EFFECTS OF EARTHWORM *Polypheretima elongata* ON PHYSICAL AND CHEMICAL PROPERTIES OF SALINE SOIL IN ABANDONED SHRIMP FARM

JARUPAN CHUNUANG

A THESIS SUBMITTED IN PARTIAL FULFILLMENT
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ENVIRONMENTAL DEVELOPMENT)
FACULTY OF GRADUATE STUDIES
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EFFECTS OF EARTHWORM *Polypheretima elongata* ON PHYSICAL AND CHEMICAL PROPERTIES OF SALINE SOIL IN ABANDONED SHRIMP FARM

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ABSTRACT

The study on the use of *Polypheretima elongata* earthworms on physical and chemical properties of saline soil in an abandoned shrimp farm from Ronot soil series had a bulk density of 1.58 g/cm^3, ECe of 1.65 ds/m, CEC of 17.99 cmol/kg, ESP of 44.97%, and pH of 7.76. Earthworm samples were collected from the area connected to abandoned shrimp farm land in Thabon Sub-District, Ranot District, Songkhla Province, Thailand. Earthworm taxonomy was conducted according to Gate (1972). The earthworms were raised to adult stage and tested for improvement in the properties of soil in an abandoned shrimp farm which had been washed with freshwater for 3 months, to study the effects of 3 factors, i.e. number of earthworms (10, 20, and 30), type of organic material (dried rice straw vs. rice straw manure), and quantity of organic material (5% and 10% by dried soil weight). Experiments were made in 20 replications inside a greenhouse for 90 days. The results showed that the *Polypheretima elongata* earthworm could survive and withstand soil salinity with the exchangeable sodium range of 18.25-87.57 cmol/kg, which was the level measured from the soil in the abandoned shrimp farm after the experiment with 20 replications. The weight of earthworms did not increase except for the treatment condition which added 30 earthworms together with 10 % rice straw manure (SW_3O_2) for which the earthworms exhibited slight growth (0.01224 grams/90 days).

Number of earthworms and type and quantity of organic materials affected changes in chemical properties of the abandoned shrimp farm soil. Addition of 30 earthworms to bare soil (SW_3) caused the mean chemical properties of the soil, i.e. the CEC, ESP, Na, NH_4-N, NO_3-N, total-N, phosphorus, and potassium values to become significantly higher than the treatments with 20 and 10 earthworms, exhibiting the best soil quality (except for ESP and Na which had high values and were considered to be negative outcomes). For treatments which added 30 earthworms with organic material, addition of rice straw manure had a better effect than addition of dried rice straw. The treatment which added 10% rice straw manure with the earthworms (SW_3O_2) caused the chemical properties, i.e. the pH, ESP, OC, OM, Na, NH_4-N, NO_3-N, total-N, phosphorus and potassium to become better than addition of dried rice straw (SW_3L_2), but addition of dried rice straw caused the soil to have better physical properties than addition of the rice straw manure. The treatment which added the dried rice straw (SW_3L_2) had lower bulk density and higher porosity than the treatment which added the rice straw manure (SW_3O_2).

KEY WORDS: *Polypheretima elongata*/ RANOT SOIL SERIES/ PHYSICAL AND CHEMICAL PROPERTIES/ POROSITY

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ผลของการใช้ไส้เดือนดิน *Polypheretima elongata* ต่อคุณสมบัติทางด้านกายภาพและเคมีบางประการของดินเค็มนากุ้งร้าง

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บทคัดย่อ

การศึกษาผลของการใช้ไส้เดือนดิน *Polypheretima elongata* ต่อคุณสมบัติทางด้านกายภาพ และเคมีบางประการของดินเค็มนากุ้งร้าง ซึ่งเป็นชุดดินระโนด มีค่า bulk density 1.58 g/cm3, ECe 1.65 ds/m, CEC 17.99 cmol/kg, ESP 44.97%, pH 7.76 เก็บตัวอย่างไส้เดือนดินจากพื้นที่ซึ่งติดกับนากุ้งร้างของ ต. ท่าบอน อ. ระโนด จ. สงขลา จำแนกชนิดไส้เดือนดินตามวิธีการของ Gate (1972) ไส้เดือนดินถูกนำมาเพาะเลี้ยงจนกระทั่งเป็นตัวเต็มวัย และนำมาทดลองปรับปรุงคุณสมบัติของดินนากุ้งร้างที่ผ่านการชะดินด้วยน้ำจืดเป็นระยะเวลา 3 เดือน เพื่อศึกษาผลของ 3 ปัจจัย คือ จำนวนไส้เดือนดิน (10, 20, และ 30 ตัว) ชนิดของอินทรียวัตถุ (ฟางข้าวแห้งและปุ๋ยหมักฟางข้าว) และปริมาณของอินทรียวัตถุ (5 และ 10 เปอร์เซ็นต์ โดยน้ำหนักดินแห้ง) ทำการทดลอง 20 ชุดการทดลองในโรงเรือน เป็นระยะเวลา 90 วัน พบว่า ไส้เดือนดิน *Polypheretima elongata* สามารถมีชีวิตรอดและทนต่อความเค็มของดินในระดับที่มีโซเดียมที่แลกเปลี่ยนได้ในช่วง 18.25-87.47 cmol/kg ซึ่งเป็นระดับที่วัดได้จากดินนากุ้งร้างหลังการทดลอง 20 ชุดการทดลอง น้ำหนักของไส้เดือนไม่เพิ่มขึ้น มีเพียงชุดการทดลองที่ใส่ไส้เดือน 30 ตัวกับปุ๋ยหมักฟางข้าว 10% (SW_3O_2) ที่ไส้เดือนมีอัตราการเจริญเติบโตเพิ่มขึ้นเล็กน้อย (0.01224 กรัม/90 วัน)

จำนวนไส้เดือนดิน ชนิดอินทรียวัตถุ และปริมาณอินทรียวัตถุ ส่งผลต่อการเปลี่ยนแปลงคุณสมบัติทางด้านเคมีของดินนากุ้งร้าง โดยการใส่ไส้เดือนที่ความหนาแน่น 30 ตัวกับดินเปล่า (SW_3) ทำให้ค่าเฉลี่ยคุณสมบัติทางเคมีของดินนากุ้ง ได้แก่ ค่า CEC, ESP, Na, NH_4-N, NO_3-N, total-N, phosphorus, และ potassium สูงกว่าการใส่ไส้เดือน 20 และ 10 ตัวอย่างมีนัยสำคัญ ซึ่งจัดเป็นคุณภาพดินที่ดีที่สุด (ยกเว้น ESP กับ Na ที่ ให้ค่าทางเคมีสูงในชุดที่ใส่ไส้เดือน 30 ตัว จึงมีผลเชิงลบ) เมื่อทดสอบผลของการใส่ไส้เดือน 30 ตัว กับปัจจัยอินทรียวัตถุ พบว่า การใส่ปุ๋ยหมักฟางข้าวทำให้ดินมีคุณภาพดีกว่าการใส่ฟาง โดยชุดที่ใส่ปุ๋ยหมักในปริมาณ10% กับไส้เดือน 30 ตัว (SW_3O_2) ทำให้คุณสมบัติด้านเคมี ได้แก่ pH, ESP, OC, OM, Na, NH_4-N, NO_3-N, total-N, phosphorus และ potassium ดีกว่าการใส่ฟาง (SW_3L_2) แต่การใส่ฟางทำให้ดินมีคุณสมบัติทางด้านกายภาพดีกว่าการใส่ปุ๋ย โดยในชุดทดลองที่ใส่ฟาง (SW_3L_2) ดินมีค่า bulk density ต่ำ และ porosity สูงกว่าชุดทดลองที่ใส่ปุ๋ยหมัก (SW_3O_2)

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CHAPTER I
INTRODUCTION

1.1Background and rational

Soil as one of natural fundamental resources is very much important for our country development. Almost yields derived from soil resources depends largely on soil fertility because soil is a source of natural mineral, water and also soil performs as supporting of plants therefore, degraded or infertile soil usually affects to environmental ecosystem as a whole especially for the potential agricultural productivity. Also, it results as negative feedback to agricultural and ecosystem services such as foods for consumption, income of farmer etc. that directly effects to both population way of lives.

Salt-affected soil is one of the important soil problems results in low potential productivity. At present, this problem extends to many regions of the world. According to the reports of a FAO in 2000 showed global distribution of salt-affected soil that saline soil covers the area of 397 million hectares and 434 million hectares of sodic soil area from total investigated area around 12,781.3 million hectares (Table 1-1). Considering to the 230 million hectares of an irrigated soil, there are 45 million hectares of land (approximate to 19 percentages) were influenced by saline. Furthermore, from 1,500 million hectares agricultural area, there is salt-affected soil covers 32 million hectares (approximate to 2.1 percentages). In Thailand, salt-affected soil covers around 3.4 million hectares which are both inland and coastal saline soil.

Sub-basin area of Songkla lake is one of the salt-affected area, which caused by natural morphology and anthropogenic soil activities. In other words, it was a former tidal flat area, saline soils were formed by marine and brackish water, whereas human activities could activate salinization especially brackish shrimp farming with improper control and lacking of good management such as waste removing from pond to closed area. On the ground of salt contaminates in soil both leaching through vertical and dispersion to the horizontal ground. In addition, ground water in surrounding area is contaminated with salt from salt water leaking. Besides, inappropriate management in farming leads to the out-break of shrimp disease and a large number of farmers lost their investments consequently. New area for aqua-culture farming has been opened while, the former areas were left to be an abandon shrimp farm.

Satellite data analysis in 2002 showed the decreasing of shrimp farm area from originated covering 52,411 rai in 1995, then decreasing to 31,341 rai in 2002, approximately 40.2 percentages (Table 1-2). Besides decreasing in shrimp farm, previous study reported the decreasing of rice fields in sub-basin of Songkhla lake from 1993 to 2002 which 1,412,916 rai to 1,126,211 rai, approximately 20.3 percentage (Wichien et al., 2005).

Although decreasing of rice field resulting from many ways, one is salt dispersion and extent to surrounding areas. It has been observed obviously that these areas were obsolete: plant could not grow except salt-tolerant species because soil becomes saline, dense and poor drainage soil. Moreover, saline soil is not suitable for doing agriculture because increasing salt is harmful for plants; water and nutrients absorption (Land Development Department, 2001).

Physical and chemical characteristic of shrimp farm soils after shrimp culture activities in the area of upper, central, and lower parts of Songkhla lake have been changed in similar ways, for example, soil properties has been degraded. Deterioration in soil properties resulting from salt dispersion and compacted by machine while shrimp pond was prepared. This process contributed to difference of soil properties for instance bulk density, saturation electrical conductivity and exchangeable sodium percentage that increased higher than the critical values. Conversely, quantity of oxygen, available water, and water permeability were decreased (Aomthip, 2004). These problems were entirely obstructive factors for underground plant roots and seed grown up. As the matter of fact, impacts of salt-affected soils from this area stir up the problems of environmental deterioration. The effects has been over the environmental carrying capacity and could not rehabilitation naturally therefore, the degraded area extremely need to be restored rather than deserted without any deteriorated ecosystem.

At the present, saline area problems have been managed by salt leaching out process using fresh water soil amendment by chemicals for removing salt, and using agricultural materials together with soil organisms. Firstly, soil improvement by salt leaching out process, soil had been raise up for agricultural practice with support from Department of Agricultural Extension during 1994-1996. The result found that such practice was not success for the procedure of removing salt by fresh water and chemicals was not appropriate to perform in this area. Even though average rainfall per year was possible to leach out salt, but freshwater shortage in dry season cause salt dispersion to surface and underground water sources (Somsak et al., 1999). Besides such practice resulted water quality as salt contaminated water. Saline soil improvement by using water washing out capable to be done for medium-well drainage soil, but for the Ranod soil series and others which had been used for shrimp farm activity was clay texture resulting in poor permeability. For soil improvement by plough to loose soil structure could improve soil drainage structure, this method has been developed and suitable for abandoned shrimp farm soil improvement. However, plough for long times resulted in decreasing of soil organic matters and soils aggregation especially plough while soils were too dry or completely dry.

Salt-affected soil properties amendment by chemical like gypsum, vermiculite and polyacrylamide are wildly used as an acceptable process. This procedure was used to improve soil properties; however, there still had some limitation to apply such procedure to the study area. Although, the area had been used for intensive-shrimp farm only once or twice, soil has changed to be sodic soil with having high quantity of electrical conductivity and sodium absorption ratio. Utilization of gypsum which had a few or small soluble quantity for raising permeability probably took long time (Aomthip, 2004). Furthermore, using gypsums had to ferment soils with both gypsum and freshwater and then rinsed solution out. However, freshwater was rare in the sampling area and extremely shortage in dry season. Polyacrylamide is a polymer substance which has its quality of inducing hydraulic conductivity and is able to leach salt from fissured soil. Making usage of polyacrylamide in non-fissured soil has a few effective including the soils that have high exchangeable sodium percentages. It swells when wetted with water: polyacrylamide can not reduce swell condition (Towatana, 2005).

As the matter of fact, salted soil improvement need an integrated method combined with many procedures which would take the highest efficiency including the selection of an appropriate approach that suited for each specific area. Biological organism is one way to restore and enhance soil fertility by natural process. Earthworm is one of the most important group of soil invertebrates and is known as soil organism to improve soil fertility. Because of their abilities to decompose organic materials, develop poor formation of soil to have more organic matters that available for plant.

Such concept, earthworms should be introduced for soil texture improvement by loosing soil structure to be more porosity and the soil permeability would be also improved. Consequently, it was expected that soil with better permeability could leach salt from soil particle. So, this process could decrease salt from soil at some certain level.

Restoration by earthworms is recognized as process which is simply and raw materials could be easily found within local area. Besides, earthworms could be increased its numbers rapidly under the suitable environment. Actually, the location of this study was formerly rice field; not mangrove area. So, the salt-tolerance plants should be suitable for land rehabilitation and possibly returning biodiversity back to such area. Tree supported to absorb salt to underground through root and salted-soil would be improved. Such natural changing process took for sometimes, however it should be better to restore that environmental ecosystem than abandon without any utilization.

Even though, physical soil property of abandoned shrimp farm soils was an obstruct for plant passage through underground soil, earthworms suppose to be suitable soil organism for improvement and allow roots grow easily resulting in occurrence of plant communities afterwards. This study focused on the effect of earthworms founded in the abandoned shrimp farm to be beneficial for physical and chemical properties of soil. It was expected that earthworms could improve saline soil in the abandoned shrimp farm area. Furthermore, basic knowledge gained from this study could apply to other study areas.

Table 1-1 Regional distribution of salt-affected soils in million hectares

Region	Total area (million ha)	Saline soil (million ha)	Percentage of saline soil	Sodic soil (million ha)	Percentage of sodic soil
Africa	1,899.1	38.7	2	33.5	1.8
Asia and the Pacific and Australia	3,107.2	195.1	6.3	248.6	8
Europe	2,010.8	6.7	0.3	72.7	3.6
Latin America	2,038.6	60.5	3	50.9	2.5
Near East	1,801.9	91.5	5.1	14.1	0.8
North America	1,923.7	4.6	0.2	14.5	0.8
Total area	**12,781.3**	**397.1**	**3.1**	**434.3**	**3.4**

Source: FAO AGL, 2000

Table 1-2 Shrimp farming areas in Sub-basins of Songkla lake in the years 1995-2002

Sub-basin of Songkla lake	Shrimp farm area in 1995 (rai)	Shrimp farm area in 2002 (rai)	Changed area (rai)	Percentage of changed area
1. Klong Papayom Sub-basin	0	0	0	0
2. Klong Thanae Sub-basin	0	0	0	0
3. Klong Nathom Sub-basin	0	0	0	0
4. Klong Thachead Sub-basin	0	0	0	0
5. Klong Bon Sub-basin	429	2,760	2,331	543.4
6. Klong Pru Phor Sub-basin	1,952	278	-1674	-85.8
7. Klong Ratthapum Sub-basin	173	33	-140	-80.9
8. Klong Authapao Sub-basin	2,605	1,987	-618	-23.7
9. Eastern coastline 1st Sub-basin	29,771	20,711	-9,060	-30.4
10. Eastern coastline 2nd Sub-basin	7,071	1,092	-5,979	-84.6
11. Eastern coastline 3rd Sub-basin	7,679	3,347	-4,332	-56.4
12. Eastern coastline 4th Sub-basin	2,731	1,133	-1,598	-58.5
Total area	**52,411**	**313,441**	**-21,070**	**-40.2**

Source: Wichien and et al., 2005

1.2 Objectives of the study

1.2.1 To study the result of earthworms density, quantity of organic matter and type of organic matters that affected to the physical and chemical properties of the abandoned shrimp farm soil.

1.2.2 To study the interaction between earthworms density type of organic matters, and quantity of organic matters that affected to the physical and chemical properties on abandoned shrimp farm soil.

1.2.3 To study the percentage difference between earthworms biomass before and after the experiments.

1.3 Conceptual Framework

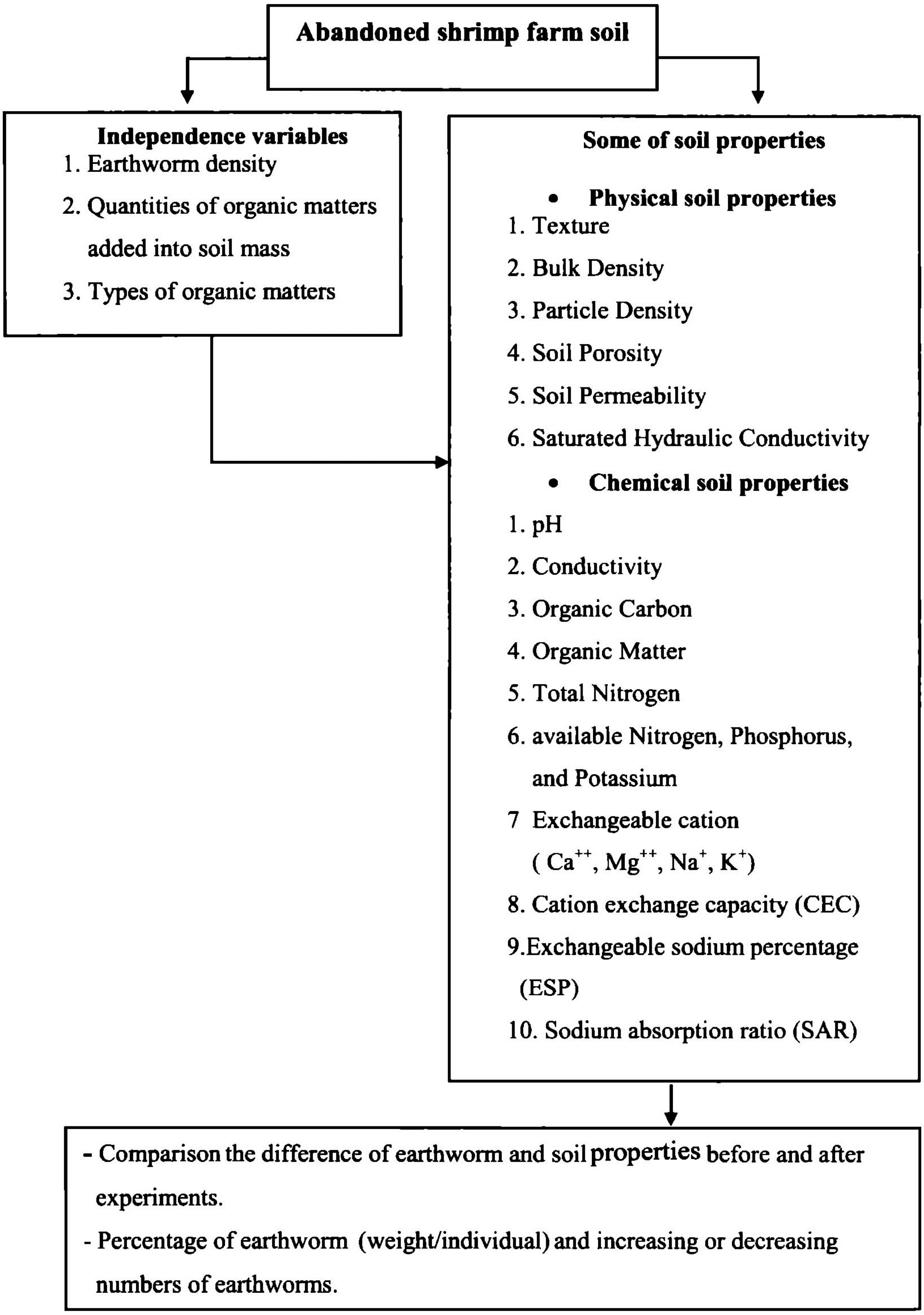


Figure1-1 Conceptual Framework

1.4 Scope of the study

1.4.1 Scope of soil sampling area

Soil sampling area for this study was an abandoned shrimp farm pond located in Ranod District, Songkhla Province.

1.4.2 Scopes of Study

1.4.2.1 Experimental variables

This study focused on effects of earthworms *(Polypheretima elongata)* density which was one of organic matters and quantity of organic maters on abandoned shrimp farm soil properties. The study variables were

1.) Independence variables: earthworms density, quantity of organic maters and types of organic mater.

2.) Dependence variables: physical and chemical of soil properties, percentage of earthworms weight per individual and increasing or decreasing numbers of earthworms.

3.) Control variables: water quantity used to moist the soil, type of organic maters and the amount of soils for each treatment.

1.4.2.2 Physical and chemical properties of soil

The study observed on changing of physical and chemical properties of soil that were studied as the following:

1.) Physical properties: texture, bulk density, particle density, porosity, permeability and saturated hydraulic conductivity.

2.) Chemical properties: pH, conductivity, organic carbon, total nitrogen, available nitrogen, phosphorus and potassium, exchangeable cation (Ca^{++}, Mg^{++}, Na^{+}, K^{+}), cation exchange capacity (CEC), exchangeable sodium percentage (ESP), and sodium absorption ratio (SAR).

Primary data of the study area before any treatment of soil properties and earthworms biomass was analyzed to compare with post experiment of soil properties which was treated with earthworms and/ or organic maters.

1.4.2.3 Location of the experiment

The experiment took place in the Laboratory of the Faculty of Environmental and Resource Studies, Mahidol University.

1.5 Expected results and anticipated benifits

1.5.1 To obtain the results of earthworms density, quantity of organic materials and type of organic materials that affect to abandoned shrimp pond soil.

1.5.2 To obtain basic knowledge of salt-affected soil area from shrimp culture and the approach to restore such area and could be applied for other saline areas.

CHAPTER II
LITERATURE REVIEW

2.1 Description of the study area

Geography of Ranot district is plain area for both sides. The western part is low land of Songkhla lake basin where water often shortages in dry season and sudden floods occur every year in rainy season and last for a long period of time. For the eastern part, it is a coastal plain area where is similar to sand dune long for about 40 kilometers.

The study area is located in Tha-Bon Sub-district. Geography of the area mostly, is flat plain along the zone. The characteristic of eastern region is a coastal plain adjacent to the coastal low plain area. Some of land use for this area was paddy field and the others next to the sea are constructed farm lands for aquatic cultures such as shrimp, fish etc.

The problems of land use in the study area related to soil: natural soil is saline and relatively to low fertile. Soil salinity resulting from salt in bottom soil caused brackish aquatic culture and dispersion of sea water from farm land into paddy area (Wuttichat, 1991).

2.2 Characteristics of soil in the study area

The series of soil in sampling area is Ranot soil series which have detailed in reconnaissance soil map of Songkhla Province. (Soil Survey Division, Bangkok, 1973) Details of soil taxonomy are

Order	Alfisols, which is a ground floor of Argillic or Kandic and a saturation 35% alkaline.
Sub Order	Aqualfs
Great group	Endoaqualfs
Sub group	Typic
Family	Very-fine, Mixed, Isohyperthermic

Soil series Ranot (Ran)

The origin of the Ranod soil series caused by flooding and composition of the brackish sediment on former tidal flat or coastal plain. Nature area is plain where is 0-1 percentage of slope. Drainage of the soil is poor: infiltration and water run off are slow.

Characteristics and properties of Ranot soil series have detailed as follow:

1.) Top soil: texture is silt clay loam; depth not exceeding 20 cm; ground color is gray brown, light brown colors of a gray include brown or sallow brown with a large number of small reddish-brown mottles; soil reaction is moderately acid to neutral; acid-base value is approximately 5.6 -7.3.

2.) Bottom soil: texture is clay; ground colors are gray, light-gray color of a green olive and include a large number of small brown mottles; soil reaction is neutral to alkaline medium; acid-alkaline value is approximately 6.6 to 8.4 (Land Development Department, 1981).

