute criterion for land characteristic for shallots development. This resulted in failure of shallots farming in location, because the plants will die due to submergence and resulting in moler attack (*Fusarium oxysporum* (Hanz)), anthracnose (*Colletotricum gleoeosporoides*), and purple spots (*Alternaria porii*).

Based on land characteristics and quality in the three location of study in which compared to the crop requirements of shallots, land suitability class will then be determined. The land characteristic of temperature and water availability in all locations is relatively the same so that they are classified into suitability class S3 (marginal) and S2 (moderate).

As a result of land evaluation, limiting factor found at IST locations is flooding hazard, and this is due to condition of land when planting shallots, climate condition is in rainy season. Therefore, the lands was flooded and resulted in crop failure. Flooding hazard at IST location caused this areas are classiffied into not suitable or Nfh. The location of ENT is an area which is made from deposition of quartz sand soils on peat soils. The limiting factor is rooting condition, with very rough texture. This location is then classified into not suitable or Nrc (Table 7).

The location of EPT has limiting factors that are not as severe as the two previous locations. Several limiting factors include temperature, rooting condition, and nutrient retention. This location is then classified into marginally suitable symbolized as S3tc, rc, nr.

Based on actual land suitability class for shallot development, it does not seem to be directly proportional between the level actual land suitability class with earthworm populations. The location of ENT with not suitable class (Nrt) in which higher than

EPT (S3 tc, rc, nr) show that limiting factor that affect growth and production of shallot, is not in line with the needs of breeding for earthworms. Lemitiri *et al* (2014) and Gonzalez *et al*. (2012) have stated that the number of earthworms is influenced by soil management practices. Bhadaura and Saxena (2010) added that agroecosystem with high production have earthworm population 75 earthworms/m^2 and 25 earthworms/m^2.

Table 7. Land characteristics for land suitability classification

Land characteristic/qualities	Land Suitability Classes				Land Suitability Classes Within Each Location		
	S1	S2	S3	N	IST	ENT	EPT
Temperature (tc)							
Temperature (°C)	20-25	25-30	30-35	>35	S3	S3	S3
Water availability (wa)		18-30	15-18	<15			
Rainfall (mm)							
Oxigen availability (Oa)	350-500	600-800	800-	>1.600	S2	S2	S2
Drainage		300-350	1.600	<250			
			230-500				
	Well	Moderate		Very			
Rooting condition (rc)	drainage	ly well	Poorly	poorly	S3	S3	S2
Texture		drained	drained	drained			
	Fine,	-		kasar			
Rough materials (%)	moderate		Moderate		-	N	S3
Soil depth (cm)	ly fine		ly fine				
Peat	<15	15-35		>55	-	S1	S1
Tickness	>50	30-50	35-55	<20	-	S2	S1
Insertion			20-30				
Ripenness	<60	60-140		>200	S1	-	-
	<140	140-200	140-200	>400	S1	-	-
Nutrient Retention (nr)	sapric+	sapric,	200-400	fibric	S2	-	-
CEC cmol (+)/kg		hemic+	hemic,				
BS (%)			fibric+				
pH H_2O							
	>16	≤16			S1	S2	S2
C organic (%)	>35	20-35	<20		S2	S1	S1
Toxixity (xc)	6,0-7,8	5,8-6,0	<5,8		S3	S1	S3
Salinity (dS/m)		7,8-8,0	>8,0				
Sodicity (xn)	>1,2	0,8-1,2	<0,8		S1	S2	S2
Alkaline/ESP (%)							
Sulfidic (xs)	<2	2-3		>5	-	-	-
Sulfidic depth (cm)			3-5				
Erossion Hazard (eh)	<20	20-30		>50	-	-	-
Slope (%)			35-50				
Erossion hazard	>75	50-75		>50	-	-	-
			30-50				
Flooding hazard (fh)	<8	8-16		>30	S1	S1	S1
Inundation	very low	low-	16-30	very high	S1	S1	S1
		moderate	high				
Penyiapan Lahan (lp)				>F0			
Surface stoniness (%)	F0	-			N	S1	S1
Rock outcrops (%)			-				
		5-15					
	<5	5-15	15-40	>40	S1	S1	S1
	<5		15-25	>25	S1	S1	S1
Actual Land Suitability Class					N fh	N rc	S3 tc, rc, nr