According to the Land Development Department's report, chemical properties and abundance of Ranod soil series showed in the Table 2-1:

Table 2-1 Physical and chemical properties of Ranot soil series (1)

Ranot series	Horizon	Depth (cm)	Particle size analysis USDA Grading %			pH		$CaCO_3$ (%)	Conductivity 1:5 EC x 10^6	Carbon (%)
			sand	silt	clay	1:1 H_2O	1:1 KCl			
Pc - 730	Ap	0-12	2.00	59.5	34.5	4.8	3.8	0.15	74.0	2.84
731	A3	12-25	1.00	20	59.5	5.4	4.2	1.07	130.0	2.43
732	B21	25-48	1.50	35.5	63	6.5	5.35	1.38	190.0	1.11
733	B22	48-81	2.50	36.5	61	7.1	6.1	1.38	160.0	0.16
734	B3	81+	1.00	32.5	66.5	7.3	6.3	2.3	370.0	0.28

Source: Land Development Department, 1981

Table 2-2 Physical and chemical properties of Ranot soil series (2)

Horizon	Exchange capacity and cation									Percent of Base Saturation	P (ppm) Bray II	K (ppm) Ammonium Acetate
	Ca	Mg	K	Na	Sum Base (B)	Ex Acidity (A)	Sum (B+A)	CEC soil	CEC Clay			
Ap	2.0	6.6	0.2	0.9	9.7	9.1	18.8	14.4	41.7	52	3.7	99
A3	3.1		0.3	1.6		7.9			59.5		2.2	140
B21	3.8	18.7	0.3	3.0	25.8	4.8	30.6	24.5	38.9	84	3.6	166
B22	3.5	20.1	0.4	4.2	28.2	3.6	31.8	23.7	38.9	88	3.9	178
B3	4.0	23.8	0.6	5.7	34.1	3.6	37.7	15.6	23.5	91	7.3	242

Source: Land Development Department, 1981

2.3 Saline soil and classification of saline soil

Saline soil is the soil that salt dissolves easily or sodium can exchange more than normal volume. There are several saline soil classification systems. Europe often uses saline soil classification according to type of salt that have different soluble properties in water, such as Na_2CO_3, Na_2SO_4 and NaCl. While developing countries often use saline soil classification according to salinity levels, which are divided into low, medium and high salinity levels. There are 2 systems of saline soil classification method used at present: 1) the Russian system, which divides saline soil to two types including Sclonchak. That is a saline soil in a white salt crust. Reaction of soil is neutral to alkaline. The second type of saline soil is Solonez. The soil in this type is black color saline soil with high density. The crust of salt on the soil surface is black. 2.) USSL system of the United States, divides a saline soil in two groups: saline soil and sodic soil (Somsri, 1996). The principles of saline soil and sodic soil chemical property classification showed in Table 2-3.

Table 2-3 Classification of soil as a basic soil, sodic soil, saline sodic soil and normal soil

Value / Type of soil	ECe (dS/m)	ESP (%)	SAR	pH
Saline soil	≥0.4	<15	<13	<8.5
Sodic soil	<0.4	>15	≥13	>8.5
Saline sodic soil	≥0.4	>15	≥13	≥8.5
Normal soil	<0.4	<15	<13	<8.5

Source: Department staff of Pedology, Kasetsart University, 2006

Remark: Value of electrical conductivity measured from the soil solution which extracted from soil, with water saturation; 1 S/m =10 dS/m

The table 2-3 showed the chemical properties used in the classification of soil salinity. A value reflects the influence of exchangeable cation. These chemical properties could be described as follows:

1.) ECe (Electrical Conductivity)

Electrical conductivity of soil solution came from measurement of extracted soil solution with water saturation. This value depends on the amount of soluble salts and water temperature when measured. So, it must use the value measured at 25 degrees as standard value. Moreover, electrical conductivity of the soil will decrease approximately 2% per degree Celsius increase (Land Development Department, 2001) whereas electrical conductivity of soil solution have been used to assess the concentration of soluble salts in the soil. There are major soluble salts in the soil like Na^+, K^+, Ca^+, Mg^{2+}, NH_4^+, Cl^-, NO_3^-, HCO_3^-, and SO_4^{2-}. Soil with high EC values is a soil with high salt solubility (Patcharee et al., 2007).

2.) Cation Exchange Capacity (CEC)

CEC is total of exchangeable cation which is absorbed by soil or clay or other materials in a unit of centimole per kilogram of soil (cmol/kg). Cation exchange capacity depends on: 1) Quantity and type of clay particles: fine texture soil has more CEC values than coarse texture soil whereas the same texture of soils which equal in clay particle volume but different CEC values show the different types of clay minerals. 2) Colloid in the soil with highest CEC value is organic matter. 3.)pH changed condition: the stable anions in soil is not vary in pH range 2.5-5.0, but the increasing of stable anions occur in pH range 5.0 -7.0. Moreover, there is a small of OH-group which breakdown in pH 6, but higher in pH 7.

3.) ESP (Exchangeable Sodium Percentage)

ESP is value of sodium percentage which exchange in the soil when compared with the capability of exchangeable nutrients in the soil. The ESP equation is ESP = $[(Na^{+})/CEC] \times 100$ (Members of the college of Faculty of Pedology, KU, 2005).

ESP value derived from the analysis of sodium exchange capacity of soil, which is a complex approach. However, it can apply SAR (Sodium Adsorption Ratio) instead because it is related to SAR (Land Development Department, 2001).

4.) SAR (Sodium Absorption Ratio)

Sodium absorption ratio of Na, Ca and Mg from soil solution is calculated by the following equation.

$$SAR = Na^{+} /(Ca^{++} + Mg^{++})^{1/2}$$

The ion concentration is in mmol/l or is meq/l (Members of the college of Faculty of Pedology, KU, 2005).

2.4 Chemical and other physical properties of soil

Other features of the chemical and physical properties of soil related to this study show as follows:

2.4.1 Chemical properties of soil

2.4.1.1 Soil reaction (pH)

pH represents the degree of acid or alkaline soil condition that shown by the soil pH value.

pH	**Conditions of acid or alkaline soil**
< 3.5	Ultra acid
3.4-3.5	extremely acid
4.6-5.0	very strongly acid
5.1-5.5	strongly acid
5.6-6.0	moderately acid
6.1-6.5	slightly acid
6.6-7.3	neutral
7.4-7.8	slightly alkaline
7.9-8.4	moderately alkaline
8.5-9.0	strongly alkaline
> 9.0	very strongly alkaline

2.4.1.2 Total Nitrogen

Rowell (1994) described all the total nitrogen in soil, including organic-N, ammonium-N and mineral-N. Nitrogen were created from nitrogen gas in the atmosphere which has been fixed by microorganisms in the soil and then transform to organic-N in the form of amino (NH_2), which is a part of the organic matter in soil. For the decomposition of organic matter, they transformed the organic-N to the mineral-N forms: ammonium (NH_4^+), nitrite (NO_3^-) and nitrate (NO_3^-). Nitrogen in soil is always changed continuously to another form. The process related to the change of nitrogen showed as the following:

1.) Mineralization

This process changes organic-N to mineral-N by microbes as shown in the equation:

$$\text{Organic-N} \rightarrow NH_4^+$$

2.) Nitrification

Nitrification is the oxidation of ammonia-N, which is transformed to nitrite and nitrate by microorganisms as shown in the equation:

$$NH_4^+ \rightarrow NO_2^+ \rightarrow NO_3^-$$

3.) Immobilization

Immobilization is the oxidation of ammonia-N, which transformed to organic-N. The process occurs when short of organic-N; therefore, microorganisms fix nitrogen from the mineral-N.

$$NH_4^+ + NO_3^- \rightarrow \text{Organic-}NH_2$$

4.) Volatilization

Volatilization is the loss of nitrogen gases from soil under alkaline conditions of the ammonium ions. They will be transformed to ammonia into the soil solution, and could be released to atmosphere.

$$NH_4^+ + OH^- \rightleftarrows NH_3 + H_20$$

5.) Denitrification

Denitrification is a process of losing nitrogen gas and nitrous-oxide from soil under the anareobic condition. The nitrate and nitrite will be reduced into gas by microbes.

6.) N-fixation

N-fixation is the process of N_2 changed to NH_4^+ by a specific group of microorganisms. Then, NH_4^+ will be transformed to organic-N.

The study about changes in the properties of abandoned shrimp pond soil in southern Thailand by Towattana et al. (2002) mentioned that pH of soil from the abandoned shrimp pond associated with organic matter in soil and process of nitrogen using by microbial in abandoned shrimp pond soil. The pH of abandoned pond soil after 3 years was decreased. The study mentioned that it was resulted from decomposition of organic residues accumulated at bottom of the pond as anaerobic and aerobic conditions in the rains and dry seasons, respectively.

In aerobic condition, microorganism was synthesized the SO_2 gas which released from soil by process of organic substances decomposition, and then some parts of them were dissolved by water and transformed to H_2SO_4: strong acid which affected to reduce pH of soil.

In anaerobic condition , microorganism was synthesized the H_2S gas. The solubility of H_2S in water transform to H_2SO_4 which affect to reduce pH of soil. In addition, the decrease of pH in soil resulting from the transformation of organic nitrogen to mineral by the process that show as the following respectively:

1.) Aminization is a decomposition digested process of organic substances by heterotrophic soil microorganisms. The final products is amine and amino acid.

2.) Amine and amino acids are be used by microorganisms to synthesis is a ammonia compound. Ammonia complex compounds are released from soil by microorganism.

3.) Ammonia complex compound released from soil will be transformed to nitrite and nitrate by nitrification process. This process releases H^+ ion resulted in decrease of pH when the soil is dried.

The pH increasing is occured after the denitrification process under anaerobic condition. Rapid denitrification process results in reduction of NO_3 to be NO_2 or N_2 from soil at the bottom of pond which, entire of H^+ and organic matters are used by microorganisms resulted in decrease of pH.

The decrease of pH in soil occurs during the nitrification process under the aerobic condition while, an increase of pH occurred under anaerobic condition. However, the net ratio between N and H^+ from the above study indirected that pH value of soil was decreased. Also, the final results from decomposition of pH in soil.

2.4.1.3 Available Phosphorus

Phosphorus in the soil found in the form of inorganic phosphate and organic matter. Generally, phosphate in soil is hardly dissolved by water. Plants uptake phosphorus in the form of $H_2PO_4^-$ and HPO_4^{2-} (Rowell, 1994). Another form of phosphorus is PO_4^{3-},which plant can up take but they was presented in a little proportion in soil solution. Phosphorus in the soil derived from organic matter by the transformation of organic matter; mineralization process. It also derived from soluble of phosphate compound by water. (Members of the college of Faculty of Pedology, KU, 2005)

Sources of phosphorus in the bottom of shrimp pond come from food residues and the excretions result in an increase of phosphorus accumulation in the bottom pond soil, especially in active pond. In addition to phosphorus, there is also accumulation of organic carbon and nitrogen (Avnimelech and Ritvo, 2003).

2.4.1.4 Available Potassium (K)

Available potassium is the quantity of of K^+ in soil solution or soil particles and it also refers to the amount of K^+ which extracted from the soil solution. Plants uptake potassium for growth in the K^+ form. Typically, K^+ in soil solution will diffuse to the plant roots, this process requires time. Therefore, plants can use K^+ in limited quantities from dried and compacted soil because there are unsufficient water to dissolve K^+ for diffusion through plant roots (Rowell, 1994).

2.4.1.5 Exchangeable cation

Exchangeable cation is a cation which are adsorbed in the surface of soil colloid. It is divided into 2 categories: acid cation like H^+ and Al^{3+} ion, which affect to acidity of soil; alkaline cation like Ca^{2+}, Mg^{2+}, Na^+ and K^+, and affect to alkalinity of soils (Members of the college of Faculty of Pedology, KU, 2001).

Exchangeable cations have an influence on soil structure. The report from Bronick and Lal (2005) mentioned the importance of Ca^{2+}, Mg^{2+}, and Na^+ that have detailed as follow:

1.) Ca^{2+} and Mg^{2+}

Calcium and magnesium ions improves soil structure by capture with clay and organic matter in soil. In generally, Calcium ion has more effective effects for of soil structure improvement than magnesium ion because calcium ion can inhibit dispersion of clay particle. This related to the soil aggregation by calcium ion subscribe to sodium and potassium ion in clay particle. Considering to dispersion of soil, magnesium has stronger effect than other ions on dispersion and swell of clay particle.

2.) Na^+

The characteristic of sodium ion is high dispersion. Sodium ion has the direct effect to breakdown soil aggregates. The indirect effect of sodium is reducing the productivity of crops. In soil, exchangeable sodium pushes positive charge of clay particles result in dispersion of clay particle. Moreover, it is also affect on disintegration of soil and organic matter which is broken down easily.

As a result of using sea water for shrimp culture, there was an accumulation of cation such Ca^{2+}, Mg^{2+}, Na^+ and K^+ in the bottom pond soil. These ions are elements from sea water (Towatana et al., 2002).

2.4.2 The physical properties of soil

2.4.2.1 Drainage

Drainage of soil depends on the size and arrangement of pore in the soil. One of the most important soil quality reflects ability of soil drainage is saturated hydraulic conductivity. Soil which is high saturated hydraulic conductivity is well drainage.(Members of the college of Faculty of Pedology, KU, 2001)

2.4.2.2 Saturated Hydraulic Conductivity

Saturated hydraulic conductivity depends on moisture and texture of soil. In condition of high moisture in the soil, water will be filled in soil's macropore and then flow out in a short time. In contrast, water will be contained in micropore when low water condition, consequently, the hydraulic conductivity is slow. For soil texture with high moisture, soil in coarse texture type has higher hydraulic conductivity than fine type because water flows through macropore. On the other hand, water flows through micropore when the soil moisture is lower therefore hydraulic conductivity of soil in coarse soil texture is lover than fine type because the continuity of micropore in coarse soil texture is not good condition as micropore in fine soil texture (Rowell, 1994).

Measurement of infiltration rates in soil, design to 2 possible methods:

1.) Constant-head method

Constant-head method using is typically used on soil with a relatively high conductivity, procedure allows water to move through the soil under a steady state head condition while the quantity (volume) of water flowing through the soil specimen is measured over a period of time.

2.) Falling head method

Falling head method is typically used on soil with relatively low conductivity. This is a way that let water above the soil sample move through the soil and then measured changes in water level above the surface over time without maintaining a constant pressure head.

The measurement of infiltration rates in this study used the falling head method, which was applied from the method of the member of the college faculty of Pedology, Kasetsart University (2001).

The evaluation on conductivity of soil saturation can be determined by the constant (K) and the classification of hydraulic conductivity values was given in the Table 2-4.

Table 2-4 Classification of hydraulic conductivity values

Hydraulic Conductivity ($m\ day^{-1}$)	**K ($cm\ h^{-1}$)**	**Conductivity Class**
< 0.2	<0.8	Very slow
0.2-0.5	0.8-2.0	Slow
0.5-1.4	2.0-6.0	Moderate
1.4-1.9	6.0-8.0	Moderately rapid
1.9-3.0	8.0-12.5	Rapid
>3.0	>12.5	Very Rapid

Source: Landon, 1984 referred to FAO (1963)

2.4.2.3 Infiltration

Infiltration is the process of the surface water flow through the outside boundaries into the soil mass. Infiltration may occur in both vertical and horizontal (Members of the college of Faculty of Pedology, KU, 2005). The properties associated with the infiltration of water into soil include: 1) Infiltration rate is a flux of water which is concerned about percolation of water through soil surface and into the soil profile. 2) Infiltration capacity is a flux of water that can be absorbed through the soil surface when the soil surface is contacted with water all the times under pressure of the atmosphere.

Infiltration of ground water may occur in different rates which from zero to maximum capacity of the soil. So if there is rain or water in quantities less than the infiltration capacity of soils, the occurrence of infiltration is the rate of soil and that is not a capacity of soil infiltration. But, if there is sufficient of water, the occurrence of infiltration is represented of infiltration capacity and that is not a infiltration rate. These describe that there are many levels infiltration rate from each soil type which is depended on the amount of water on the soil surface. However, infiltration capacity is only one level (Rowell, 1994).

To measure the infiltration of soil, the double ring or cylinder were used in this study applied from the methodology of Landon (1984) and FAO corporate document repository (2009). To evaluate the level of infiltration rate, could be done by using the criteria of BAI systems that shown in Table 2-5:

Table 2-5 The infiltration category

Class	Infiltration category	Basic infiltration rate (cm h^{-1})
1.	Very Slow (non-irrigable)	< 0.1
2.	Slow	0.1-0.5
3.	Moderate slow	0.5-2.0
4.	Moderately	2.0-6.0
5.	Moderately rapid	6.0-12.5
6.	Rapid	12.5-25
7.	Very rapid	>25

Source: Landon, 1984 refers to C Berryman, in liaison with FAO and MAFF worker

2.5 The occurrence of saline soil

Processes that occur between the saline soils have detailed as follows:

2.5.1 Salinization

Salinization is a process of salt accumulated in soil and allows to soil surface when the water surface or water in soil can not drain. Then, water evaporates from the soil and salt is more intense.At initial, sodium salt is found in more intensity rather than other salts. because the solubility of calcium carbonate and calcium sulfate is slowly and less than sodium salt. Therefore, their sedimentation occurs later.

2.5.2 Alkalization

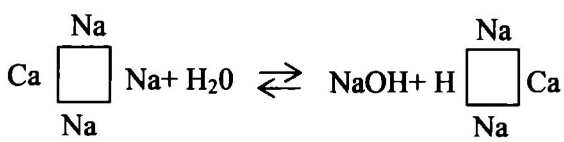
As the increasing of salt accumulates in soil, the balance between the cation in soil solution and another one which absorbed in the soil particle will be occurred. The more increased of soluble sodium in solution contribute to more increased of soil particles. Then, exchangeable sodium is increased resulting in the soil reaction is alkaline. So this process is called alkalization.

2.5.3 Desalinization

Desalinization is a process of wash the exceeding salt from soil. The amount of salt has been washed. Then, particle of clay is likely to split off and the infiltration is reduced.

2.5.4 Solotization

If the desalinization is continued without gypsum or calcium carbonate, the shortage of cation will occur and could not to replace sodium. First process, sodium will combine with water and transform to NaOH and H^+ and then hydrogen in the soil will be increased. Second process, sodium hydroxide has a chemical reaction with carbonic acid (H_2CO_3) which derives from carbon dioxide in the air and water in soil. Final product is sodium carbonate (Na_2CO_3). These processes showned in the equation below.



$$CO_2 + H_20 \rightarrow H_2CO_3 + NaOH \rightarrow Na_2CO_3 + {}_2H_2O$$

The reaction of soil is acid condition when sodium carbonate is washed out. However, sufficient quantities of calcium carbonate or gypsum will affect Ca^{2+}.to replace Na^+.

2.6 The impact of brackish shrimp culture on soil properties

The brackish shrimp culture resulted in deterioration of soil properties in both physical and chemical properties of soil. Generally, the physical properties of soil affected by the brackish shrimp culture was changed for example bulk density of soil was increased, the quantity of soil porosity was decreased and soil had low infiltration rate. For the chemical properties, it was found that the value of electrical conductivity (EC), exchangeable sodium percentage (ESP) and sodium absorption ratio (SAR) was increased. The impact also resulted in a decrease in soil organic matter. There are research studies related to the properties of the soil affected by salinity in the shrimp farm showed as the following:

Study of the impact of shrimp farm on the chemical properties of soil resources in Ranod district, Songkhla province concluded that the using of sea water for shrimp culture affected chemical properties of soil. That was the change of rice field into an area of shrimp culture has resulted in increasing of soil acidity and electrical conductivity which higher than the value from paddy soil in the same level. However, increased salinity would decrease as the depth of soil profile. The dispersion rate of salinity in vertical of abandoned shrimp pond soil was over 40 cm per year. As well as the cumulative sodium and potassium in the soil, the presentage of accumulated sodium from bottom of pond until the depth of 130 cm was found in 1st year pond, and more than 150 cm in the 3 years pond. For potassium, the higher quantity was found in the 100-120 cm depth in new pond, but it was not increase in old pond. Further more, also found that, the electricity conductivity of soil in the abandoned shrimp pond was positive relationship with sodium and potassium. The quantity of organic matter and sulfur in the abandoned shrimp pond soil decreased as the depth of soil profile (Pipob et al.1994).

Somsak et al. (1999) studied the impact of the shrimp culture on the chemical properties of soil in surrounding area. The soil sampling was performed from the cultivated areas of Neem tree next to the abandoned shrimp pond. There had canal of brine drainage between Neem tree cultivated areas and abandoned shrimp pond. The collection of soil samples was performed at every depth of 15 cm to 120 cm. Soil samples were collected in the first hole at a distance 5 m from the shrimp pond, the second and third holes away from the first hole 30 and 60 m respectively. The soil samples were collected in the rainy and drought season. The result of this study pointed out the electrical conductivity and salinity. The saturation electrical conductivity (EC) of soil collected from the first hole was higher than 4 mS/cm through the depth. Then, at the second and third drilled holes found that the salinity of the soil was less than 2 mS/cm and the salinity tended to increase along the depth. However, the researchers concluded that they did not found the change of salinity at any levels because salt in soil was moved according to the direction of underground water.

Towattana et al. (2003) studied the changes in soil properties of abandoned shrimp pond in the southern Thailand. Chemical properties between active shrimp ponds and abandoned one with the Bangkok soil series were compared. For the abandoned one, the culture activities had been stopped for 3 years. Soil samples were collected at depths intervals of 0-10, 10-20, 20-30, 30-40, and 40-50 cm from the bottom of pond. This study indicated that soil in the abandoned shrimp pond composed of sea elements; Ca, Mg, P and Na higher than the active by 1.3-3.4, 1.4-2.1, 7.0-30 and 1.2-6.3 times respectively. EC values of the of abandoned shrimp pond soil was 1.3 -10.9 times higher than the soil from active one. These results indicates that the quantity of rain for 3 years could not leach the accumulated salts in the ground soil of pond without restoration. The quantity of organic matters, sulfur (S) and phosphorus (P) at all the depth of abandoned pond soil decreased when compared with the active pond. In addition, it also found that the pH of soil in active shrimp pond decreased; pH of soil in the active shrimp pond at points A and B was 8.17-8.40 and 7.91-8.26 respectively whereas the pH of soil in abandoned pond at points A and B is 8.01-8.06 and 7.51-7.69 respectively. This showed that 3 years without any culture activity, the pH of soil in abandoned shrimp pond reduced to nearly neutral value, and it was more suitable for plant than active pond.

Aomtip (2004) mentioned the impact of shirmp culture on soil resources in the area of upper, central, and lower region of Songkhla lake was changed in similar ways, for example, soil properties were degraded. First part, of the report mentioned about soil quality in upper area of Songkhla lake and the characteristic of paddy soil texture was clay. It also stated that a little proportion of clay particle had been changed when compared with paddy soil at the same level. Second part, mentioned about soil quality in central region, It was found that the proportion of clay particle was reduced, while the accumulation of sand and silt sand particle increased. Third part stated about the abandoned shrimp pond soil in the lower region. It was found the higher proportion of sand and silt sand particle than paddy soil.

For soil texture, the increased value of physical property was soil bulk density whereas the decreased value were volume of water and porosity in soil, plant available water, saturated hydraulic conductivity and the resistance to penetration.

Apart from the chemical properties of soil, the report mentioned an increased of pH, electrical conductivity and exchangeable cation i.e. Na, Ca, Mg, and K. However, cation exchange capacity and soil organic matter had been decreased.

2.7 Improvement of saline soils

Members of the college of Faculty of Pedology, KU (2005) mentioned about the improvement of saline soil (saline-non-sodic soil), saline-sodic soil and sodic soil (sodic-non-saline soil) which detailed as follows:

2.7.1 Improvement of saline soil

Saline soil has an excessive soluble salt. Improvement of a saline soil implies the reduction of the salt concentration of the soil by fresh water overflow for sometimes then drained out. Soil infiltration and drainage improvement done by soil plough with organic matter.

2.7.2 Improvement of sodic and saline sodic soil

Saline sodic soil has a high quantity of SAR. Soil reaction is alkaline, and there has an excessive sodium exchange. The characteristics of soil is compacted and poor drainage. To add gypsum on soil surface result in exchangeable calcium ion replace the exchangeable sodium ion. This allows better soil structure.

Researches related to improvement and rehabilitation of saline soil in abandoned shrimp ponds showed in the following:

Towatana et al. (2003) studied reclamation of abandoned shrimp pond soil in Southern Thailand for cultivation of Mauritius grass, which used to feed animals. This grass spread in the paddy area, swamp and areas with moderate salinity. Soil sampling were collected by using a composite sampling technique at depth of 0-15 cm from the bottom pond of abandoned shrimp ponds in Ranot District, Songkhla Province. Some of soil were analyzed for the chemical properties. Another part was prepared for the experiment in green house. The experiment consisted of desalination by leaching soil with deionised water at the rates of 5, 10, 15, 20 and 25 l per 3 kg of dry soil, applications of mixing with rice husk at the rate of 2, 4 and 8 % by weight, and 0.329 g of gypsum/3 kg soil. Then study on the growth of grass in the abandoned shrimp pond soil and changes of chemical properties of soil after 10 weeks of experiment was done. The results were summarized as: 1) The number of tillers and dry weight of grass mostly depended upon increases in amounts of deionised water and rice husk application. 2) Application of gypsum as a soil amendment significantly high increasing number of tillers and dry weight of the grass, especially at 8% rice husk application. 3) Improvement of soil in abandoned shrimp pond with application of rice husk alone without deionised water application could not improve the properties of the pond soil to make them suitable for the survival of grass. 4) pH of the soil before and after grass growing experiment did not change. The pH values was in the range of 8.07-8.43. While the electrical conductivity of the soil almost treatment soils was decreased which was in the range 2.05-4.02 ms/cm.

Kanjanat (2005) studied on the effect of soil amendments on abandoned shrimp pond. By the basic analysis of soil improvement material properties. It was found that sawdust had the highest ratio of carbon to nitrogen (C:N). The rice husk and coconut flake were the second and third, respectively. From Table 2-5, it showed that organic fertilizer, manure, chicken dung and coconut flake had high sodium quantity. The decomposed process of these materials could release sodium. The study was applied agricultural wastes to the experiment by mixed with abandoned shrimp pond soil to focus on quality of soil amendmends affected to hydraulic conductivity, and also the leaching sodium out from both application of gypsum and without gypsum.

Materials that improve hydraulic conductivity was coarse materials including rice husk, sawdust and coconut flake. The physical characteristic of them contribute to soil spaces. Beside, increase of large particles of mentioned materials possibly remove sodium from soil easier. The fine texture materials such as chicken and cattle manures did not help to increase the soil spaces and also had high salinity.

Polymers material (PAM) cause aggregation of soil into large granuals and contributed to large soil spaces. One the one hand, PAM could not support soil resistance to the force of the water. Moreover, the ESP of soil was highly, therefore soil granular were soluble and swelled and then hydraulic conductivity decreased rapidly.

It also found that, the application of gypsum with materials that could improve hydraulic conductivity in top soil lead to better soil improvement in deep profile and better than using gypsum alone.

Table 2-6 Basic properties of soil amendments

Materials	Total N	Total P	Total K	Total Na	Total Ca	Total Mg	Percent	
							Moisture	Organic Carbon
Sawdust	0.17	0.33	0.14	0.01	0.1	0.04	11.31	50.93
Coconut flake	0.4	0.77	1.34	0.33	0.33	0.11	12.09	39.64
Cattle manual	1.38	0.86	0.9	0.25	1.54	0.59	12.68	30.19
Chicken manual	2.16	1.95	2.09	0.44	2.43	0.66	11.81	36.05
Rice husk	0.33	0.08	0.28	0.01	0.1	0.22	8.02	40.64

Source: Kanjanat, 2005

2.8 Decomposition of organic matter

Decomposition of organic matter depends on the physical characteristic of the material, chemical composition, moisture, temperature, and acid-alkaline level (Land Development Department, 2008). These coul be described as follows:

1.) Physical characteristics of materials

Fraction material which have a numerous of small surface area could be more easier to digested than a large one.

2.) Chemical composition

Ratio between carbon and nitrogen is important for the process of decomposition. Because microorganisms use carbon for synthesize basic compound of cells, and also nitrogen is the main component of proteins. Materials with ratio between carbon and nitrogen more than 100:1 is difficult to decompose. Generally, the ratio between carbon and nitrogen of compost should less than or equal to 20:1 which is provided as good quality compost and not harmful for plants.

3.) Ventilation

Ventilation is essential to aerobic microorganisms. So, ventilation is necessary to provide sufficient oxygen for growth of microorganism and the process of humus digestion.

4.) Temperature

The decomposition of organic matter in high temperature is better than low temperature. The temperature about 70° C is considered too hight and could inhibit microorganisms activities resulting in decrease of organic compound process.

5.) The acid-alkaline levels

The products derived from digestion of organic matter in first stage is some type of organic acid which affect on pH decreased to 4.5-5.0. In the latter stage, temperature will be increased and then the level of pH will be stable to 7.5-8.5.

Typically, pH of plant litters is neutral or slightly acid. The chemical quantity of litters has been decomposted and could act as buffer that could maintain the level of pH.

2.9 Properties of rice straw

Straw is agricultural materials available in the study area. Chemical analysis of rice straw showed the percentage of nitrogen, phosphorus as P_2O_5, potassium and carbon are 0.55, 0.09, 2.39 and 48.82 respectively. In addition, ratio of carbon to nitrogen in straw is 89 and pH is 8.20 (Land Development Department, 2008).

2.10 Earthworms

Earthworm is the invertebrate classified in Kingdom Animalia, Phylum: Annelida, Class: Oligochaeta, Order: Opisthopora. There are many families of earthworms and have different classification by scientists. Family classification of the earthworm which is widely used and reliable document is Gate (1972) that categorize earthworms in group of 14 families (Gates, 1972).

In Thailand, the realistic report of earthworm family consist of 8 families and 27 species which derived from the latest report of Gates in 1972. There has been no any study about taxonomy of earthworm for 40 years until the year 2004. The Study of the Blakemore on the Gate's review document has reported 27 species of earthworm in Thailand, that showed in Table 6. (Somsak, 2007)

Table 2-7 List of earthworm species found in Thailand

Order	Suborder	Family
1. Moniligastrida	1.Moniligastridae	*Drawida bessarii* , *D. vulgaris*
2. Haplotaxida	2. Megascolecidae	*Amynthas alexandri* , *A. Comptus*, *A. Evansi* , *A. exiguus austrinus*, *A. exiguus exiguous* , *A. Gracilis*, *A. hupbonensis*, *A. longicauliculatus*, *A. manicatus manicatas*, *A. mekongianus*, *A. morrisi*, *A. Papulosus Lampito mauriti*, *Metaphire anomala*, *M. bipora* ,*M. Houlleti*, *M. malayana*, *M. Peguana*, *M. Planate*, *M. Posthuma*, *M. Virgo*, *Polypheretima elongate*, *Perionyx excavatus*
	3. Octochaetidae	*Dichogaster (Diplothecodrilus) affinis*
	4. Glossoscolecidae	*Pontoscolex corethrurus*

Source: Adapted from Somsak et al. (2007)

2.11 General features of earthworms

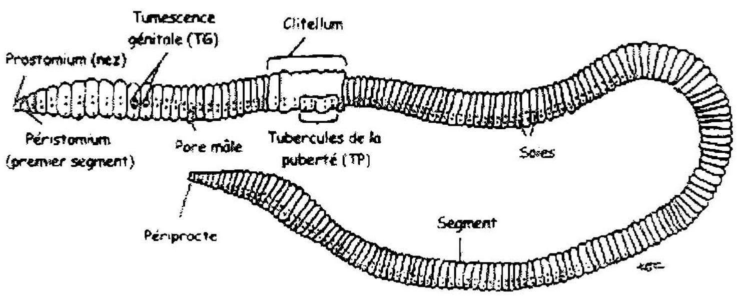


Figure 2-1 External features of earthworm

Source: Image purchased by Mr and Mrs Smith's Life Science by subscription, from http://www.smithlifescience.com/SciWormObservationNotes.htm

2.12 Grouping of earthworms

Scientists generally divide earthworm into three groups by using of soil depth where earthworm present (Anat, 2006) as the following:

1.) Epigeic species: This group lives in few depth near ground level page and found in soil with high organic matter. Epigic species is very important to decompose the organic substances. This groups is prefer to create a continued cavity in the soil, and frequently create horizontal cavity.

2.) Endogeic species: The habitat of endogenic earthwoms is top soils. They often move down to the soil surface for living. This group have minor roles in decomposition of organic substances; however crucial roles of them are soil forming process, breaking the remainder of dead plant roots, mixture of soil, and movement of air within the soil.

3.) Anecic species: This group of earthworm created durable cavities which are in a vertical and down from the ground floor. They ingest humus and remainder of dead animals.

2.13 The Earthworm used in this study: *Polypheretima elongata*

Figure 2-2 Ventral view of earthworm, species *Polypheretima elongata*
Source: adapted from Sims and Eastaon, 1979

Polypheretima elongata have divided into a group of endogeic species. This species has only found in tropical and can not live in the cold region. Apart from Gates' report (1972), there was mentioned this species in the name of *Polypheretima elongata.* Habitats of this species are Black mud soils: red, black cotton soil (Indian, Burma), black taro soil (Hawaii), taro fields, in yard with animal feces of dairy farm, gardens (Hawaii, several times), under rubbish and compost, and sometimes down to depth of 12-18 inches below the suface (Gate, 1972).

2.13.1 Life cycle

Life cycle of the earthworm consists of cocoon stage, larva stage, pupa stage and mature stage. When they form a pair for repoduction, the individuals produced the covering of silk threats that called cocoon outside the body, near female pore. The larva will develop inside a cocoon and hatch later (Anat, 1996). Bhattachariee and Chaudhuri (2002) studied about the cocoon producing, morphology, hatching pattern and fecundity in seven tropical earthworms which collected from pasture of India. Under the experimental laboratory, *Polyheretima elongata* continuously produced spheroidal cocoon and this species is a continuous breeder. The incubation period take 49.5 days and about 40 percentage of hatching success, The maximum times for about cocoon building are 2 times per year in April and July with the maximum temperature about 30-32 degree Celsius. The different temperature affects the incubation period of cocoon, it increases when increase in room temperature. In contrast, cocoon producing is decreased when average temperature is less than 27 degree Celsius. However, it can produce at the temperature of 21 degree Celsius. Moreover, *Polypheretima elongata* can reproduce by self-fertilization; however this study did not mention the duration of development time to a mature stage after hatch from the cocoon.

2.13.2 Environmental factors

Environmental factors have an influence on earthworm include moisture, temperature, acidity-alkaline, ventilation, concentration of carbon-dioxide, type and structure of soil, volume of organic matter and sources of food. The earthworms living in various regions of the world have different resistance in environmental condition. That also depends on the environmental tolerance of species. However, the majority of earthworms prefer to the high humidity rather than dry conditions. Humidity influences the cocoon production. The acid-alkaline that suitable for almost types of earthworm species is approximately 7.0. For soil structure, the majority of the earthworm population is more often found in loose soil than, moderately loose soil, clay or sandy soil mixed with gravels and riverbank sediment respectively. Most earthworms widespread on the soil with organic matter. They ingest anythings surrounding the habitats: first group living in top soil or soil surface ingest organic matter and faces; second group living in a deep strata ingest soils that compost of high minerals. Also found that earthworms ingest protozoa, the small microorgahism such as nematodes, fungi, bacteria and microbes (Anat, 2006). Moreover, Wallwalk (1983) mentioned that earthworm could ingest all of natural organic substances that available in surrounding habitats.

2.13.3 The experimental application for food, moisture and density of endogeic earthworm: *P. elongata.*

The studies about the application of endogeic earthworm (*P. elongata*) have detail as follows:

1.) The study on digestion of vertisol by endogeic earthworm *Polypheretima elongata* increased soil phosphate extractability (Brossard et al., 1996). The respective soil samples was prepared by mixing 50 samples taken at random with an auger from the 0-20 cm layer in a pasture. The sample was air dried, crushed and sieve at 2 mm to provide an homogeneous medium for earthworm cultures. Soil was moistened with water content 0.61 g g^{-1} soil (soil moisture ~61 %). and filled into 10 boxes containing ca. 1 kg of compacted fresh soil. Two adult earthworms of 2 g fresh weight were placed in each box. The study did not mentioned about adding of food for earthworms.

2.) Fransis and Transer (1998) reported about the study on effect of 3 earthworms species on soil macroporosity hydraulic conductivity. The soil samples was air dried, crushed and sieve at 2 mm into PVC. The bottom 25 cm of each cylinder was filled with subsoil density of 1.3 g/cm^3, and the top 25 cm was filled with top soil density of 1.2 g/cm^3 a dry bulk density of 1.3. These bulk density values were representative for agricultural soil activities. Dried, ground ryegrass was mixed well with top soil or subsoil at a rate of 8 or 2 g dried grass per kg (0.8 or 0.2% by weight) of dried soil respectively. Earthworms were then inoculated at the surface of cylinder at a rate of 300 ind/m^2 for *A. caliginosa*, and 600 ind/m^2 for *O. cyaneum* or *L. rubellus*.These rate are in the range of total earthworm populations commonly found in agricultural soils in New Zealand. The cylinder were sealed with fine gauzed to prevent the exit or entire of earthworms, and then buried in the field and exposed to nature climatic conditions. Six months later all cylinders were removed and transport to the laboratory. The study did not mention about soil moisture.

3.) The study on enhancement of growth and reproduction of the tropical earthworm *Polypheretima elongata* by addition of *Zea mays* and *Mucuna pruriens* var. *utilis* litter to the soil (Huerta et al, 2005). The soil samples was air dried, sieve at 2 mm and moistened into the content of 33% moisture which represented to soil moisture in field. The 300 g of soil samples was then contained into container and mixed with utilis of dried *Zea mays* and *Mucuna pruriens* in a rate of 1.5 and 4.5 g /100 g soil respectively. These litters were let to decompose for 0, 2, 4 and 6 weeks before taking an experiment with earthworm *P. elongata*. The experiment provided earthworm in a rate of 3.3 ind /1kg soil.

4.) Blanchart et al (2004) reported on the study on respective roles of earthworms in restoring physical properties of vertisol under pasture. The study took places in the field which earthworm *Polypheretima elongata* released in a rate of biomass 90 g/m^2 .The study not mentioned about food of earthworm because study done in the field.

2.14 The role of earthworm to the soil forming and soil properties

Earthworms contribute to the soil forming process by affecting soil pH, physical digestion of organic materials, humus formation, improvement of soil texture and enhancing soil abundance (Wallwalk, 1983). Properties of soil are related to density of earthworm, especially porosity that vary from the density of earthworm. In high numbers, earthworms can have notable effect on soil and porosity (Edwards, 1998).

Brossard et al. (1996) studied the digestion of a vertisol by the endogenic earthworm, *Polypheretima elongta*, to increase soil phosphate extractability. The soil sample was air dried, crush and sieve at 2 mm, to provide an homogeneous medium for earthworm culture. Soil was moistened and packed into 10 boxes containing 1 kg of compacted fresh soil. Two adults earthworms: 1 gm fresh weight were placed in each box. After that, representative sample of fresh casts and non-ingested soil were taken for the analytical determinations. The results showed that the total P content of fresh cast did not differ from that in the non-ingest soil. The phosphate content extracted from cast is higher than the non-ingested soil. In addition, particle-size distribution of ingested soil and cast significantly differed from that in the non-ingested soil, in which cast contained a higher proportion of finer particles than the soil.

Moreover, Particle size fractionation was performed to separate sand, silt, and clay particles and investigated C and P concentration in each particle sizes. It was found that no difference of organic carbon concentration in soil and cast particles except in the particle size of 20-200 micrometers which organic carbon concentration in cast was higher than soil. In addition, there was a higher proportion of finer minerals (0-20 micrometers) in casts and greater C content in coarse fraction. These results could refer to selection in feeding by earthworms on the finer soil particles.

Fransis and Fransor (1998) studied the effect of three earthworm species on soil macropore and hydraulic conductivity. Three species of earthworm were *Apporretodea caligona*, *Octolasion cyaneum* and *Lumbricus rubellus*. Top soil sample (0-25 cm depth) and subsoil (25-50 cm depth) was removed from a field. Top soil and subsoil was mixed with well dried ground ryegrass at a rate of 8 and 2 gm dried grass per 1 kg of dry soil respectively. Then, subsoil was added to the bottom 25 cm of PVC cylinder and the top 25 cm PVC cylinder was filled with top soil. Mature earthworm were inoculated at surface of the cylinders at a rate 300- 600 m^{-2}. These rates are in the range of total earthworm population commonly found in agricultural soils in New Zealand. The mean weight of the inoculated earthworms was 0.58 g for *A. caliginosa*, 0.98 g for *L. rubellus* and 0;93 g for *O. cyaneum*. The mixed species treatments was assigned at a rate 70% *A. caliginosa*; 20 % *L. rubellus*; and 10% *O. cyaneum*. Then the cylenders were buried in the field by surface of cylinders was in the same level as top soil. Six months later, the PVC cylinder were removed from the field and transported to laboratory for observed the hydraulic conductivity and analyzing the binary images of macropores. The study was found that each species contributed number and area of macropores. *O. Cyaneum* caused the largest size of macropore while *A. caliginosa* caused the largest number of macropore in bottom soil.

Blanchart et al. (2004) studied the roles of earthworms in restoring physical properties of vertisol. The soil had a clayey texture dominated by fine particles (fraction <20 micrometers = 70-80 percent). CEC values ranged from 35-40 cmol / kg and ESP was about 10% in the upper 10 cm.The experimental design consisted of three plots: the first plot was used for intensive gardening; the second plot was converted to pasture and planted with tropical grass *D. decumbens*; and the third plot was used for intensive farm crops gardening until 1991. At the end of 1991, the third plot was converted into a *D. decumbens* pasture.

In 1993, three sub-plots were installed in the third plot in order to distinguish the effect of roots and earthworms (*P. elongata*) on the dynamics of carbon storage and physical properties. Three experiment sub-plots were sub-plot with plant and no earthworms, second sub-plot with plant only and third sub-plot with plant and earthworms. Earthworms (*P. elongata*) were introduced at a density of 90 ind m^2.

The study found that earthworm biomass largely differed between first plot ($1 g/m^2$) and second plot ($100 g/m^2$). In the third plot, biomass of earthworms in sub-plot with grass and earthworm were rapidly declined, then increase slowly to reach a mean value of 42 g/m^2. Earthworm population in third plot after 2 years of experiment had mean biomass 53 g/m^2.

The average of soil carbon content after 4 years differed among 3 sub-plots. The highest carbon content was found in plot only used for pasture. The lower carbon content was found in the plot that used for farm crops gardening and convert into pasture, sub-plot with grass only, sub-plot with grass and earthworms, and sub-plot without both grass and earthworm respectively.

The dispersion of clay particle was determined from dispersion Index value. It was found that present of earthworms *Polypheretima elongata* could reduce clay dispersion; however dispersion of clay particle was increased in the plot without earthworms.

The results from the study of soil erodibility by rainfall simulation suggested that soil looses largely differed among plots. The lowest soil loss was observed in pasture plot (534 g/m^2). Soil looses in sub-plot with grass only, sub-plot with grass and earthworms, and the plot was used for intensive farm crops gardening and then converted into pasture was 900, 839, and 742 g/m^2 respectively.

The results from the study of soil structural porosity pointed out long term of pasture activity after used land for intensive farm crops gardening increase soil structural porosity of top soil. The results showed value of soil porosity derived from pasture area, and intensive farm crops gardening area was 0.105 and 0.051 cm^3g^{-1} respectively. In sub-plots, it was found that air volume of soil from sub-plot without earthworm and plant was significant decreased, in contrast, it was increased in other sub-plot with plant or earthworm.

CHAPTER III
MATERIALS AND METHODS

3.1 Soil Collection

Soil samples were collected from an area of abandoned shrimp pond located in Tha-bon Sub-district, Ranot District, Songkhla Province. (Figure 3-1 and 3-2) The sampling area was 50 $\times$60 m^2. The sampling plots were set by applying the procedure of systematic sampling method with 5 m of distance from each sampling plot. There was 23 sampling plots: 3 sites represented pond soil to examined chemical and physical properties; and 20 sites were provided for the experimental with earthworms. Three replications of each 20 sites were performed to collect the sample of soil (Figure 3-3). The soil collection done by the following 2 techniques.

3.1.1 Undisturbed soil structure method

This technique was performed to maintain soil structure. Undisturbed soil samples were collected by soil core (dimension: width = 20 cm, long = 5 cm and depth = 20 cm) for earthworms experiments. Furthermore soil samplings were collected by using cylinder core and PVC pipe to examine bulk density and hydraulic conductivity of pond soil (Figure 3-3, 3-4, 3-5, and 3-6).

3.1.2 Disturbed soil structure method

Soil samples were collected by spade (Figure3-7). This method was suitable for disturbed soil structure collection. Then soils were grinded and sieve for chemical analysis.

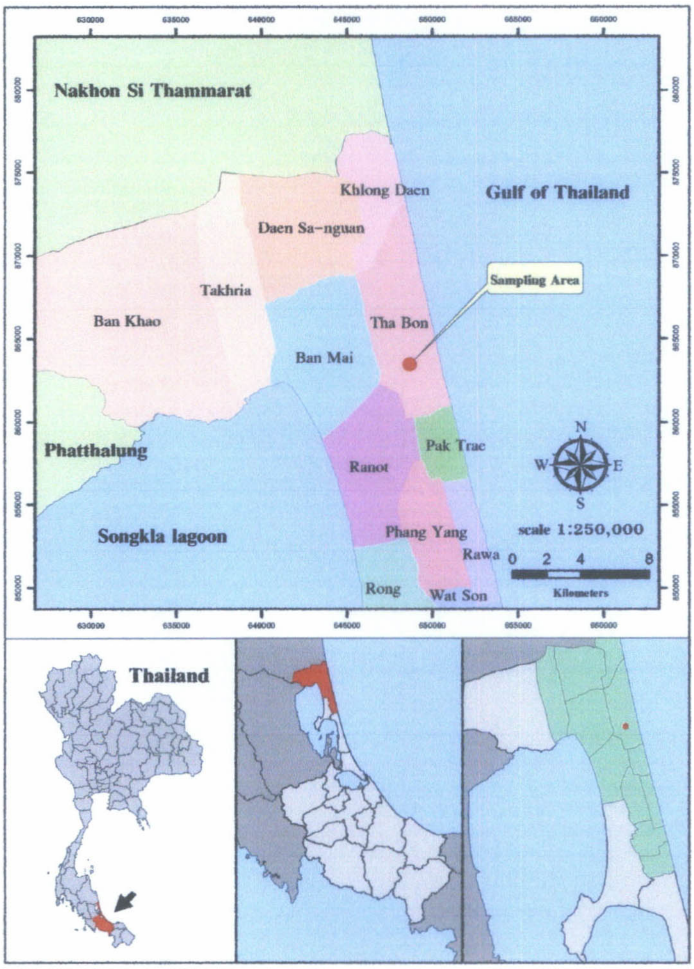


Figure 3-1 Soil sampling area of the study

Figure 3-2 An area of abandoned shrimp pond

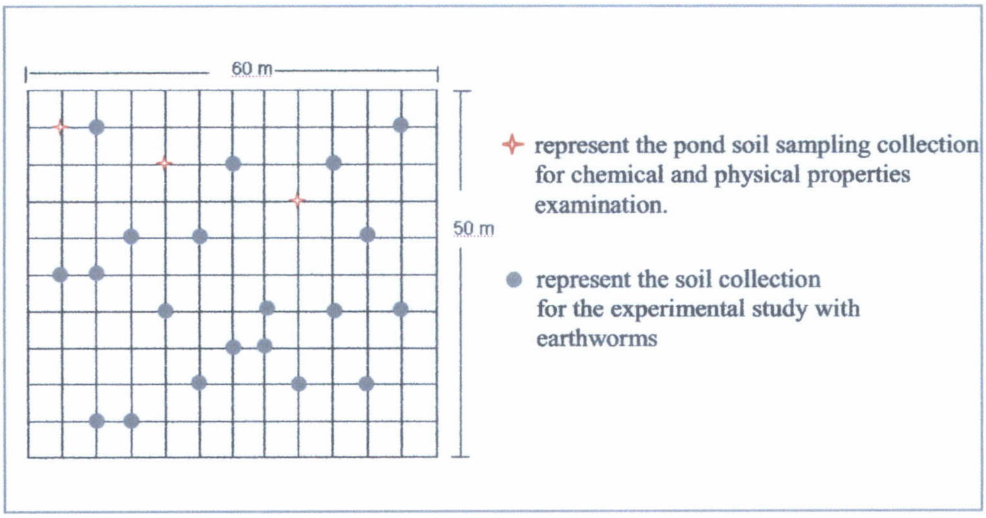


Figure 3-3 Soil sampling points of the study

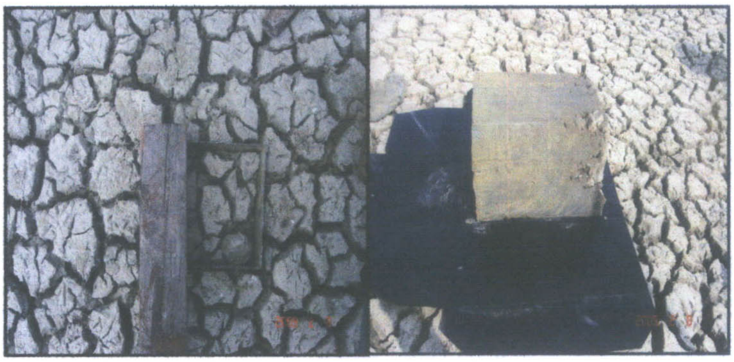


Figure 3-4 The soil was collected by square cylinder core

Figure 3-5 Soil collection by circular cylinder core

Figure 3-6 Soil collection by PVC pipe

Figure 3-7 Soil collection by spade

Figure 3-8 Infiltration test of pond soil

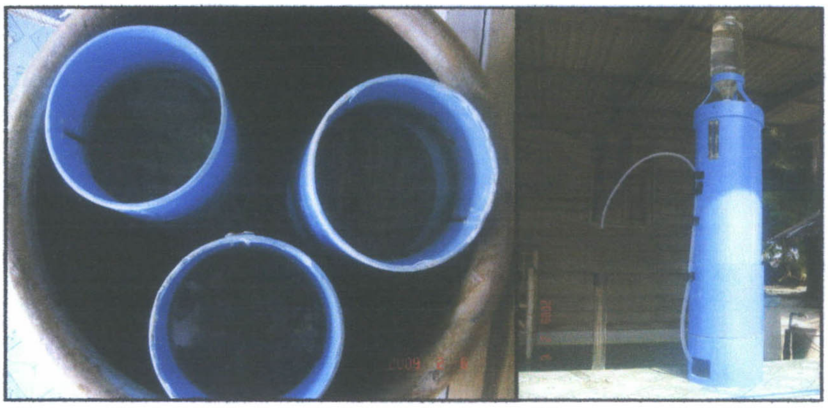


Figure 3-9 Saturated Hydraulic conductivity test of abandoned shrimp pond soil

3.2 Soil Preparation

Soil samples for chemical analysis was treated by air dried, grinded and then sieved at 2 mm. Undisturbed soil samples was already prepared and then induced earthworms into soil. Compost manure or rice straw was on the top of soil for 20 treatments (Figure 3-10). The soil has been moistened by spraying with distilled water every day for 3 months, after that, undisturbed soil was removed from square packages to inspect the number of survival earthworms. They were only 2 boxes of undisturbed soils were found (Figure 3-11 and 3-12). Consequently, it was necessary to renew and adjust the experiment by the others method for this study.