Source: Ritung *et al*, (2012)

The other relevant information to support the analysis include data shallots production for such study area. The production of Pikatan variety at EPT reach 10.36 ton/ha (Firmansyah and Karjo, 2018) and production of Sembrani variety at IST is 9.13 ton/ha (Firmansyah *et al.,* 2014). While at EPT with use of Bima Brebes variety, the production reach 15 ton/ha (Firmansyah *et al*., 2019).

CONCLUSION

The highest earthworm populations is in location of ENT because soil pH is neutral and this lead to optimum condition to support proliferation of earthworms, besides low use of pesticides with have relatively contact with the soil such as nematicides or herbicides. The actual land suitability of location IST is classified into not suitable with flooding hazard as limiting factor (Nfb), while for location of ENT is also not suitable with rooting conditon as limiting factor (Nrc) and for the best location is EPT classified as marginal ly suitable with several limiting factor involving temperature, rooting condition, and nutrient retention (S3 tc, rc, nr).

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REFERENCES

Araneda AD, P Undurraga, D Lopez, K Saez, anda R Barra. 2016. Use of earthworms as a pesticide exposure indicator in soils under conventional and organic management. *Chilean Journal of Agricultural Research*. 76(3):356-362. DOI: http://dx.doi.org/10.4067/S0718-58392016000300014

Bierman P. 2007. Ohio sil healt card. Centers at Piketon. Ohio State Univ. http://wwww/ag.ohiostate.edu/-pre.

Dewi W, M Senge. 2015. Earthworm diversity and ecosystem service under threat. Reviews in Agricultural Science. 3:25-35.

Dwiastuti S, S Widoretno, P Karyanto. 2018. Identifiksi caing tanah dan interaksinya dengan lingkungan lahan berkapur. *J. Biogenesis* 14(2):23-28.

Firmansyah MA, dan Anto A. 2013. Teknologi Budidaya Bawang Merah Pada Lahan Marjinal di Luar Musim. Kantor Perwakilan Bank Indonesi Provinsi Kalimantan Tengah. (36 pages)

Firmansyah MA, Suparman, Harmini, Wigena dan Subowo. 2014. Karakterisasi Populasi dan Potensi Cacing Tanah Untuk Pakan Ternak Dari Tepi Sungai Kahayan dan Barito. Jurnal Berita Biologi. 13(3). DOI: 335-343. 10.14203/beritabiologi.v13i3.677

Firmansyah TRM. Setyawati, dan AH Yanti. 2017. Struktur komunitas cacing tanah (Kelas Oligochaeta) di kawasan hutan Desa Mega Timur Kecamatan Sungai Ambawang. Protobiont, 6(3):108-117.

Firmansyah MA, TA Atikah. 2019. Pengaruii Kompos Limbah Sagu Terhadap Bawaing Merah (*Allium ascalonicum* L.), dan Karakteristik Sifat Fisik Tanah Serta Populasi Cacing Tanah (*Lumbriscus Terestris*) Dilahan Kering Musim Kemarau. *Jurnal Daun* 6(1):1-9.

Gonzalez FDL, MF Ponce, and FP Zelaya. 2012. Earthworm and agricultural systems management: emphasis on the Latin American Region. Dynamic Soil, Dinamic Plant. Global Science Books. P:14-25

Iordache M, I Borza. 2011. Study of the acute toxicity of some pesticides on earthworms Eisenia foetida (Savigny, 1826). Research Journal of Agricultural Science. 43(4):95-100.