To renew the experiment, soil samples from first experiment were disturbed their structure and dried by air (Figure 3-13). Five kilograms of dry soil was filled in the bottle and moistened by distilled water until soil had been aggregated and homogeneous (Figure 3-14). Earthworms were then released into soils for one day before the application of adding compost and rice straw on the top of soil (Figure 3-15 and 3-16). The top part of bottles were covered by net to prevent earthworms escaping. Small water containers were placed under each bottle to prevent ant disturbance (Figure 3-17). The study of 20 treatments were experimented in shelter (Figure 3-18). The numbers of earthworms and quantity of organic matters used in each procedure were showed in the experimental design.

Figure 3-10 Twenty treatments of undisturbed soils incubated with rice straw manure and rice straw and sprayed by distilled water for 3 months.

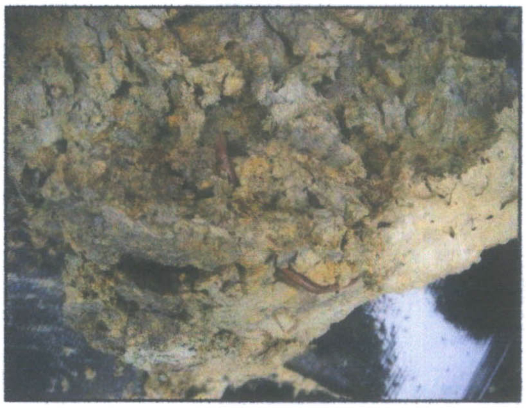


Figure 3-11 An adult earthworm was found in undisturbed soils.

Figure 3-12 The juvenile earthworm was found in undisturbed soils.

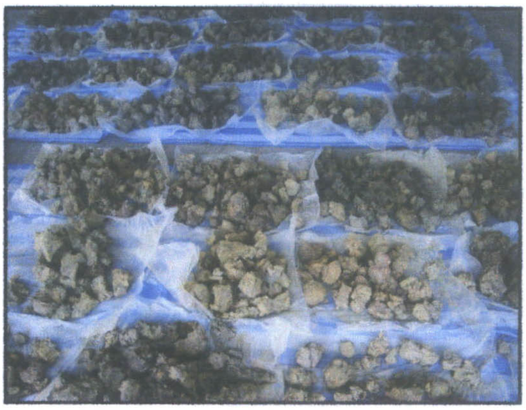


Figure 3-13 Dried Soil samples from the first experiment were air dried.

Figure 3-14 The homogeneous of 5 kilograms of dried soil were prepared.

Figure 3-15 Releasing of earthworms into soil packed in the bottle
before addition of organic matters.

Figure 3-16 Organic matters: rice straw manure and rice straw were added on the top of soil after earthworms releasing.

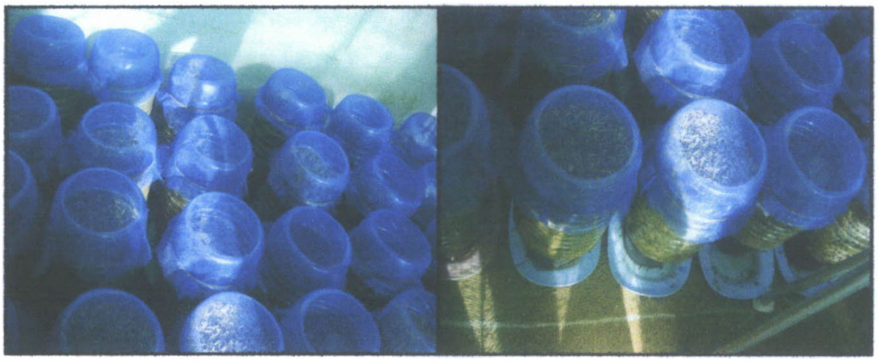


Figure 3-17 The top of bottles were covered by net to prevent earthworms escaping and small water containers were placed under each bottle to prevent ant disturbance.

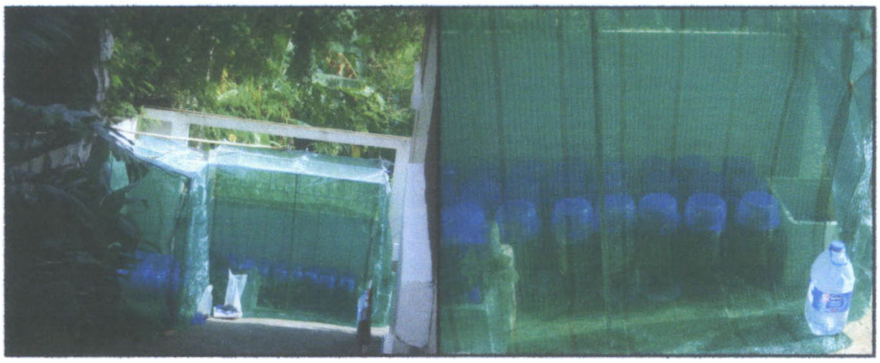


Figure 3-18 Twenty treatments were experimented in shelter.

3.3 Experimental Design

The experimental design for this study was planned as factorial in CRD consisted of three factors: earthworm density, quantity of organic matter and type of organic matter, the detail was as follows:

1.) Earthworm density: 10, 20, and 30 earthworms per 5 kilograms of dry soil.

2.) Quantity of organic matters: 0, 5, and 10 percentage of organic matters by soil weight.

3.) Types of organic matters: 1 cm of shortened rice straw and compost from plant materials.

The study divided the experiment into 2 groups. For control group, soil was treated without any earthworms the other was experiment group which the treatment design into 20 treatments with 3 replications for each treatment. Detail of the experiment showed in Figure 3-19 and Table 3-1.

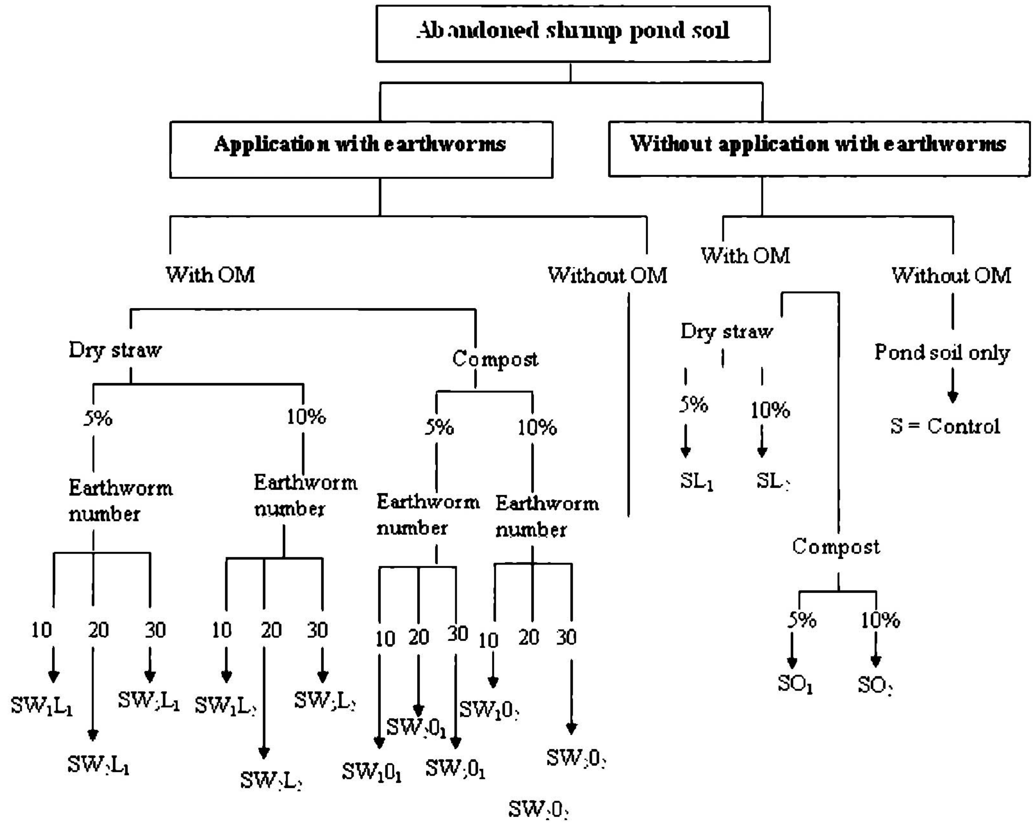


Figure 3-19 The experimental design to study the effects of earthworms on soil properties.

Table 3-1 Detail of 20 procedures for the experimental study on effects of earthworm on soil properties.

Experimental treatments with earthworms
S W_1L_1 = pond soil + 10 earthworms+ 5% of rice straw (T_1)
S W_2L_1 = pond soil + 20 earthworms + 5% of rice straw (T_2)
S W_3L_1 = pond soil + 30 earthworms + 5% of rice straw (T_3)
S W_1L_2 = pond soil + 10 earthworms + 10% of rice straw (T_4)
S W_2L_2 = pond soil + 20 earthworms + 10% of rice straw (T_5)
S W_3L_2 = pond soil + 30 earthworms + 10% of rice straw (T_6)
S W_1O_1 = pond soil +10 earthworms + 5% of compost (rice straw manure) (T_7)
S W_2O_1 = pond soil + 20 earthworms + 5% of compost (rice straw manure) (T_8)
S W_3O_1 = pond soil + 30 earthworms + 5% of compost (rice straw manure) (T_9)
S W_1O_2 = pond soil +10 earthworms + 10% of compost (rice straw manure) (T_{10})
S W_2O_2 = pond soil + 20 earthworms + 10% of compost (rice straw manure) (T_{11})
S W_2O_2 = pond soil + 30 earthworms + 10% of compost (rice straw manure) (T_{12})
S W_1 = pond soil + 10 earthworms (T_{13})
S W_2 = pond soil + 20 earthworms (T_{14})
S W_3 = pond soil + 30 earthworms (T_{15})
Experimental treatments without earthworms
SL_1 = pond soil + 5% of rice straw (T_{16})
SL_2 = pond soil + 10% of rice straw (T_{17})
S O_1 = pond soil + 5% of compost (rice straw manure) (T_{18})
S O_2 = pond soil +10% of compost (rice straw manure) (T_{19})
S = pond soil (Control) (T_{20})

3.4 The execution of the experiment

Duration of the experimental study lasted at least 90 days. During conducting experiment, soils were moistened by adding 50 ml of water every 2 days. The examination of chemical and physical properties of soil, including data regarding and earthworm biomass was performed at the beginning, and at the end of the experiments.

Table 3-2 Parameters and methodology of soil analysis applied in this study.

Parameter	Methods of Analysis
Physical Properties	
1. Soil Texture	1. Hydrometer Method (IPST corporate document originated by GLOBE, Thailand)
2. Bulk Density	2. Core method (IPST corporate document originated by GLOBE, Thailand)
3. Particle Density	3. Specific gravity (IPST corporate document originated by GLOBE, Thailand)
4. Soil Porosity	4. Calculation from particle density and bulk density (IPST corporate document originated by GLOBE, Thailand)
5. Soil Infiltration	5. Double ring (FAO, 2009)
6. Saturated Hydraulic Conductivity	6. Constant-head method (Staff of Pedology, 2001)
Chemical Properties	
1. pH	1. pH meter soil: water 1:5 (Land Develompent Department, 2001)
2. ECe	2. Conductivity Meter (Soil: Water) = 1:5 (Mongkol, 2006)
3. Organic Carbon & Organic Matter	3. Walkley and Black (Land Develompent Department, 2001)
4. Total Nitrogen	4. Kjeldahl method (Land Develompent Department, 2001)
5. available Nitrogen	5. A Rapid, Simple Spectrophotometric Method for Simultaneous Detection of Nitrate and Nitrite. (Katrina M. and et al,2001)
6. available Phosphorus	6. Extracted by Olsen Method and Detection by UV spectrophotometer Method (Land Develompent Department, 2001)
7. available Potassium	7. Extracted by Ammonium acetate method and Detection by Flame photometer method (Land Develompent Department, 2001)

Table 3-2 Parameters and methodology of soil analysis applied in this study. (continued)

Parameter	Methods of Analysis
8. Exchangeable Ca^{++}, Mg^{++}, Na^{+}, K^{+}	8. Extracted by Ammonium acetate method and Detection by Flame photometer method (Land Develompent Department, 2001)
9. CEC	9. Ammonium acetate method (Land Develompent Department, 2001)
10. ESP	10. Calculation from the values of exchangeable Na+ and CEC (Land Develompent Department, 2001)
11. SAR	11. Calculation from the values of exchangeable Ca^{++}, Mg^{++}, Na^{+} (Land Develompent Department, 2001)

3.5 Data Analysis

The statistic analysis for this study could not test the interaction of 3 factors by MANOVA because Box's Test of Equality of Covariance Matrices was not computed. (There had fewer than two nonsingular cell covariance matrices.)

One Way Analysis of Variance was used for influence of earthworm numbers on soil physical and chemical properties. The independent factor was earthworm numbers while the dependent factors were physical and chemical of soil properties. The physical parameters of soil were soil texture, bulk density, particle density, and porosity. The chemical parameters of soil were pH, ECe, organic carbon, organic matter, total nitrogen, available nitrogen, available phosphorus, available potassium, exchangeable Sodium, cation exchange capacity (CEC), exchangeable sodium percentage (ESP) and sodium adsorption Ratio (SAR)

Independence t- test was application for mean difference of soil properties which was influenced by types and quantity of organic matter factors. The test was done between the treatment of earthworms with dry straw and the treatment of earthworms with rice straw manure. Another treatment was between the application with 5% and 10% of organic matter.

CHAPTER IV
RESULS

4.1 Properties of soil before and after the experiment

Features and changed characteristics in both before and after treatments with earthworms and organic matter with the Ranot soil series in abandoned shrimp ponds were as follows:

4.1.1 Soil properties before the experiment

1.) Physical properties

Physical properties of soil cover of the abandoned shrimp farm: the soil was clay texture consisted of clay, silt, and sand at 62.77, 31.39 and 5.83 percentages, respectively. The average values of the soil physical properties were as follow: bulk density 1.58 g/cm^3, particle density 2.3 g/cm^3, porosity 31.37%, infiltration rate less than 0.1 cm/hr, which was considered to be very slow, and infiltration rate of the soil that was saturated with water was at the very slow level, with Ksat < 0.8

2.) Chemical Properties

Average values of chemical properties of the soil were: pH 7.76, ECe 1.65 ds/m, SAR 5.11, CEC 17.99 cmol/kg, ESP 44.97%, organic carbon 0.26%, organic matter 0.46%, NH_4-N 18.99 μ g/g, NO_3-N 7.25 μ g/g, total nitrogen 1.08 %, available phosphorus 3.79 mg/kg, and available potassium 619.07 mg/kg.

4.1.2 Soil properties after the experiment

4.1.2.1 Noticeable changes in the soil

Changes in the soil after experimentation with various processes for the period of 3 months could be observed externally as follows

Soil characteristics resulted from the treatments added 5% dried rice straw as organic materials to improve soil together with 10, 20, and 30 earthworms were treatments names, SW_1L_1, SW_2L_1 and $SW3L_1$. And the treatments added 10% dried rice straw with 10, 20, and 30 earthworms were treatments names, SW_1L_2, SW_2L_2 and SW_3L_2. It was found that the characteristics of the topsoil showed no any changes according to the activities of the earthworms while the soil was damp (Figure 4-1 and 4-2).

Soil characteristics from the treatment added 5% rice straw manure as the organic material to improve soil together with 10, 20, and 30 earthworms in treatments SW_1O_1, SW_2O_1 and SW_3O_1, respectively. It was found that the topsoil had changes from activities of the earthworms, as noticed from the excrement of the earthworms from 1-13 weeks of the experiment. The topsoil had pores resulting from the activity of the earthworms. The first half of the added rice straw manure completely decomposed within the 7^{th} week of the experiment. The rice straw manure was added for the 2^{nd} time at the 7^{th} week to complete the 5% mixture and was nearly completely decomposed in the last week of the experiment (Figure 4-3).

Soil from the treatment added 10% rice straw manure with 10, 20, and 30 earthworms, namely, SW_1O_2, SW_2O_2 and SW_3O_2 during the 1^{st}-7^{th} weeks of the experiment the excrement of the earthworms were founded. The quantity of the rice straw manure was decomposed with in the 7^{th} week and after the 2^{nd} time of rice straw manure was added to complete the 10% mixture in the 7^{th}. It was noticeable that the activities of the earthworms was found. Topsoil had the remains of rice straw manure during the last week of the experiment (Figure 4-4).

For the treatment with 10, 20, and 30 earthworms, namely, SW_1, SW_2 and SW_3 revealed that the topsoil had earthworm excrement since the first week of the experiment. The topsoil started to be covered with green stain since the 5^{th} week of the experiment (Figure 4-5).

Soil which added only 5% and 10% of rice straw manure in treatments SO_1 and SO_2 showed that the rice straw manure in all treatments had very little decomposition, as observed by the high quantity of the remain of the material (Figure 4-6 and 4-7).

As for the soil from the control treatment, a green stain also covered the soil on the 5^{th} week of the experiment. The soil was very dry and hard (Figure 4-7).

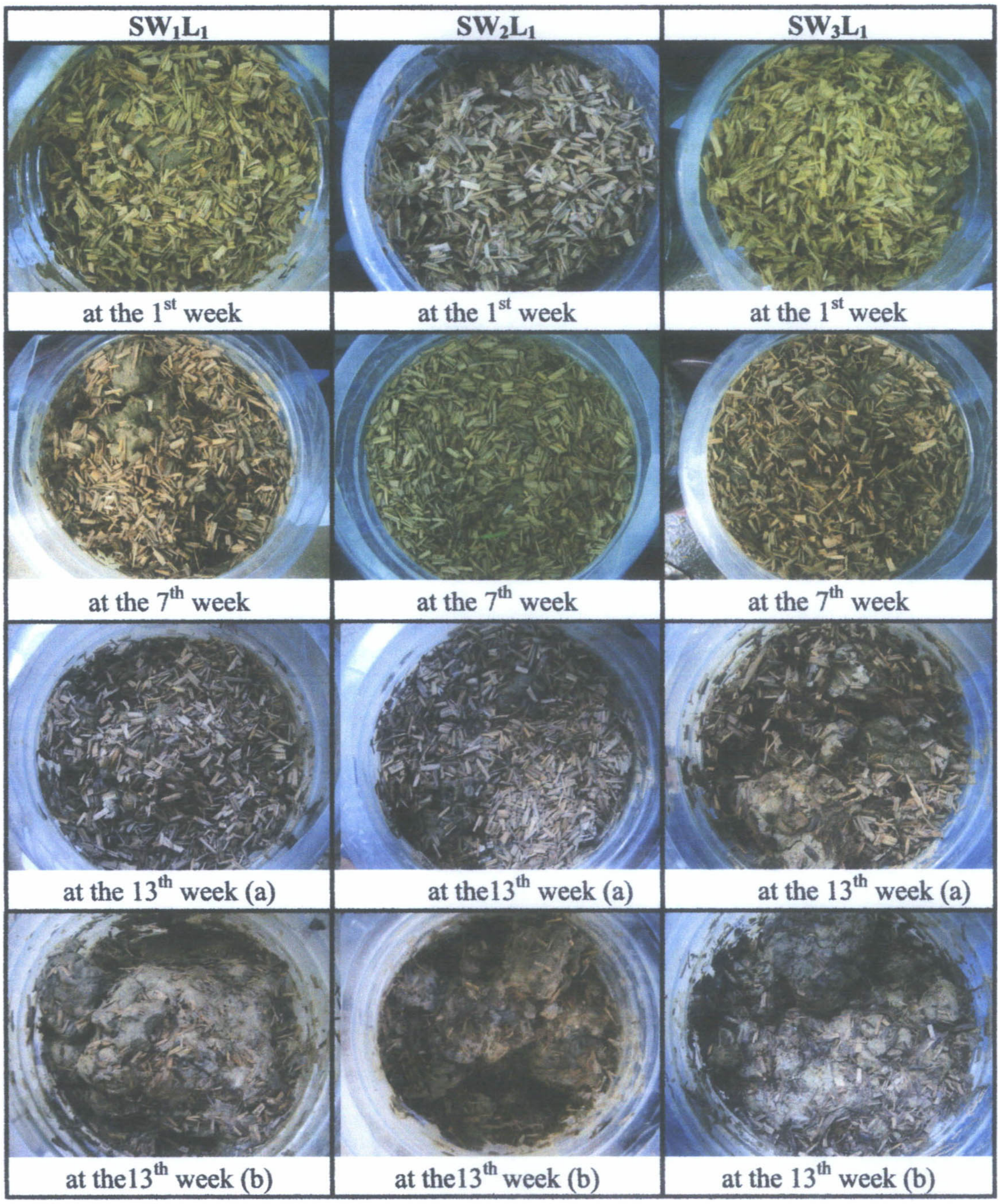


Figure 4-1 Characteristics of topsoil from treatments SW$_1$L$_1$, SW$_2$L$_1$, and SW$_3$L$_1$ at the 1^{st}, 7^{th} and 13^{th} weeks of the experiments a) Topsoil covered with organic material b) Characteristics of topsoil which the remain organic material was removed.

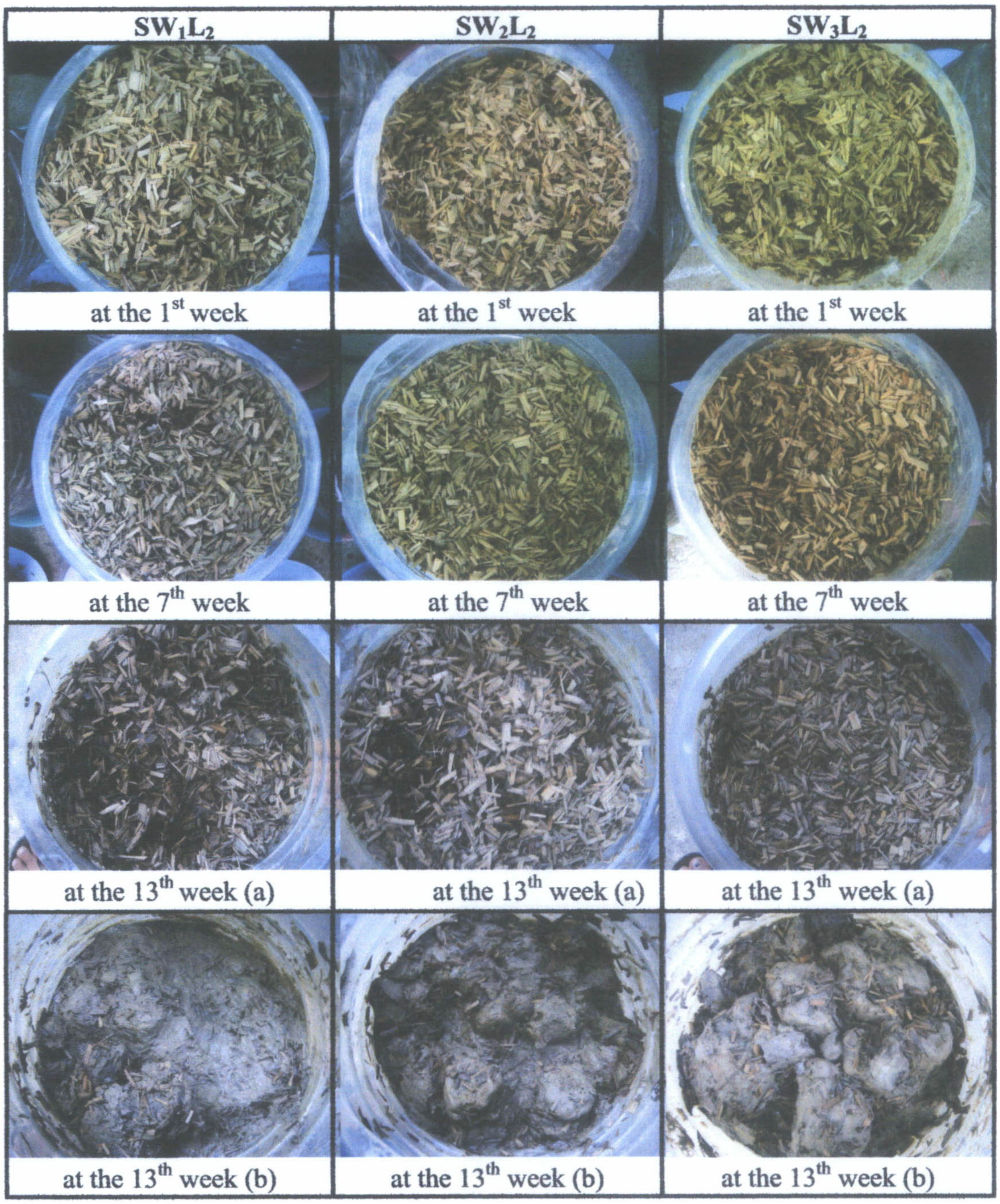


Figure 4-2 Characteristics of topsoil from treatments SW_1L_2, SW_2L_2, and SW_3L_2 at the 1st, 7th and 13th weeks of the experiments a) Topsoil covered with organic material b) Characteristics of topsoil which the remain organic material was removed.

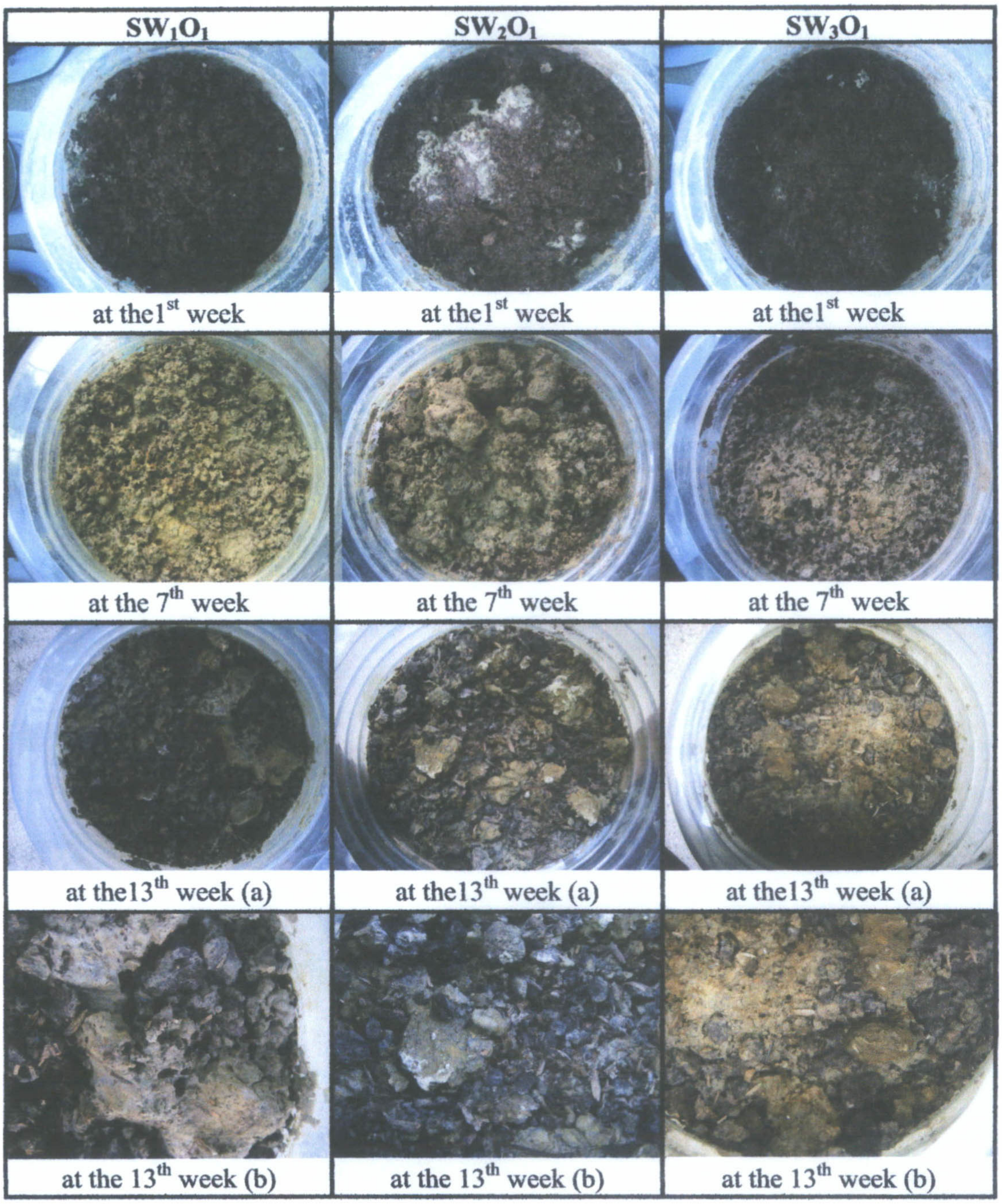


Figure 4-3 Characteristics of topsoil from treatments SW_1O_1 , SW_2O_1 and SW_3O_1 at the 1st, 7th and 13th weeks of the experiments a) Topsoil covered with organic material b) Characteristics of topsoil which the remain organic material was removed.

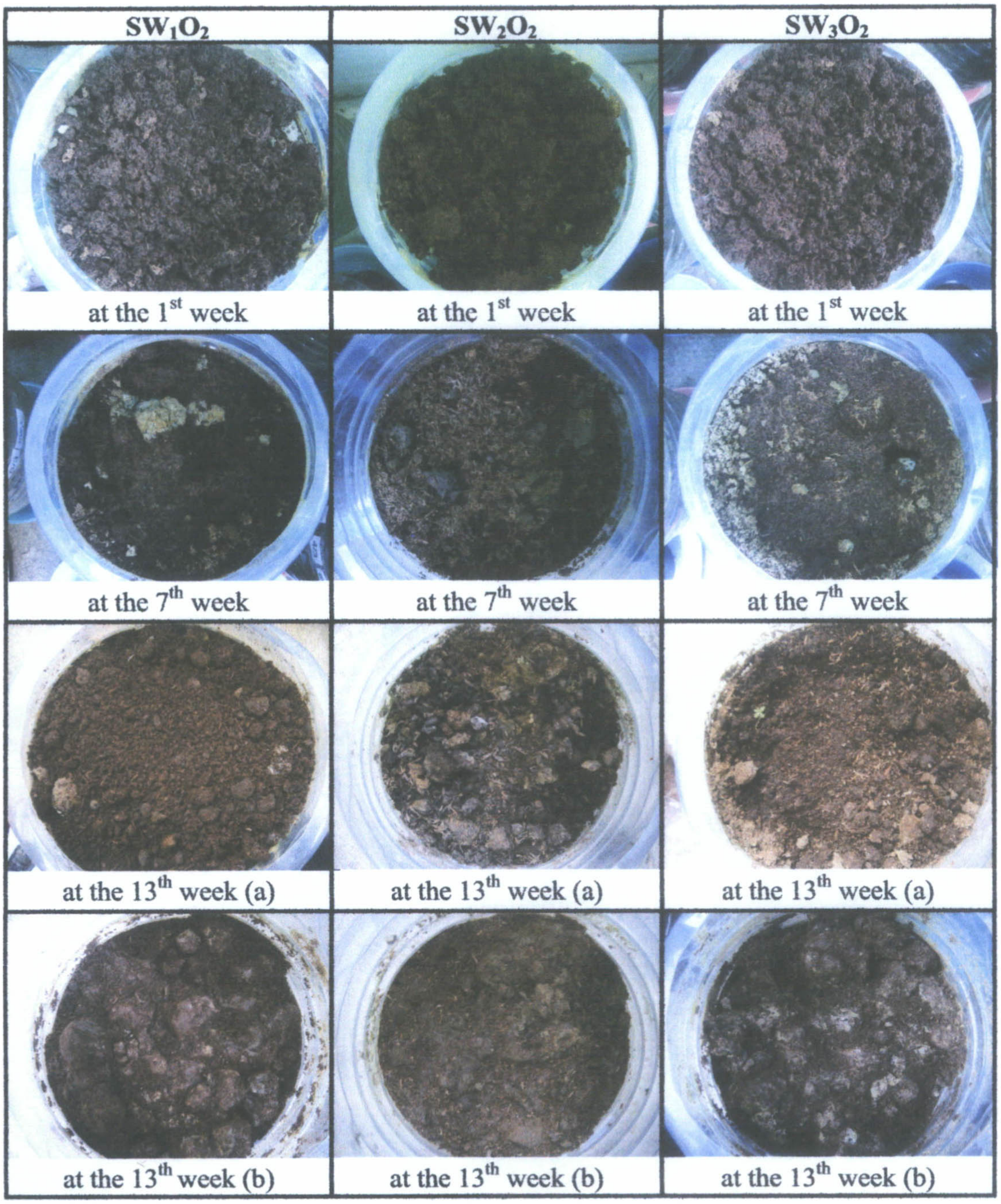


Figure 4-4 Characteristics of topsoil from treatments SW_1O_2, SW_2O_2 and SW_3O_2 at the 1st, 7th and 13th weeks of the experiments a) Topsoil covered with organic material b) Characteristics of topsoil which the remain organic material was removed.

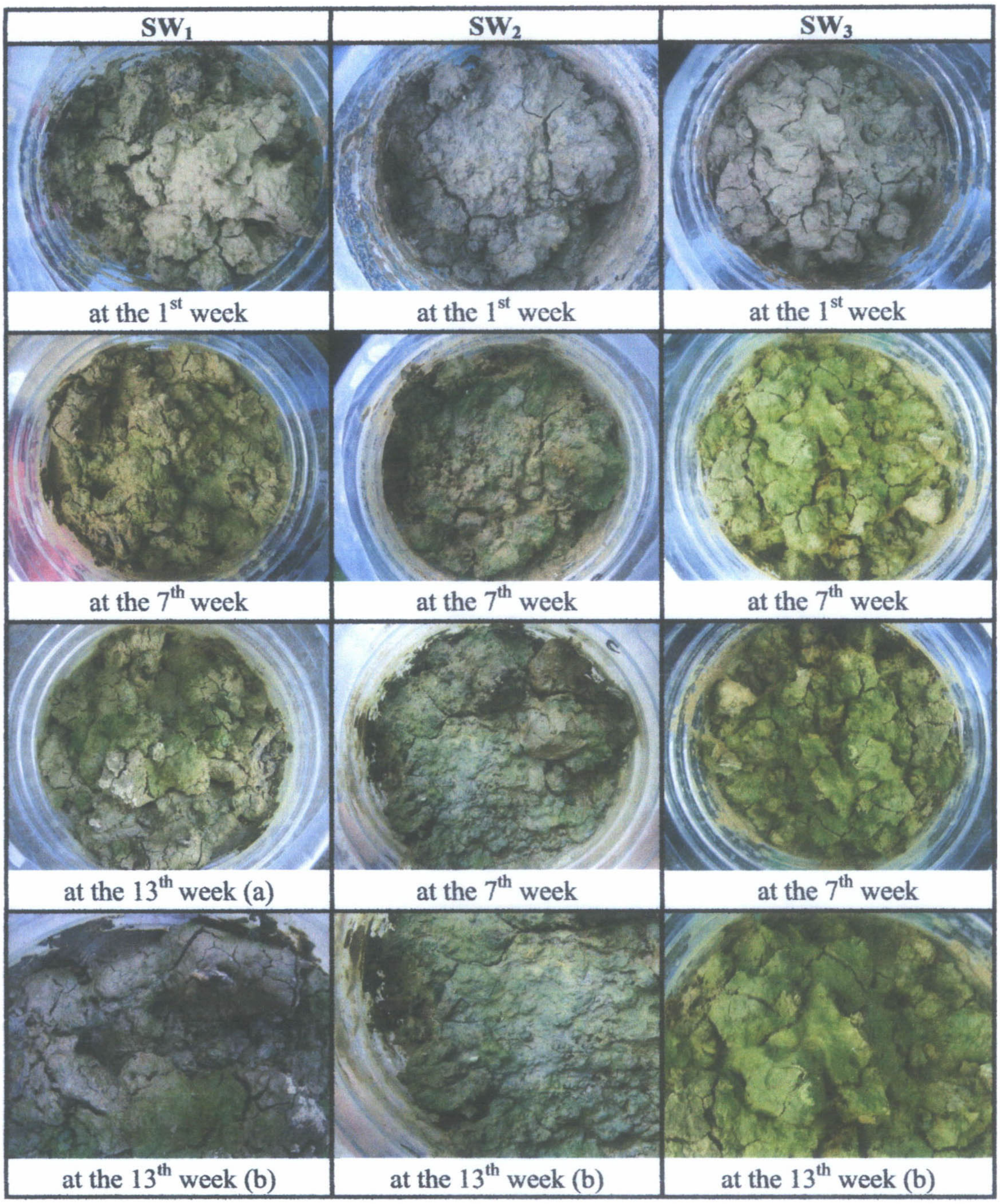


Figure 4-5 Characteristics of topsoil from treatments SW_1, SW_2, and SW_3 at the 1^{st}, 7^{th} and 13th weeks of the experiments a) Topsoil covered with organic material b) Characteristics of topsoil which the remain organic material was removed.

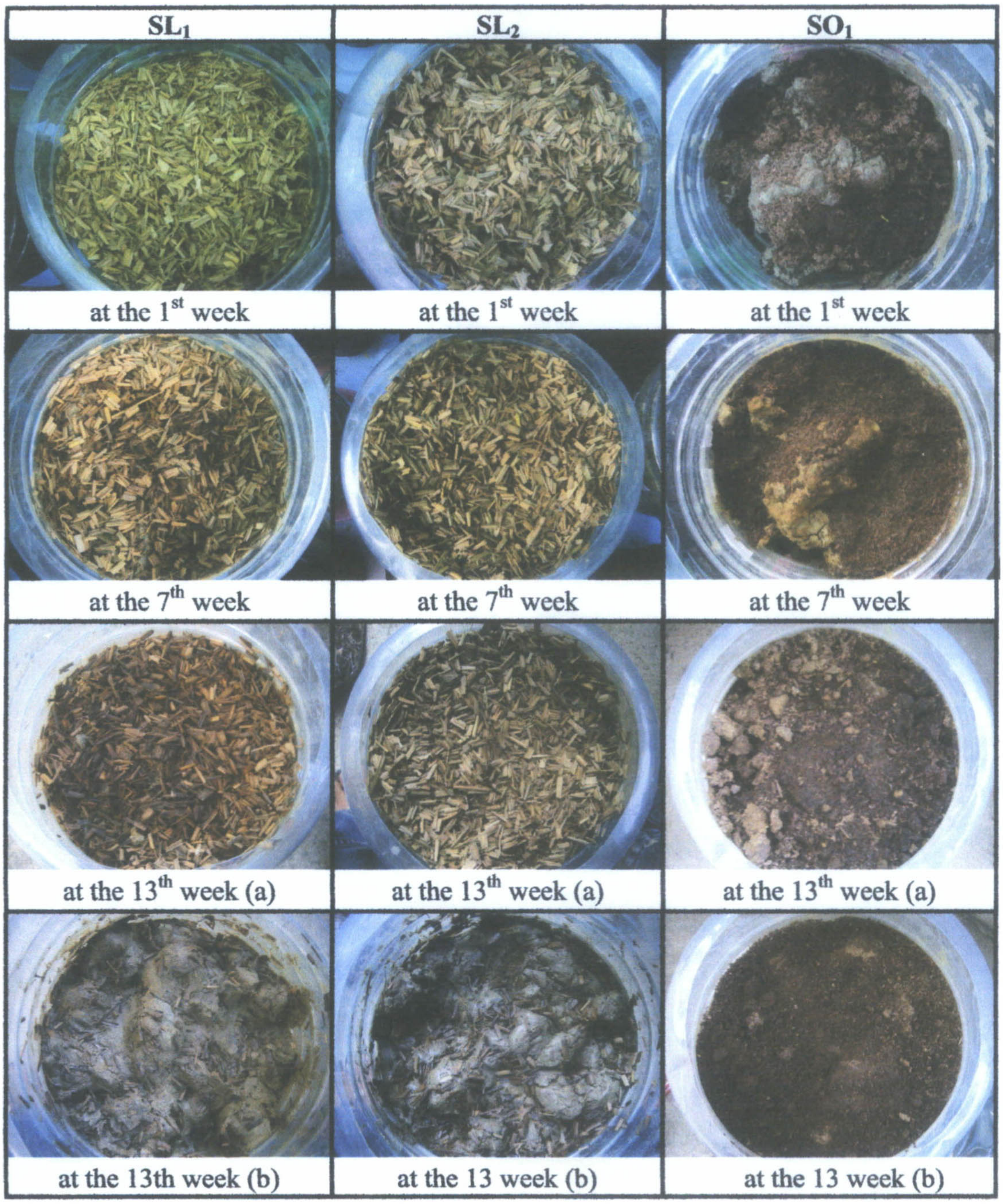


Figure 4-6 Characteristics of topsoil from treatments SL_1 , SL_2, and SO_1 at the 1st, 7th and 13th weeks of the experiments a) Topsoil covered with organic material b) Characteristics of topsoil in which the remain organic material was removed.

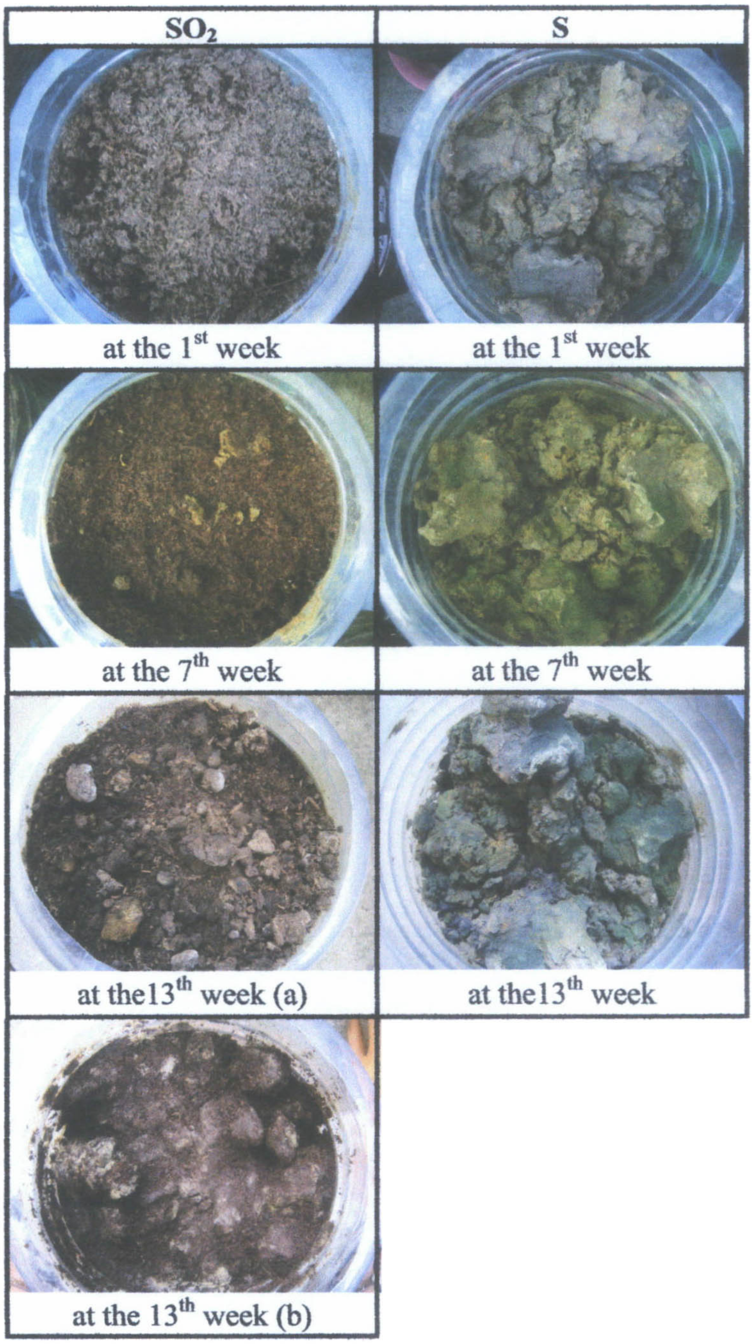


Figure 4-7 Characteristics of topsoil from treatments SO_1 and S at the 1st, 7th and 13th weeks of the experiments a) Topsoil covered with organic material b) Characteristics of topsoil in which the remain organic material was removed.

4.1.2.2 Physical and chemical properties of soil from the abandoned shrimp farm

The raw data of soil physical and chemical properties after rehabilitation experiment with 20 procedures for 90 days, i.e. the bulk density, particle density, porosity, percentage of clay particles, silt, sand, pH, ECe, SAR, CEC, ESP, organic carbon, organic matter, NH_4-N, NO_3-N, total nitrogen, available phosphorus , and available potassium were displayed in Appendix A, Table A-1. For the soil infiltration rate which was found to be very slow and the water did not decrease resulted level observation in both rings and was tested with the soil in all experiments did not decreased.

4.2 Effect of the number of earthworms on soil properties in the abandoned shrimp farm

The effect of the number of earthworms on soil properties was conducted by testing the differences in soil qualities mean values in the treatments which added the earthworms to the shrimp farm soil, with 30 earthworms (SW_3), 20 earthworms (SW_2), 10 earthworms (SW_1) and the Control (S). The results were as follows.

1.) Physical properties

The effect of the number of earthworms on the soil physical properties from the abandoned shrimp farm showed that the number of earthworms had no significant statistical difference among the mean values of physical properties (Appendix A, Table A-2)

Although physical properties of the soil had no statistical difference, considering from the bar chart of the soil physical properties after the experiment of adding earthworms (Figure 4-8) it was found that the bulk density of the soil from each treatment had similar values. The treatment added 30 earthworms (SW_3) had the highest bulk density, and higher than the control (S), the particle density of the soil in all treatments was higher than the control (S). The treatment added 30 earthworms (SW_3) yielded the highest particle density, the porosity of the soil in all treatments had

Although the number of earthworms had no effect on changes in the mentioned chemical properties, considering from the bar charts are considered (Figure 4-9), it was noticed that:

1.) pH of the soil from the treatment added 20 earthworms (SW_2) and 30 earthworms (SW_3) had lower mean values than the control (S) and lower than the treatment which added 10 earthworms (SW_1), while the soil from the treatment which added 10 earthworms (SW_1) had higher mean pH value than the control

2.) ECe of the soil from the treatment added 30 earthworms (SW_3) had the highest mean value, followed by the treatment added 20 earthworms (SW_2), 10 earthworms (SW_1), and the control (S)

3.) SAR of the soil from the treatment added 30 earthworms (SW_3) had higher mean value than the control (S) and higher than the treatment which added 20 earthworms (SW_2)

4.) OC of the soil from the treatment added 20 earthworms (SW_2) and 30 earthworms (SW_3) had lower mean than the control, but the treatment which added 10 earthworms (SW_1) had higher value than the control (S)

5.) Organic matter (OM) percentage of the soil from the treatment added 20 earthworms (SW_2) and 30 earthworms (SW_3) decreased from the control, but the treatment which added 10 earthworms had higher value than the control (S)

6.) Total-N (total nitrogen) of the soil from all treatments were higher than the control, the treatment added 30 earthworms (SW_3) had the highest value, followed by the treatment added 20 earthworms (SW_2) and 10 earthworms (SW_1), respectively.

Although the number of earthworms had no effect on changes in the mentioned chemical properties, considering from the bar charts are considered (Figure 4-9), it was noticed that:

1.) pH of the soil from the treatment added 20 earthworms (SW_2) and 30 earthworms (SW_3) had lower mean values than the control (S) and lower than the treatment which added 10 earthworms (SW_1), while the soil from the treatment which added 10 earthworms (SW_1) had higher mean pH value than the control

2.) ECe of the soil from the treatment added 30 earthworms (SW_3) had the highest mean value, followed by the treatment added 20 earthworms (SW_2), 10 earthworms (SW_1), and the control (S)

3.) SAR of the soil from the treatment added 30 earthworms (SW_3) had higher mean value than the control (S) and higher than the treatment which added 20 earthworms (SW_2)

4.) OC of the soil from the treatment added 20 earthworms (SW_2) and 30 earthworms (SW_3) had lower mean than the control, but the treatment which added 10 earthworms (SW_1) had higher value than the control (S)

5.) Organic matter (OM) percentage of the soil from the treatment added 20 earthworms (SW_2) and 30 earthworms (SW_3) decreased from the control, but the treatment which added 10 earthworms had higher value than the control (S)

6.) Total-N (total nitrogen) of the soil from all treatments were higher than the control, the treatment added 30 earthworms (SW_3) had the highest value, followed by the treatment added 20 earthworms (SW_2) and 10 earthworms (SW_1), respectively.