Jayanthi S, R Widhiastuti, dan E Jumilawaty. 2014. Komposisi komunitas cacing tanah pada lahan pertanian organik dan anorganik di Desa Raya Kecamatan Berastagi kabupaten Karo. Jurnal Biotik. 2(1):1-9. http://dx.doi.org/10.22373/biotik.v2i1.228

Lalthanzara H, SN Ramanujam, and LK Jha. 2011. Population dynamics of earthworm in relation to soil physico-chemical parameters in agroforestry systems of Mizoram, India. J. Environ. Biol. 32:599-605.

Lemitiri A, G Colinet, T Alabi, D Cluzeau, L Zirbes, E Haubruge, and F Francis. 2014. Impact of earthworm on soil componen and dynamics. Areview. Biotechnol. Agron. Soc. Environ. 18(1):1-13.

Maftu'ah E, M Alwi, dan M Willis. 2005. Potensi makrofauna tanah sebagai bioindikator kualitas tanah gambut. Bioscientiae. 2(1):1-14.

Mayilswami S, B Reid. 2010. Effect of earthworm on nutrients dynamics in soil growth of crop. World Conggres of Soil Science, Soil Solutions for a Changing World. 1-6 August. Brisbane, Australia. P: 50-52

Puspitasari A. 2016. Kondisi cacing tanah (*Pheretima* sp) pada lahan pertanian yang menggunakan pupuk berlebihan di Kecamatan Kejajar Kabupaten Wonosobo. *J. Rekayasa Lingkungan*. 16(2):1-19.

Qudratullah H, TM Setyawati, dan AH Yanti. 2013. Keanekaragaman cacing tanah (Oligochaeta) pada tiga tipe habitat di Kecamatan Pontianak Kota. Protobiont. 2(2):56-62.

Rai N, P Ashiya, and DS Rathore. 2014. Comparative study of the effect of chemical fertilizer and organic fertilizer on Eisenia foetida, *Int. J. of Innov. Res. In Sci. Eng. And Tech*. 3(5):12991-12998.

Ritung S, K Nugroho, A Mulyani, dan E Suryani. 2011. Petunjuk teknis evaluasi lahan untuk komoditas pertanian. Balai Besar Penelitian dan Pengembangan Sumberdaya Lahan Pertanian. Badan Penelitian dan Pengembangan Pertanian. Kementerian Pertanian.

Shruthi N, AP Biradar, and S Muzammil. 2017. Toxic effect inorganic fertilizers to earthworms (Eudrilus eugeniceae). *Jurnal of Entomology and Zoology Studies*. 5(6):1135-1137. http://dx.doi.org/10.22271/j.ento

Subowo G, Purwani J. 2013. Pemberdayaan sumber daya hayati tanah mendukung pengembangan pertanian ramah lingkungan. *J. Litbang Pert*. 32(4):173-179. DOI: http://dx.doi.org/10.21082/jp3.v32n4.2013.p173-179.

Suin NM. 2014. Ekologi hewan tanah. Cetakan ke empat. Bumi Aksara Jakarta dan Pusat Antar Universitas Ilmu Hayati ITB Bandung.

Supriati R, Darmi, Mardiana S. 2011. Peran populasi cacing tanah (*Pontoscolex corethrurus* Fr. Mull) terhadap pertumbuhan dan produksi tanaman organik bawang merah (*Allium ascalonicum* L.). Konservasi Hayati. 7(2):12-18.

Tribrata Y, R Siahaan, JJ Pelealu, dan SM Mambu. 2015. Kepadatan cacing tanah pada lahan pertanian tomat terpapar pestisida di Desa Ampreng, Kecamatan Langowan Barat, Provinsi Sulawesi Utara. *J. Bioslogos.* 5(1):1-4. https://doi.org/10.35799/jbl.5.1.2015.7045

Yulipriyanto H. 2009. Suatu kajian struktur komunitas cacing tanah di lahan pertanian organik di Daerah Istimewa Yogyakarta. Proseding Seminar Nasional Penelitian, Pendidikan dan Penerapan MIPA. Fakultas MIPA. Universitas Negeri Yogyakarta, 16 Mei 2009. Hal: 68-72.