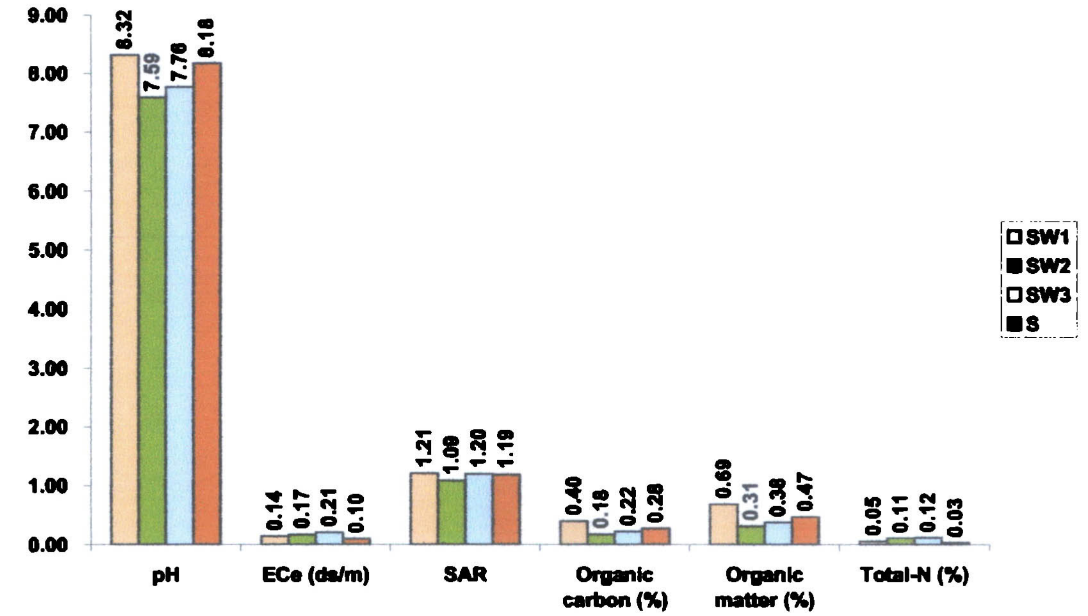


Figure 4-9 Diagram showing plotted means of soil chemical properties from the abandoned shrimp farm, i.e. pH, ECe, SAR, organic carbon, organic matter and total - N experimented with adding 10 earthworms (SW_1), 20 earthworms (SW_2), 30 earthworms (SW_3), and without earthworm as the control (S)

Although the number of earthworms had no statistically significant effect on difference in mean values of pH, ECe, SAR, organic carbon, organic matter, and total-N, the number of earthworms still affected the difference in the chemical means of certain qualitative properties of the soil, i.e. the CEC ($F_{3,8}$ = 73.895, p= 0.00), ESP ($F_{3,8}$ = 15.068, p= 0.001), Na ($F_{3,8}$ = 73.895, p= 0.45.648), NH_4-N ($F_{3,8}$ = 74.244, p= 0.00), NO_3-N ($F_{3,8}$ = 1362.671, p= 0.00), phosphorus ($F_{3,8}$ = 4.619, p= 0.037), potassium ($F_{3,8}$ = 52.374, p= 0.00) (Appendix A, Table A-3)

Each of the soil chemical properties showed in Figure 4-10 and it was revealed that the mean values of chemical properties were different according to the number of earthworm-added in each treatment, the multiple comparisons was performed by using Scheffe's test as detail in Appendix A, Table A-4 to Table A-11.It was found that:

1.) CEC

As shown in the bar charts (Figure 4-10), the CEC values of the soil from all treatments were all higher than the control. The treatment added 30 earthworms (SW_3) had the highest value, followed by the treatment added 20 earthworms (SW_2) and 10 earthworms (SW_1), respectively.

The results of multiple comparison with Scheffe's test against the control (S) revealed that the mean CEC value of the soil from the abandoned shrimp farm were different in all treatments. The treatment with 30 earthworms (SW_3) caused the highest CEC value up to 35.75 cmol/kg (39.61%), followed by the treatment with 20 earthworms (SW_2) the CEC was 20.85 cmol/kg (23.10 %), and the treatment with used 10 earthworms (SW_1) the CEC was 11.50 cmol/kg (12.74 %), respectively.

Comparing among treatments, it was found that the treatment added 30 earthworms (SW_3) had the highest mean CEC at 126.01 cmol/kg, higher than the treatment 20 earthworms (SW_2) at 14.90 cmol/kg (16.51%) and the treatment added 10 earthworms at 24.25 cmol/kg (26.87 %), respectively. (Appendix A, Table A-4).

2.) ESP

The bar charts (Figure 4-10) showed that the ESP values of the soil from all treatments were lower than the control. The treatment with 30 earthworms (SW_3) had the highest value, followed by the treatment with 20 earthworms (SW_2) and 10 earthworms (SW_1), respectively.

The results of the multiple comparison with Scheffe's test against the control (S) revealed that the treatment which used 10 earthworms (SW_1) had the lowest ESP, which was 17.36% lower than the control. The mean ESP values in treatments added 20 earthworms (SW_2) and 30 earthworms (SW_3) increased, but the mean values were lower than that of the control by 16.84% and 11.78%, respectively.

Comparing among treatments, it was found that the mean ESP values had no statistically significant differences (Appendix A, Table A-5)

3.) Na

The bar charts (Figure 4-10) showed that the Na values of the soil from all treatments were higher than the control. The treatment added 30 earthworms (SW_3) had the highest value, followed by the treatment added 20 earthworms (SW_2) and 10 earthworms (SW_1), respectively.

The results of the multiple comparison with Scheffe's test against the control (S) revealed that the mean Na of the soil of the abandoned shrimp farm was different between the treatment added 30 earthworms (SW_3) and the control. The treatment added 30 earthworms had higher Na than the control by 9.47 meq/100 g soil (20.87%)

Comparing among treatments, it was found that the treatment added 30 earthworms had higher average Na than the treatment added 20 earthworms by (SW_2) 8.5 meq/100 g soil (20.30%), and higher than the treatment added 10 earthworms (SW1) by 12.24 meq/100 g soil (32.09%) (Appendix A, Table A-6).

4.) NH_4-N

The bar charts (Figure 4-10) of NH_4-N values of the soil from all treatments were higher than the control. The treatment added 30 earthworms (SW_3) had the highest value, followed by the treatment added 20 earthworms (SW_2) and 10 earthworms (SW_1), respectively.

The results of multiple comparison with Scheffe's test against the control (S) showed that the soil from the treatment added 30 earthworms (SW_3) and 20 earthworms) had higher average NH_4-N than the control at 10.88 μg/g (79.58%) and 3.20 μg/g (23.42%), respectively.

Comparing among treatments, it was found that the treatment added 30 earthworms (SW_3) had the highest average NH_4-N, higher than the treatment added 20 earthworms (SW_2) by 7.68 μg/g (46.03%) and higher than the treatment added 10 earthworms (SW_1) by 10.81 μg/g (78.62%). In addition, the treatment added 20 earthworms (SW_2) had higher average NH_4-N than the treatment added 10 earthworms (SW_1) by 3.13 μg/g (22.76%) (Appendix A, Table A-7).

5.) NO_3-N

The bar charts (Figure 4-10) showed that the NO_3-N values of the soil from all treatments were higher than the control. The treatment added 30 earthworms (SW_3) had the highest value, followed by the treatment added 20 earthworms (SW_2) and 10 earthworms (SW_1), respectively.

The results of the multiple comparison by Scheffe's test against the control showed that all treatments had higher average NO_3-N than the control. The treatment added 30 earthworms (SW_3) and 20 earthworms (SW_2) and 10 earthworms (SW_1) had higher values than the control (S) by as much as 693.03%, 682.24% and 235.89%, respectively.

Comparing among treatments, it was found that the soil from the treatment added 30 earthworms (SW_3) had the highest mean NO_3-N value, higher than the treatment added 20 earthworms (SW_2) by 1.38% and higher than the treatment added 10 earthworms (SW_1) by 58.43%. In addition, the treatment added 20 earthworms (SW_2) had higher mean NO_3-N than the treatment added 10 earthworms (SW_1) by 132.83% (Appendix A, Table A-8).

6.) Total- Nitrogen

The mentioned chemical properties, the bar charts (Figure 4-9) showed that the total-N values of the soil from all treatments were higher than the control. The treatment added 30 earthworms (SW_3) had the highest value, followed by the treatment added 20 earthworms (SW_2) and 10 earthworms (SW_1), respectively.

The results of the multiple comparison by Scheffe's test against the control (S) showed that the treatment added 30 earthworms (SW_3) was increased in the total-nitrogen value higher than the control by 0.086%, followed by the treatment which used 20 earthworms (SW_2) at 0.075% and the treatment which used 10 earthworms (SW_1) at 0.025%, respectively.

Comparing among treatments, it was found that the treatment added 30 earthworms (SW_3) had the highest total-Nitrogen value at 0.12%, higher than the treatment added 20 earthworms (SW_2) and the treatment with 10 earthworms (SW_1) at 0.012% and 0.063%, respectively (Appendix Table A-9).

7.) Phosphorus

The bar charts showed that the phosphorus values of the soil from all treatments were lower than the control. The treatment added 10 earthworms (SW_1) had the highest value, followed by the treatment added 20 earthworms (SW_2) and 30 earthworms (SW_3), respectively.

Comparing against the control, it was found that the mean phosphorus value of the soil from the shrimp farm in the treatment added 20 earthworms (SW_2) was higher than the control (S) by 2.75 mg/kg (90.51%)

Comparing among treatments, it was found that the soil from the treatment with 20 earthworms (SW_2) had the highest mean phosphorus value, followed by the treatment with added 10 earthworms (SW_1) and 30 earthworms (SW_3), respectively. There was no any statistical difference among treatments (Appendix A, Table A-10).

8.) Potassium

The bar charts (Figure 4-10) showed that the potassium values of the soil from all treatments were higher than the control. The treatment added 30 earthworms (SW_3) had the highest value, followed by the treatment added 20 earthworms (SW_2) and 10 earthworms (SW_1), respectively.

Comparing against the control, it was found that the soil from the control had higher mean potassium value than the soil from the treatment added 10 earthworms (SW_1) and 20 earthworms (SW_2) by as much as 109.29 mg/kg (29.41%) and 87.70 mg/kg (22.34%), respectively.

Comparing among treatments, it was found that the soil from the treatment added 30 earthworms had the highest value of potassium, and higher than the soil from the treatment added 20 earthworms (SW_2) by 134 mg/kg (34.13%) and 10 earthworms (SW_1) by 155.59 mg/kg (41.93%) (Appendix A, Table A-11).

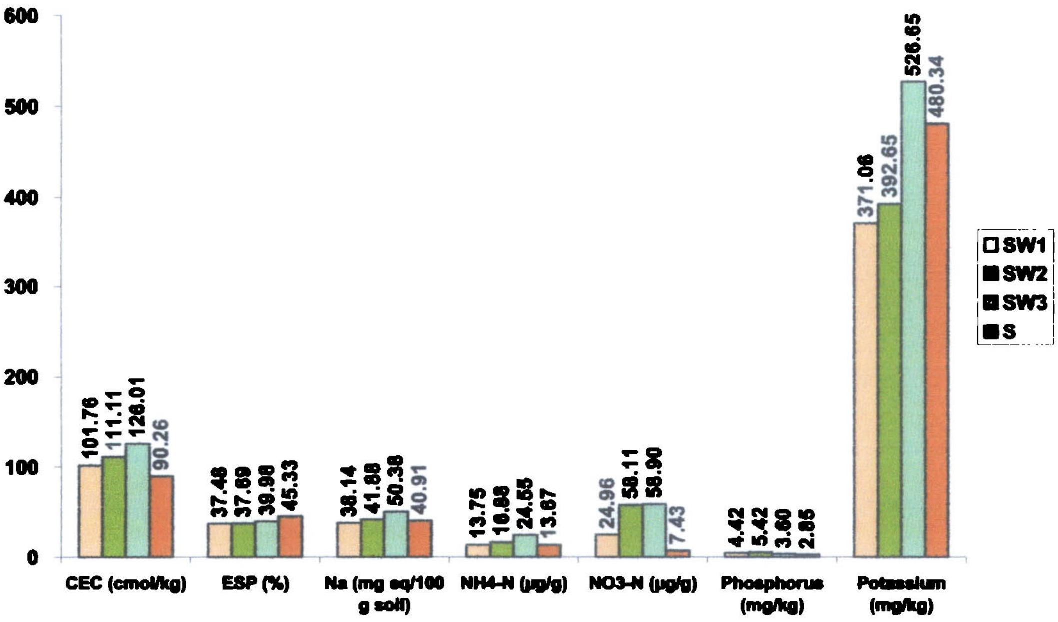


Figure 4-10 Plotted means of chemical properties of the soil from the abandoned shrimp farm, i.e. CEC, ESP, Na, NH_4-N, NO_3-N, phosphorus and potassium experimented by adding 10 earthworms (SW_1), 20 earthworms (SW_2), 30 earthworms (SW_3) and without earthworm as the control group (S)

From the analyzed results in Appendix Table 1-4 to Appendix Table 1-11, it could be concluded that adding 30 earthworms (SW_3) improved the most mean values of chemical properties of the soil in the shrimp farm significantly (except for ESP and Na which yielded high values in the treatment added 30 earthworms, thus had negative results), Thus the data from the treatment added 30 earthworms were then tested together with organic matter, dried rice straw and rice straw manure. The treatments with 20 and 10 earthworms were also tested with organic matter in the same way in order to cover all treatments for this study.

4.3 Effects of organic matter and addition of 30 earthworms on the qualities of the soil from the abandoned shrimp farm

The treatments added 30 earthworms with organic matters were tested for mean values of the quality of the soil. The effect of dried rice straw as organic matter was tested against the effect of rice straw manure as organic matter on changes in soil quality. There were 2 groups of treatments tested, 1) the treatment added 5% dried rice straw (SW_3L_1) in comparison to 5% rice straw manure (SW_3O_1), and 2.) the treatment added 10% dried rice straw (SW_3L_2) in comparison to 10% rice straw manure (SW_3O_2).

4.3.1 Effects of 5% dried rice straw and 5% rice straw manure

1.) Physical properties

The treatment added 30 earthworms with organic matter to test changes in physical properties showed that both treatments which added 30 earthworms with 5% dried rice straw (SW_3L_1) and the control which added 30 earthworms with 5% rice straw manure (SW_3O_1) had no statistically significant effect on the mean values of the soil physical properties. In order to show the difference between addition of dried rice straw and rice straw manure at 5% level, the soil physical properties were shown as bar chart in Figure 4-11.

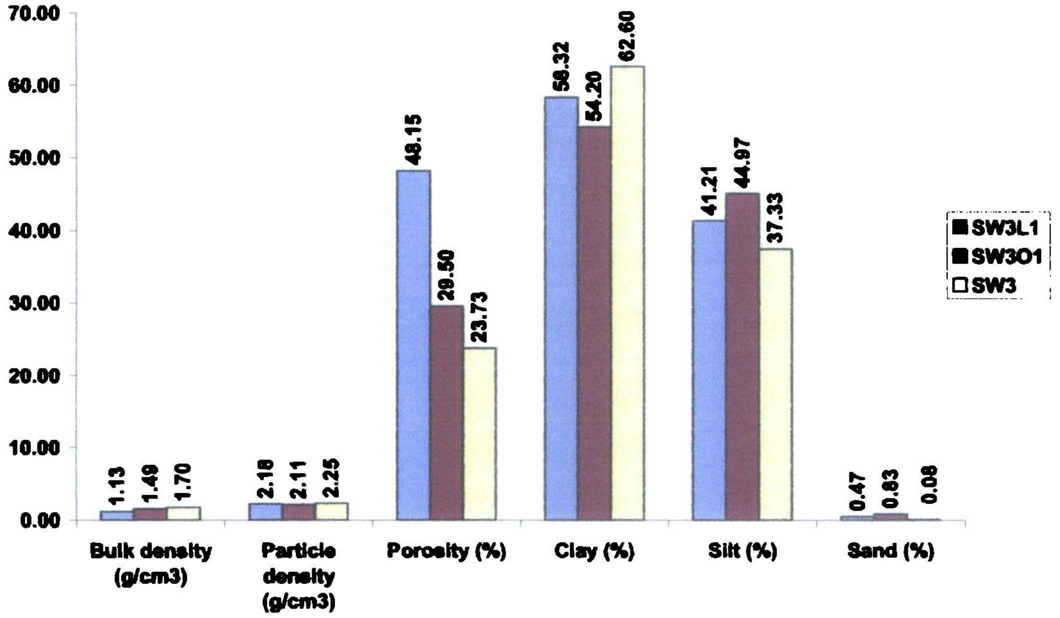


Figure 4-11 Plotted means of the physical properties of the shrimp farm soil experimented with addition of 30 earthworms together with 5% dried rice straw (SW_3L_1), 5% rice straw manure (SW_3O_1), and the treatment without organic matter added (SW_3)

2.) Chemical properties

The types of organic matters at 5% concentration levels caused significantly differences the mean values of chemical properties of the soil from the shrimp farm, i.e. CEC, %OC, %OM, Na, NH_4-N, NO_3 -N, total-N, phosphorus, potassium. The treatment added 5% organic matters with 30 earthworms showed that rice straw manure improved soil quality higher than dried rice straw. The experiment revealed that the treatment which added 5% rice straw manure with 30 earthworms (SW_3O_1) yielded the most mean values of soil properties that were higher than the treatment added 5% dried rice straw with 30 earthworms (SW_3L_1), except for the value of Na that had lower average values. It was considered as a good result, as shown in Appendix A, Table A-12.

In order to show the differences between addition of dried rice straw and rice straw manure at 5% level the soil chemical properties were shown as bar chart in Figure 4-12.

Afterward, the results of the treatment which used 30 earthworms with 5% rice straw manure (SW_3O_1) were tested against the control group (SO_1). It was found that, the soil chemical properties, i.e. the values of ESP, %OM, Na, NH_4, NO_3, nitrogen, potassium differed significantly from the control. It was also found that the treatment added 30 earthworms and 5% rice straw manure (SW_3O_1) caused positive changes in the soil quality, i.e. increasing of OM (78%), NH_4-N (30%), NO_3-N (99%) , and potassium (247%) and also resulting in negative changes in soil quality, i.e. the increase value of ESP by (37%), Na (49%), Nitrogen (83%) as detail in Appendix A, Table A-13. In order to show the difference between addition of dried rice straw and rice straw manure as organic matters at 5% concentration levels, the soil chemical properties were shown as bar chart in Figure 4-12 and Figure 4-13.

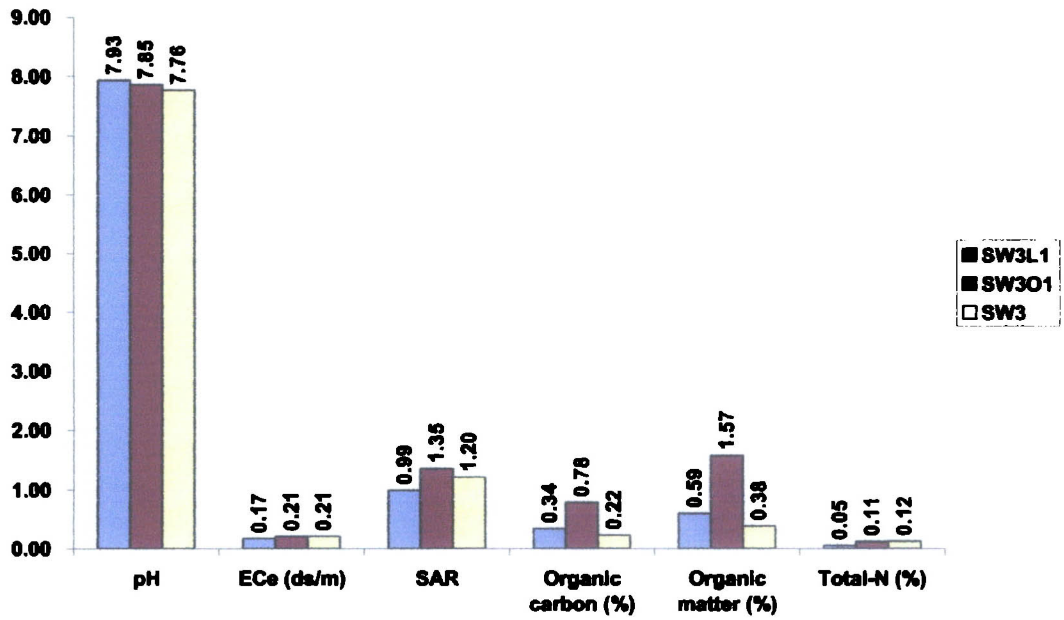


Figure 4-12 Plotted means plots of the pH, ECe, SAR, OC, OM and total-N values of shrimp farm experimented with addition of 30 earthworms together with 5% dried rice straw(SW_3L_1), 5% rice straw manure (SW_3O_1), and the treatment without organic matter (SW_3)

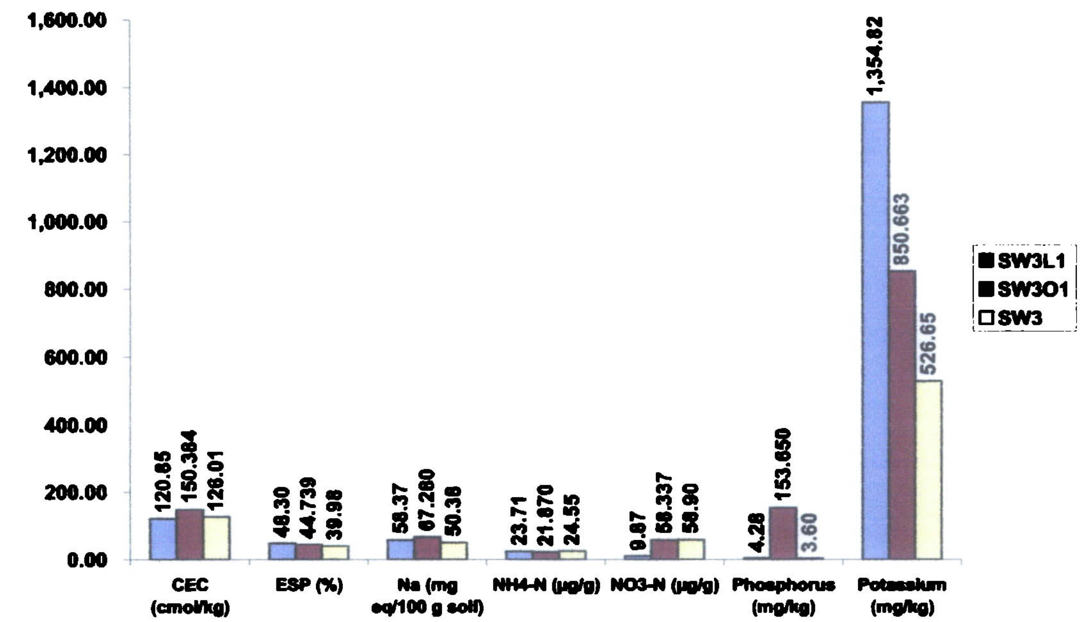


Figure 4-13 Plotted means of CEC, ESP, Na, NH_4-N, NO_3-N, phosphorus and potassium values of shrimp farm soil experimented with addition of 30 earthworms together with 5% dried rice straw (SW_3L_1), 5% rice straw manure (SW_3O_1), and the treatment without organic matter (SW_3)

4.3.2 Effect of the treatments with 10% dried rice straw and 10% rice straw manure

1.) Physical properties

Both treatments added 30 earthworms together with 10% dried rice straw (SW_3L_2) and the treatment added 30 earthworms together with 10% rice straw manure (SW_3O_2) caused significantly differences mean values of physical properties of shrimp farm soil, i.e. bulk density and porosity. The bulk density in the treatment that used 10% rice straw manure had higher mean values than the treatment with 10% dried rice straw (SW_3L_2) while the porosity value was lower, which was considered to be negative effects for soil quality. Therefore, dried rice straw adding provided better results to soil bulk density and porosity (SW_3L_2) than rice straw manure (SW_3O_2) as detail in (Appendix A, Table A-14 Figure 4-15 and Figure 4-16).

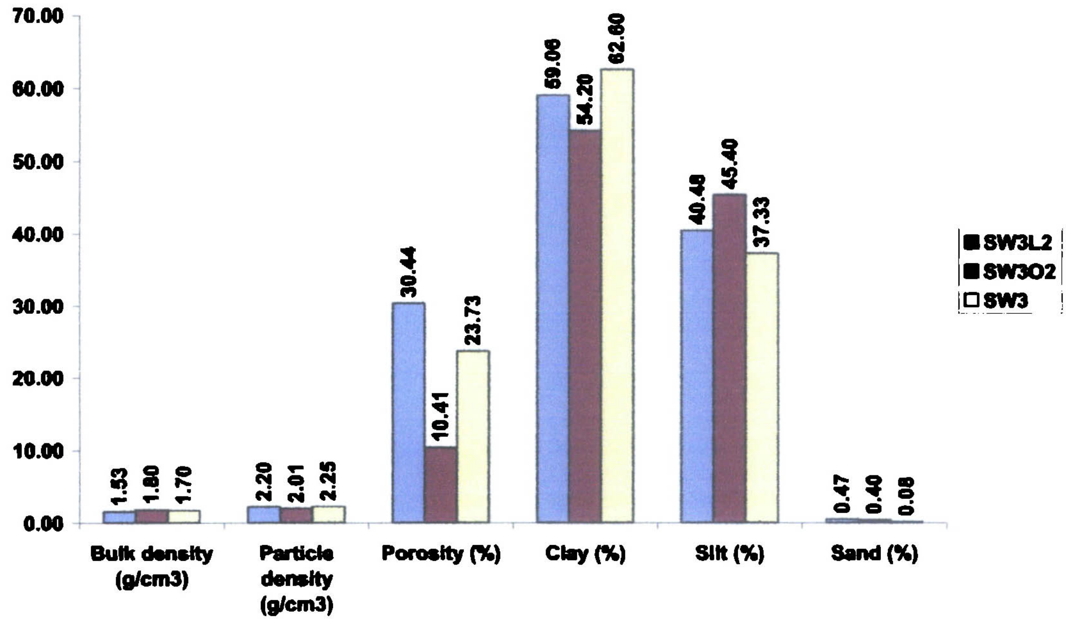


Figure 4-14 Plotted means of physical properties of shrimp farm soil experimented with addition of 30 earthworms 10% dried rice straw (SW_3L_2), 10% rice straw manure (SW_3O_2), and the treatment without organic matter (SW_3)

2.) Chemical properties

Both treatments added 30 earthworms together with 10% dried rice straw (SW_3L_2) and the treatment added 30 earthworms together with 10% rice straw manure (SW_3O_2) caused differences mean values of chemical properties of shrimp farm soil, i.e. pH, ESP, %OC, %OM, Na, NH_4-N, total-Nitrogen, phosphorus and potassium. The treatment which used 10% rice straw manure (SW_3O_2) yielded high mean values of most soil properties than the treatment which used 10% dried rice straw (SW_3L_2) except for the values of Na and pH which had lower means, and were considered as positive effect (Appendix Table A-14 Figure 4-15 and Figure 4-16).

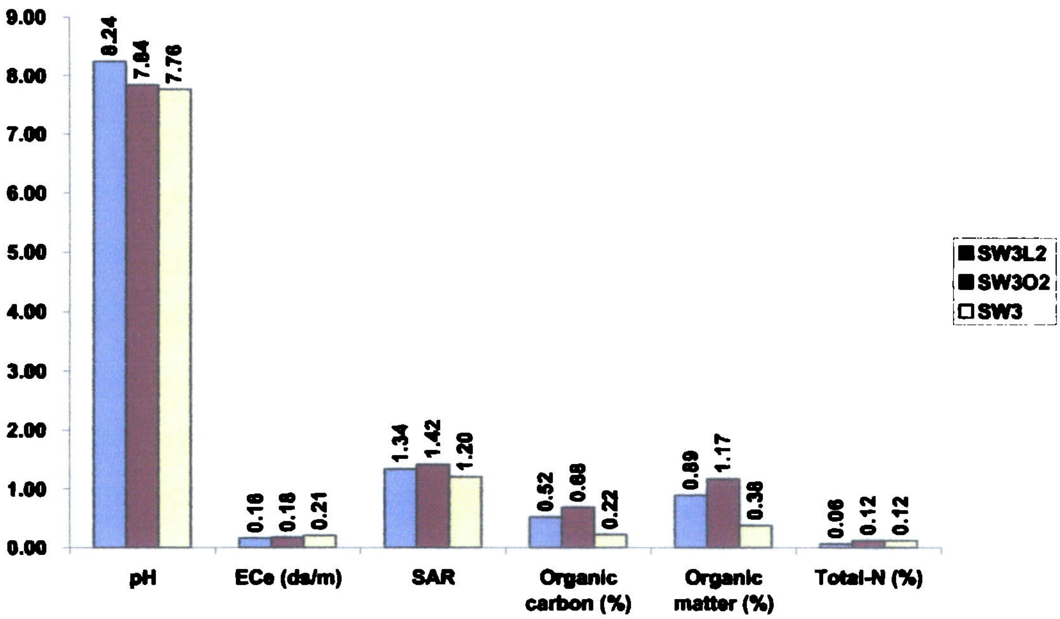


Figure 4-15 Plotted means displaying pH, ECe, SAR, OC, OM and total-N values of the shrimp farm soil experimented with addition of 30 earthworms together with 10% dried rice straw (SW_3L_2), 10% rice straw manure (SW_3O_2), and the treatment without organic matter (SW_3)

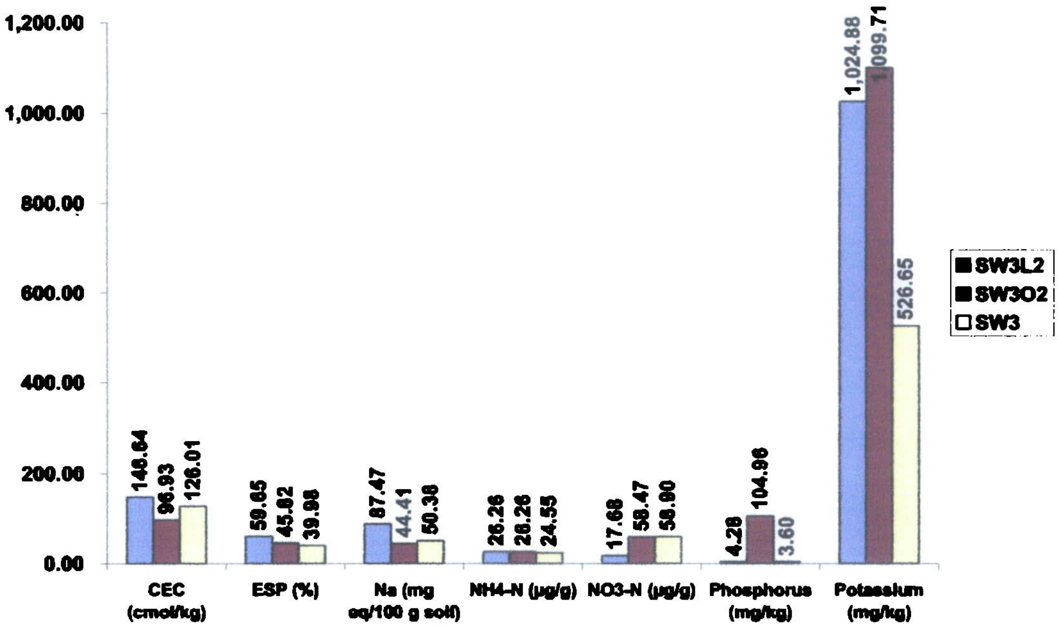


Figure 4-16 Plotted means displaying the CEC, ESP, Na, NH_4-N, NO_3-N, phosphorus and potassium values of the shrimp farm soil experimented with addition of 30 earthworms together with 10% dried rice straw (SW_3L_2), 10% rice straw manure (SW_3O_2), and the treatment without organic matter (SW_3)

The results of addition of 30 earthworms together with rice straw manure as organic matter at 5% concentration level (SW_3O_2) caused the means properties of the shrimp farm soil improvement significantly. The research results then tested whether the increased values of organic matter had any effect on the chemical properties of the shrimp farm soil. The results of the analysis were shown in Appendix A, Table A-15.

4.4 Effect of quantity of organic matter with 30 earthworms on soil qualities

4.4.1 Comparison of the amount of rice straw manure (5% and 10%)

1.) Physical properties

The amount of rice straw manure as organic matter had no effect on the difference of the mean values of physical properties of the soil from the abandoned shrimp farm in all soil qualities. However, the amount of rice straw manure had no effect on the means of soil qualities, the physical properties of the soil which added different amounts of rice straw manure were also studied as shown in Figure 4-17.

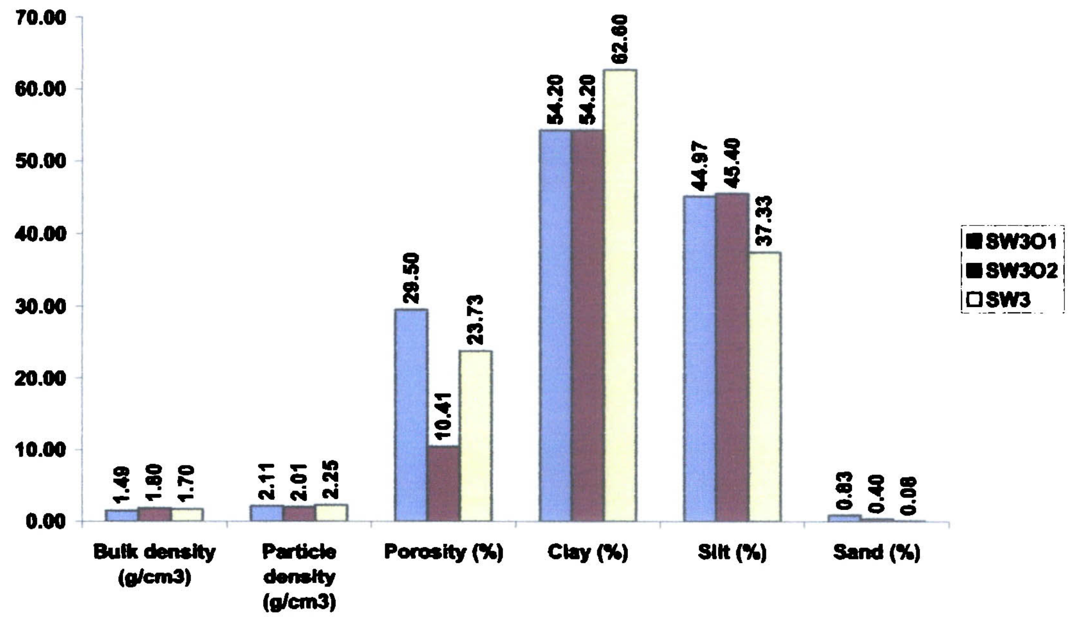


Figure 4-17 Plotted means of the physical properties of the shrimp farm soil experimented with addition of 30 earthworms together with 5% rice straw manure (SW_3O_1), and 10% rice straw manure (SW_3O_2), and the treatment without organic matter (SW_3)

2.) Chemical properties

The amount of rice straw manure as organic matter significantly increased the mean values of chemical properties of shrimp farm soil, i.e. CEC, Na, NH_4-N, total-Nitrogen, organic carbon, organic matter and potassium (Appendix A, Table A-15). The treatment which added 30 earthworms and 10% rice straw manure as organic matter (SW_3O_2) caused the mean values of soil quality higher than the treatment added 30 earthworms and 5% rice straw manure as organic matter (SW_3O_1), except for the value of Na yielded lower than average mean, and was considered to be a positive outcome. The chemical properties of the soil which added different amounts of rice straw manure were also studied as shown in Figure 4-18.

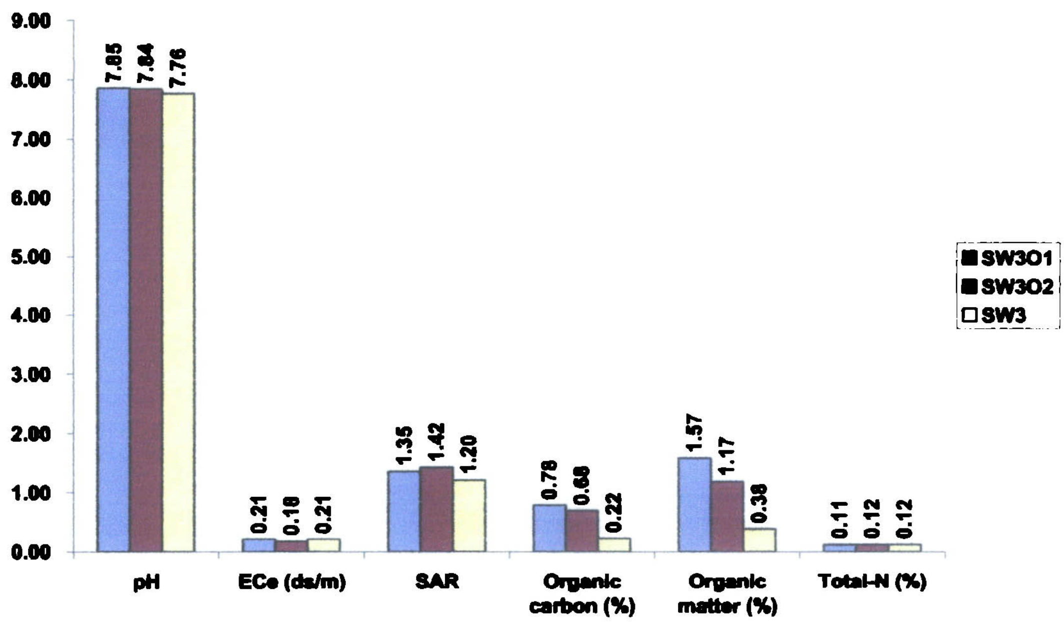


Figure 4-18 Plotted means of pH, ECe, SAR, OC, OM and total-N mean values experimented with addition of 30 earthworms together with 5% rice straw manure (SW_3O_1), and 10% rice straw manure (SW_3O_2), and the treatment without organic matter (SW_3)

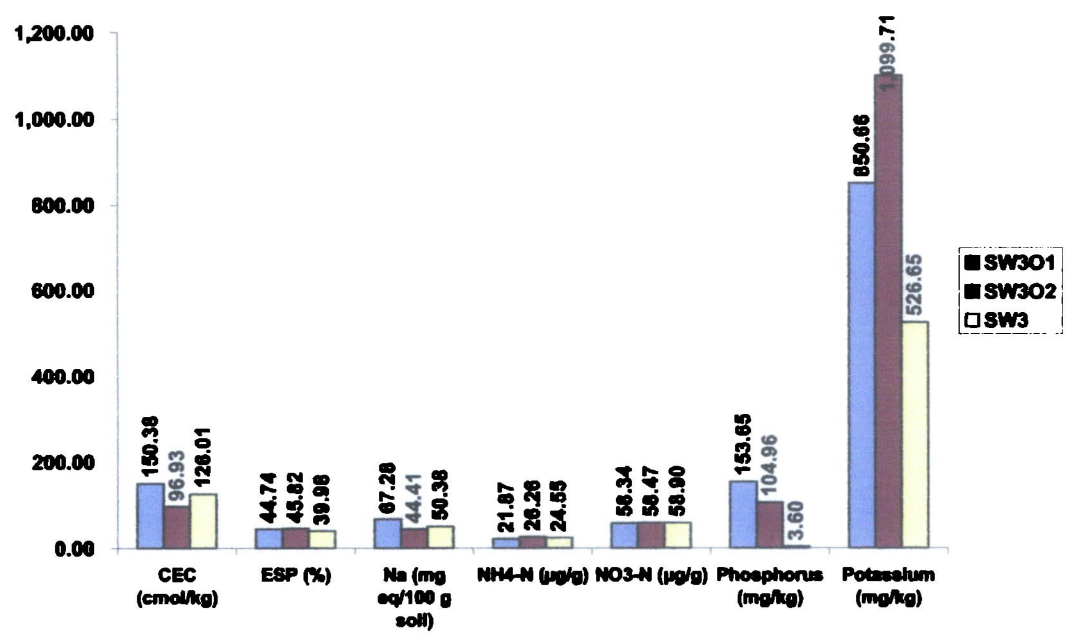


Figure 4-19 Plotted means of CEC, ESP, Na, NH_4-N, NO_3-N, phosphorus and potassium of the shrimp farm soil experimented with addition of 30 earthworms together with 5% rice straw manure (SW_3O_1), and 10% rice straw manure (SW_3O_2), and the treatment without organic matter (SW_3)

The test of the amount of rice straw manure and the effect on soil quality showed that the treatment added 30 earthworms together with 10% rice straw manure yielded better soil quality than the addition of 5% rice straw manure treatment, except for bulk density and porosity which had better result in the treatment with 5% rice straw manure. Then, the data from the treatment which used 30 earthworms together with 10% rice straw manure (SW_3O_2) was compare against the control group (SO_2), as detailed in items 4.4.2 and Appendix A, Table A-16

4.4.2 Comparison of the treatment added 30 earthworms with 10% rice straw manure against the control

The result of the comparison of soil quality from the treatment which used 30 earthworms with 10% rice straw manure (SW_3O_2) against the control group (SO_2) showed that soil qualities differed in the following aspects:

1.) Physical properties

The mean values of physical properties of shrimp farm soil, i.e. the bulk density and porosity, differed significantly between the control (SO_2) and the treatment added 30 earthworms with 10% rice straw manure (SW_3O_2) as shown in Figure 4-20 and Appendix A, Table A-16.

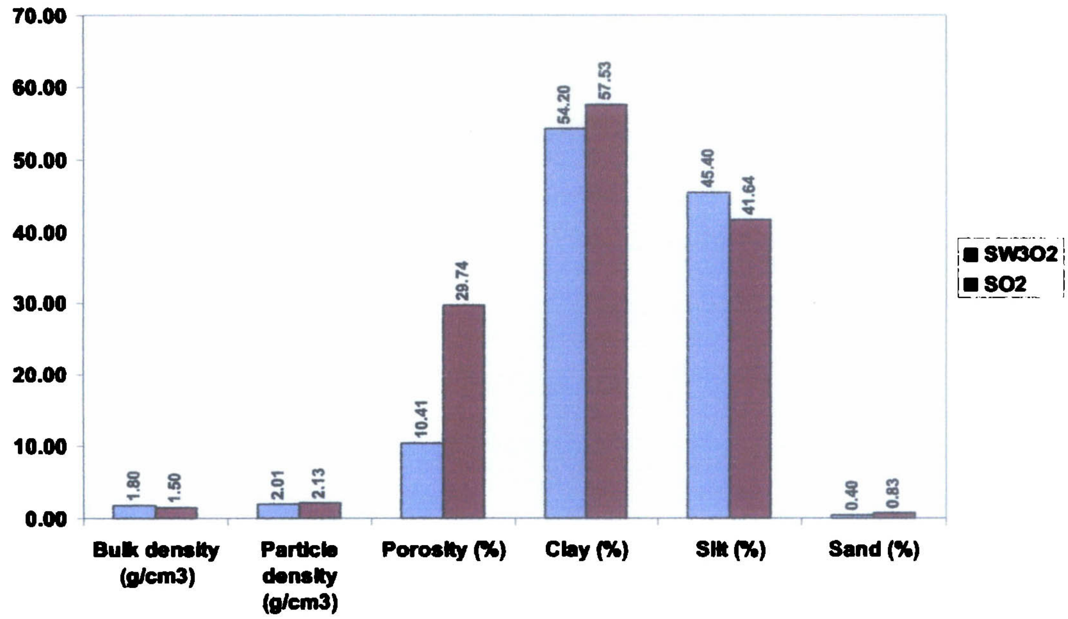


Figure 4-20 Plotted means of physical properties of shrimp farm soil experimented with addition of 30 earthworms together with 10% rice straw manure (SW_3O_2) and the control (SO_2)

2.) Chemical properties

The quality of the soil in the control treatment (SO_2) was compared against the treatment with 30 earthworms together with 10% rice straw manure as organic matte (SW_3O_2), it was found that the mean values of chemical properties of shrimp farm soil, i.e. ECe, NH_4-N, total-N, phosphorus, and potassium, differed significantly (Appendix A, Table A-16). Addition of 30 earthworms together with 10% rice straw manure caused the soil to have higher bulk density 20% (negative outcome), the porosity decreased 65% (negative outcome), ECe decreased 26% (positive outcome), NH_4-N to increased 23% (positive outcome), phosphorus value increased by 61% (positive outcome), and the potassium value increased by 43% (positive outcome).

The addition of 30 earthworms yielded the best result with added 10% rice straw manure (SW_3O_2), except for the bulk density and porosity, which 10% dried rice straw added (SW_3L_2) yielded better results. The details were shown in Appendix A, Table A-16 Figure 4-21 and Figure 4-22.

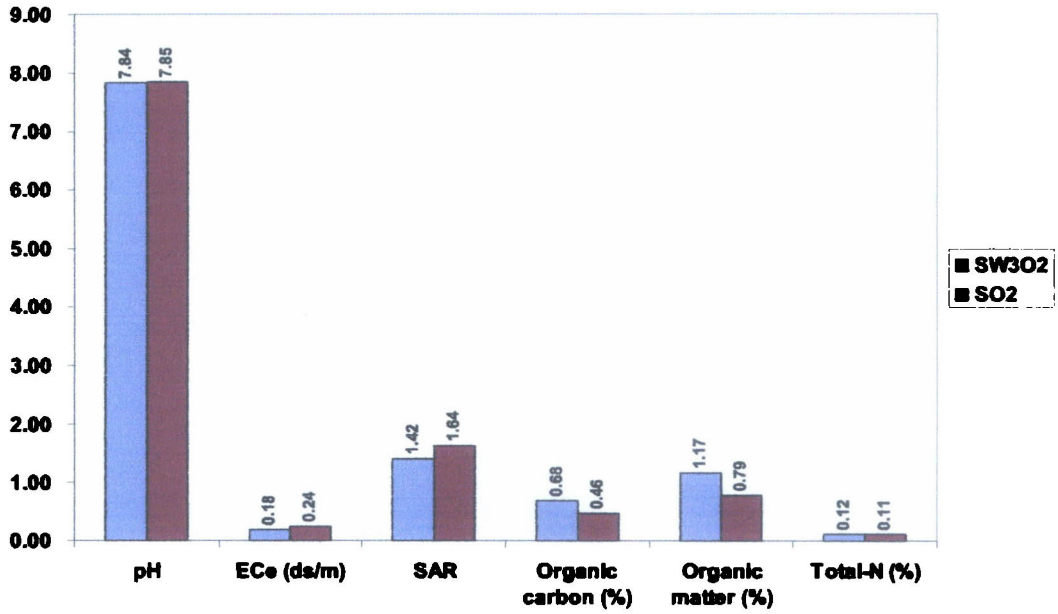


Figure 4-21 Plotted means of the values of pH, ECe, SAR, OC, OM and total-N experimented with addition of 30 earthworms in the treatments added 10% rice straw manure (SW_3O_2) and the control (SO_2)

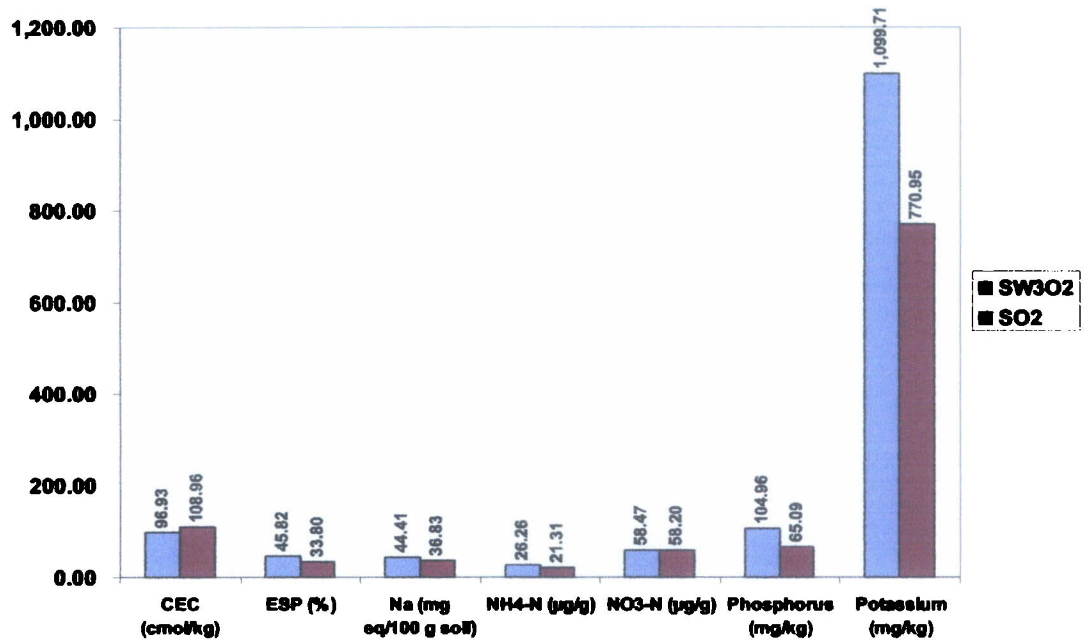


Figure 4-22 Plotted means plots of the values of CEC, ESP, Na, NH_4-N, NO_3-N, phosphorus and potassium of the shrimp farm soil experimented with addition of 30 earthworms in the treatment added 10% rice straw manure (SW_3O_2) and the control (SO_2)

Detail of the type and quantity of organic matter effected to changes in soil quality together with the use of 20 earthworms, 10 earthworms, and the treatments added only organic matter shown in details in items 4.5, 4.7 and 4.9.

4.5 Effect of using 20 earthworms with different types of organic matter on soil quality

For the treatment added 20 earthworms, the mean values of soil qualities were tested on the effect of addition of dried rice straw and rice straw manure as organic matters and changes in soil qualities. The tests were conducted 1) the treatment added 5% dried rice straw (SW_2L_1) in comparison to 5% rice straw manure (SW_2O_1), and 2.) the treatment added 10% dried rice straw (SW_2L_2) in comparison to 10% rice straw manure (SW_3O_2). The results were as follows:

4.5.1 Effects of 5% dried rice straw and 5% rice straw manure

1.) Physical properties

Comparing the treatment added 20 earthworms and 5% dried rice straw as organic matter (SW_2L_1) with the treatment added 20 earthworms and 5% rice straw manure as organic matter (SW_2O_1), the results showed that the particle density differed significantly, but there was no statistically significant effect on the differences in bulk density, porosity, clay components, silt components, and sand components (Appendix A, Table A-17).

2.) Chemical properties

Comparing the treatment added 20 earthworms and 5% dried rice straw as organic matter (SW_2L_1) with the treatment added 20 earthworms and 5% rice straw manure as organic matter (SW_2O_1), it had statistically significant mean values of soil chemical properties, i.e. ECe, CEC, ESP , %OC , %OM, Na, NH_4-N, NO_3-N, total-N, and phosphorus. The treatment which added rice straw manure as organic matter (SW_2O_1) caused the mean soil qualities higher than the treatment added dried rice straw as organic matter (SW_2L_1) except ESP (Appendix A, Table A-17).

4.5.2 Effects of 10% dried rice straw and 10% rice straw manure

1.) Physical properties

Comparing the treatment added 20 earthworms and 10% dried rice straw as organic matter (SW_2L_2) with the treatment added 20 earthworms and 10% rice straw manure as organic matter (SW_2O_2), it had no statistically significantly different physical properties in shrimp farm soil.

2.) Chemical properties

Comparing the treatment added 20 earthworms with 10% dried rice straw (SW_2L_2)with the treatment added 20 earthworms with 10% rice straw manure (SW_2O_2) it had significantly different mean values of soil chemical properties, i.e. pH, CEC, ESP, Na, NO_3-N, and total-N. The treatment added 10% rice straw manure (SW_2O_2) yielded higher means than the treatment added 10% dried rice straw (SW_2L_2), it was considered as a positive outcome, except for the values of Na and ESP in the treatment added 10% dried rice straw (SW_2L_2) and had lower values than addition of 10% rice straw manure (SW_2O_2) which were considered as positive outcomes (Appendix A, Table A-18)

4.6 Effects of the use of 20 earthworms and the quantity of organic matter on soil qualities

4.6.1 Comparing of the amount of rice straw manure (5% and 10%)

1.) Physical properties

The amount of 5% and 10% rice straw manure had no statistically significant effect on the difference in the mean values in all soil physical properties of the soil.

2.) Chemical properties

The different quantities of rice straw manure as organic matter, at 5% and 10%, caused significantly differences to the soil chemical properties, i.e. pH, CEC, Na, NH_4-N, total-N and potassium. The treatment added 10% rice straw manure caused the mean values of soil qualities, i.e. NH_4-N, total-N and potassium higher than the treatment added 5% rice straw manure, except for Na the former had lower value than the treatment added 5%. It was considered to be a positive outcome. Only for the mean values of pH and CEC with the addition of 5% rice straw manure (SW2O1) resulted in better soil quality than addition of 10% rice straw manure (SW2O2). Addition of 5% rice straw manure (SW_2O_2) caused the soil to have lower pH and higher CEC than the addition of 10% rice straw manure (SW_2O_1) (Appendix A, Table A-19).

4.6.2 Comparing of the amount of dried rice straw (5% and 10%)

1.) Physical properties

The treatment added 10 earthworms together with 5% dried rice straw (SW_2L_1) and the treatment added 10 earthworms with 10% dried rice straw (SW_2L_2) had significantly different bulk densities. The soil from the treatment added 20 earthworms together with 5% dried rice straw had lower bulk density than the treatment added 20 earthworms with 10% dried rice straw which was considered to be a positive outcome (Appendix A, Table A-20).

2.) Chemical properties

Both treatments added 10 earthworms together with 5% dried rice straw (SW_2L_1) and the treatment added 10 earthworms together with 10% dried rice straw (SW_2L_2) caused significantly differences to the mean values of soil chemical properties, i.e. ECe, CEC, ESP, OM, Na, NH_4-N, NO_3-N, total-Nitrogen, and potassium. The treatments added 20 earthworms together with 10% dried rice straw (SW_2L_2) yielded higher values of OM, NH_4-N, NO_3-N, total-Nitrogen, and potassium than the treatment which used 5% dried rice straw (SW_1L_1), except for the values of Na and ESP they had lower means, which were considered to be positive chemical properties of the soil.

The soil from the treatment added 20 earthworms together with 5% dried rice straw (SW_2L_1) yielded better quality of soil in terms of the ECe and CEC values than the treatment added 20 earthworms together with 10% dried rice straw. The mean ECe value was lower than the treatment which used 20 earthworms together with 10% dried rice straw (SW_2L_2), while the CEC value was higher, which were considered as positive soil qualities (Appendix A, Table A-20).

4.7 Effects of the type of organic matter and the use of 10 earthworms on soil qualities

4.7.1 Effect of 5% dried rice straw and 5% rice straw manure

1.) Physical properties

Analysis for the type of organic matter which had an effect on changes in physical properties of the shrimp farm soil revealed that both the rice straw manure and the dried rice straw had no statistically significant effect on the changes in soil physical properties. The treatment added 10 earthworms together with 5% dried rice straw (SW_1L_1) and the treatment added 10 earthworms together with 5% rice straw manure (SW_1O_1) had no statistically significant difference in all mean values of physical properties of the soil.

2.) Chemical properties

Addition of rice straw manure and dried rice straw had an effect on changes in chemical properties of the soil. The treatment which added 10 earthworms with 5% dried rice straw (SW_1L_1) was compared with the treatment added

10 earthworms and 5% rice straw manure (SW_1O_1), it was found that the mean values of the soil chemical properties, i.e. ESP, Na, NO_3-N, total-N and phosphorus differed significantly. The treatment added 10 earthworms together with 5% rice straw manure (SW_1O_1) yielded all mean values of soil properties higher than the treatment which added 10 earthworms together with 10% dried rice straw (SW_1L_1). They were considered to be positive outcomes, except for the values of Na and ESP (Appendix A, Table A-21).

4.7.2 Effect of 10% dried rice straw and 10% rice straw manure

1.) Physical properties

Analysis for the type of organic matter that affected changes in soil physical properties showed that both rice straw manure and dried rice straw had no effect to the changes in soil physical properties of the soil. The treatment added 10 earthworms together with 10% dried rice straw (SW_1L_2) and the treatment added 10 earthworms together with 10% rice straw manure (SW_1O_2) had no statistically significant difference in the mean values of all physical properties of the soil.

2.) Chemical properties

Comparing the treatment which added 10 earthworms together with 10% dried rice straw as organic matter (SW_1L_2) with the treatment added 10 earthworms together with 10% rice straw manure as organic matter (SW_1O_2), it had higher mean values of soil physical properties, i.e. particle density, ECe, Na, NO_3-N, total-N, phosphorus, and potassium, differed significantly. The treatment added 10% rice straw manure (SW_1O_2) had higher mean values of soil qualities than the treatment added 10% dried rice straw (SW_1L_2), except for the value of potassium. The mean values of soil qualities in the treatment added 10% rice straw manure (SW_1O_2) were high and yielded better soil quality than the treatment added 10% dried rice straw, except for the particle density and Na, for which the addition of dried rice straw gave lower values, which were considered to be positive outcomes (Appendix A, Table A-22).

4.8 Effects of the quantity of organic matter and usage of 10 earthworms on soil qualities

4.8.1 Comparing the rice straw manure quantities (5% and 10%)

1.) Physical properties

The quantity of organic matter 5% and 10% rice straw manure had statistically significant effect on the difference in particle density values but had no effect on the differences in bulk density and porosity of the soil (Appendix A, Table A-23)

2.) Chemical properties

The amount of 5% and 10% rice straw manure as organic matter caused significantly differences to the soil chemical properties, i.e. ECe ,CEC, ESP ,Na, NH_4-N, NO_3-N, total-N and phosphorus. Addition of 10% rice straw manure caused the soil to have higher mean values of soil qualities than addition of 5% rice straw manure, i.e. for particle density, ECe, CEC, ESP, Na, NH_4-N, NO_3-N and total-N , all of which were considered to be positive soil qualities, except for particle density, Na, and ESP. Besides, it was found that 2 soil qualities (pH and phosphorus) in the treatment added 5% rice straw manure gained higher values than the treatment added 10% rice straw manure as detail in (Appendix A, Table A-23).

4.8.2 Comparing of the quantity of dried rice straw (5% and 10%)

1.) Physical properties

Physical properties of shrimp farm soil in the treatment added 10 earthworms together with 5% dried rice straw (SW_1L_1) and the treatment added 10 earthworms together with 10% dried rice straw (SW_1L_2) had no statistically significant difference.

2.) Chemical properties

It was found that both the treatment, added 10 earthworms together with 5% dried rice straw (SW_1L_1) and the treatment added 10 earthworms together with 10% dried rice straw (SW_1L_2) caused significantly differences to the chemical properties of the shrimp farm soil, i.e. ESP, Na, NO_3-N, total-Nitrogen, and potassium. The treatment added 10 earthworms together with 10% dried rice straw (SW_1L_2) yielded most of the mean values of soil qualities to be higher than those in the treatment which added 5% dried rice straw (SW_1L_1), except for the values of Na and ESP, they had lower means and were considered to be positive chemical qualities of the soil (Appendix A, Table A-24).

4.9 Effect of addition of organic matter on soil quality among the treatments without earthworms

Test of the effect of organic matter for the treatment without earthworm was conducted for mean values of soil qualities between two groups: 1.) Between the treatment added 5% dried rice straw (SL_1) and the treatment added 5% rice straw manure (SO_1), and; 2.) Between the treatments which added 10% dried rice straw (SL_2) and 10% rice straw manure (SO_2). The results were as follows:

4.9.1 Effect of the type of organic matter (comparison between dried rice straw and rice straw manure at 5% level)

1.) Physical properties

The type of organic matter had no statistically significant effect on the mean values of the physical properties of the shrimp farm soil in all soil qualities. The quantity of rice straw manure also had no effect on the difference in mean values of physical properties.

2.) Chemical properties

For soil qualities experiments between the treatment added 5% dried rice straw (SL_1) and the treatment added 5% rice straw manure (SO_1), it was found that the treatment added the 5% rice straw manure (SO_1) caused the soil to have significantly higher CEC, ESP, NO_3-N, total-N, and phosphorus than the treatment which added 5% dried rice straw (SL_1) (Appendix Table A-25). The higher chemical properties values was considered as a positive outcome on the quality of the soil except ESP.

4.9.2 Effect of the type of organic matter (comparing between dried rice straw and rice straw manure at 10% level)

Test of the effect of organic matter for the treatments without earthworms was conducted for the mean values of soil qualities between two groups: 1.) Between the treatments added 5% dried rice straw and 5% rice straw manure, and; 2.) Between the treatments added 10% dried rice straw and 10% rice straw manure, as follows:

1.) Physical properties

The type of organic matter had no statistically significant effect on the mean values of the physical properties of the shrimp farm soil in all soil qualities (Appendix Table 1-26). The quantity of rice straw manure had no effect on the difference in mean values of physical properties.

2.) Chemical properties

Comparing the soil qualities between the treatment added 10% dried rice straw (SL_1) and the treatment added 10% rice straw manure (SO_2), it was found that the chemical properties of the soil of the 2 treatments had statistically significant differences. The pH, ECe, and SAR values of the treatment added dried rice straw was lower than the treatment added rice straw manure. The values of CEC and potassium were considered to be positive outcomes (except for ECe), the ESP, and the Na of the soil added the rice straw manure were lower than those in the soil added the dried rice straw and were considered to be positive outcomes. The values of NH_4-N, NO_3-N, total-N, and phosphorus of the soil added rice straw manure were higher than those in the soil added dried rice straw, and were considered to be good soil qualities.

4.9.3 Effect of the amount of organic matter

4.9.3.1 Comparing the treatment added the dried rice straw

1.) Physical properties

The quantity of organic matter had a statistically significant effect on the differences in the mean bulk density and porosity. Addition of 10% rice straw manure caused the soil to have higher bulk density than addition of 10% dried rice straw, while the porosity was also higher than the treatment added dried rice straw (Appendix A, Table A-27).

2.) Chemical Properties

The treatment added 5% dried rice straw (SL_1) and the treatment added 10% dried rice straw (SL_2) caused significantly differences to the mean values of the chemical properties of shrimp farm soil, i.e. pH, ECe, CEC, Na, NO_3-N, total-Nitrogen, and potassium (Appendix Table 1-27). The treatment with 10% dried rice straw (SL_2) yielded higher means of most soil qualities than the treatment with 5% dried rice straw (SL_1). These were considered as positive soil qualities, except for the values of Na and pH, which had higher means and were considered as negative chemical qualities of the soil.

4.9.3.2 Comparing among the treatments which added the rice straw manure

1.) Physical properties

The different of 5% and 10% rice straw manure at had no statistically significant effect on the difference of mean values of soil physical properties (Appendix A, Table A-28).

2.) Chemical properties

The treatment added 5% rice straw manure (SO_1) and the treatment added 10% rice straw manure (SO2) caused significantly difference to the mean values of chemical properties of the shrimp farm soil, i.e. ECe, CEC, Na, NH_4-N, NO_3-N, total-Nitrogen, phosphorus and potassium. The treatment with 10% rice straw manure (SO_2) yielded better means of most soil qualities than the treatment with 5% rice straw manure (SL_1) and were considered to be good soil quality, except for the values of CEC, total-N, and phosphorus, for which the treatment with added 5% rice straw manure yielded better results and had significantly higher means (Appendix A, Table A-28).

4.10 Growth rates of the earthworms

From the Figure 4-23, there were only 2 treatments in which the earthworms experienced growth (increase in weight), i.e. the treatment added 20 earthworms together with 10% rice straw manure (SW_2O_2) and the treatment added 30 earthworms together with 10% rice straw manure (SW_3O_2).

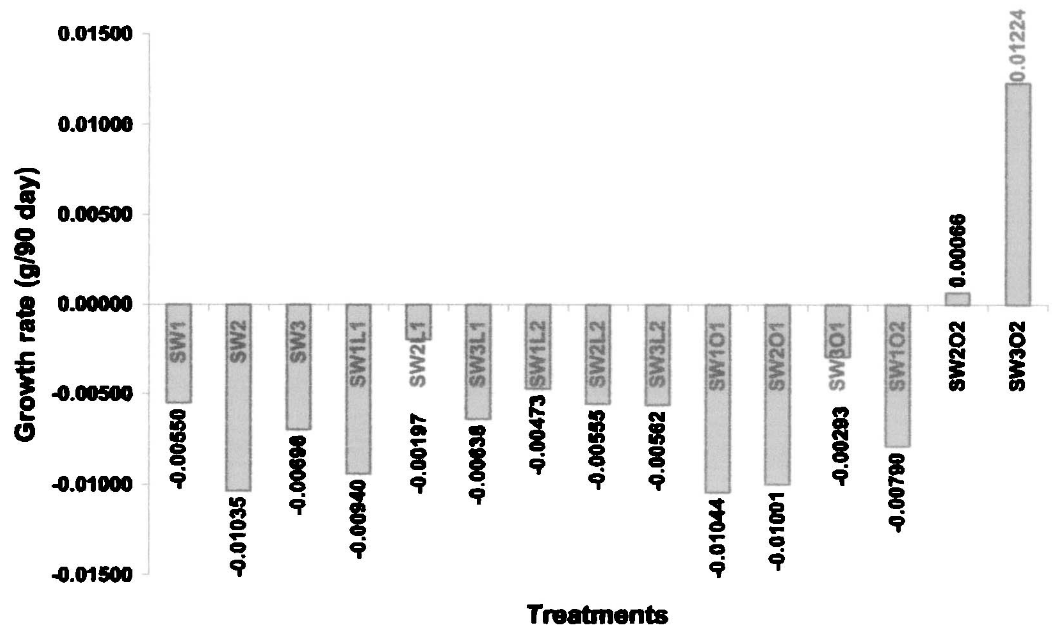


Figure 4-23 Growth rates of earthworms of the 15 earthworms-added treatments

4.11 Survival rates of the earthworms

Survival rates of the earthworms after 90 days experiment showed that there were only 2 treatments in which the earthworms had more than 80% survival rates, they were the treatment added 10 earthworms together with 10% dried rice straw (SW_1L_2), and the treatment added 20 earthworms together with 10% rice straw manure (SW_2O_1)

The treatments sets with survival rates of the earthworms more than 50% were the treatments added 20 earthworms (SW_2), the treatment added 30 earthworms (SW_3), the treatment added 10 earthworms together with 5% dried rice straw (SW_1L_1), the treatment added 20 earthworms together with 5% dried rice straw (SW_2L_1), the treatment added 10 earthworms together with 5% dried rice straw (SW_1L_1), the treatment added 10 earthworms together with 10% rice straw manure (SW_1O_1), the treatment added 20 earthworms together with 5% rice straw manure (SW_2O_1), the treatment added 10 earthworms together with 10% rice straw manure (SW_1O_2), and the treatment added 20 earthworms with 10% rice straw manure (SW_2O_2) (Figure 4-11).

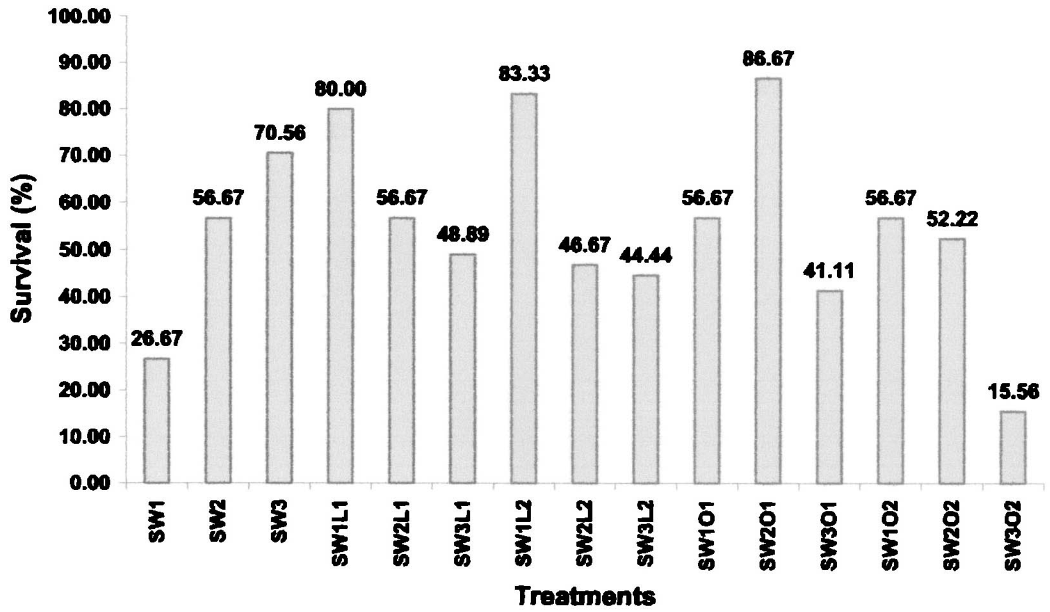


Figure 4-24 Survival rates of earthworms of the 15 sets of earthworms-added treatments

4.12 Factors affected the growth rates and survival rates of the earthworms

4.12.1 Effect of the number of earthworms

Tests of the difference of the mean survival rates and the growth rates of the earthworms based on the number of earthworms by each treatment groups, there were the treatments added only earthworms and bare soil (S), the treatments added earthworms and 5% dried rice straw (SWL_1), the treatments added earthworms and 10% dried rice straw (SWL_2), the treatment added earthworms and 5% rice straw manure (SWO_1), and the treatments added earthworms and 10% rice straw manure (SWO_2). The results showed that the number of earthworms had no statistically significant effect on the survival rates and the growth rates of the earthworms. The analyzed results were shown in Appendix A, Table 1-29 to Appendix A, Table 1-33.

4.12.2 Effect of the type of organic matter (comparing between dried rice straw and rice straw manure at 5% level)

From Appendix A,Table 1-28, it was found that at the 5% level of addition of organic matter, the type of organic matter (rice straw manure and dried rice straw) caused significantly differences to the survival rate of the earthworms in experiment treatments added 10 earthworms. Addition of 5% dried rice straw enabled the 10 added earthworms had higher survival rate than the treatment added rice straw manure. For the test with 20 earthworms added to in the experiment with 5% dried rice straw, it caused the earthworms to have lower growth rate than addition of rice straw manure.

4.12.3 Effect of the type of organic matter (Comparing between dried rice Straw and rice straw manure at 10% level)

From Appendix Table 1-35, it was found that at the 10% level of addition of organic matter (rice straw manure and dried rice straw), there was no effect on the survival rates and the growth rates of the earthworms in the treatments.

4.12.4 Effect of the quantity of organic matter (Comparing among the treatments added dried rice straw)

From Appendix Table 1-36, the effect of the quantity of organic matter related to the survival rates and growth rates of the earthworms in the treatments added dried rice straw were considered, it was found that the quantity of the dried rice straw had significant effect on the differences in growth rates of the earthworms in treatments added 10 earthworms. Addition of 10% dried rice straw caused the earthworms to have a lower growth rate than the addition of 5% dried rice straw.

4.12.5 Effect of the quantity of organic matter (Comparing among the treatments added rice straw manure)

From Appendix A, Table A-36, the effect of the quantity of organic matter related to survival rates and growth rates of the earthworms were considered, it was found that addition of rice straw manure at 5% and 10% levels had no effect on the difference in growth rates, but resulted in different survival rates of the earthworms.

The treatment which added 20 earthworms and 5% rice straw manure had higher survival rate than the treatment added 10% rice straw manure.

CHAPTER V
DISCUSSION, CONCLUSION AND RECOMMENDATION

5.1 Conclusions and Discussion

5.1.1 Effect of the number of earthworms on soil quality

The effect of the number of earthworms on soil quality, it was considered from the treatments which added the earthworms and soil without added organic materials, showed that the number of earthworms had no effect on the mean differences of physical properties of the soil but caused significantly differences to the mean values of the chemical properties of the soil, i.e. CEC, ESP, Na, NH_4-N, NO_3-N, total-N, phosphorus and potassium. Addition of 30 earthworms caused the most mean values of soil chemical properties increased which could be considered as positive outcomes for soil quality (except for the values of Na and ESP, the higher values referred to bad quality of soil).

The number of earthworms had no statistically significant effect on changes in soil physical properties due to the fact that the number and density of earthworms added in the treatments were too low referred to unclear results. However, the number of earthworms had no statistically significant effect on changes in physical properties of the soil. Changes were obviously observed in term of soil quality. Thus the following discussion could be made on the effect of the number of earthworms on physical and chemical properties of the soil:

1.) Infiltration rate

The infiltration rates in all treatments were very slow (Landon, 1984). The water level in both rings tested for the soil from all treatments did not decrease. The soil in the bottles were compact in all treatments; the treatments added with earthworms, the treatments without earthworms, the treatments added organic material, and the treatments without organic material added. The force of impact from watering the soil throughout the entire experiment exerted a pressure on the silt article to aggregate and made the soil compacted, thus water drainage was very slow. Soil compaction is associated with Mg, for which negative feedback would be found in soil conditions for soil which had a high Mg:Ca ratio. This study showed that the soil from all treatments had higher exchange cation value for Mg higher than Ca (Appendix A, Table A-1) at 2.71 to 4.47 times. The high Mg^{2+} : Ca^{2+} ratio would affect the aggregation and lamination of the soil, and also had negative effect on the soil infiltration rate, which concurred with the study by Katerina and Darrell (1999) on the effect of the Ca^{2+}: Mg^{2+} ratio on soil aggregation, infiltration rate, and clay erosion, and the result showed that the Mg^{2+} ion had a direct effect on clay flocculation and lamination at the soil surface when contacted with water.

Bad soil infiltration was also associated with the increasing amount of sodium, which an ion dispersed soil particles, when it contacted with water, the soil texture like starch paste and formed a thin film on the soil surface. For soil with more than 12% sodium content, when it dried, soil structure would be broken decreased water in soil infiltration and ventilation(Land Development Department, 1985) and (Bronick & Lal, 2005)

2.) Soils Bulk density

This study found that the addition of only earthworms could not decrease the total bulk density of the soil. It was observed that the use of 30 earthworms caused the soil bulk density higher than other treatments. It was considered to be negative outcome since the density was at the "very compact" and "highly compact" levels, with the values above the standards at 1.43-1.60 g/cm3 and 1.6-1.8 g/cm3, respectively(Pam & Brain, 2007). The high total bulk density of the soil also caused water to be unable to pass through the two rings, resulting to the assessment of infiltration rate was impossible. Besides, the high bulk density was also associated with the changeable sodium content in the soil from the excretion of the earthworms, and the water that was added into the soil which had the sodium content of 0.23 me/l. Sodium caused the soil to be compact due to the concentrated amount of sodium when water evaporated form the soil, and resulted in the precipitation of calcium and magnesium, causing the sodium to adhere better to the clay particles.

When it was dried, the soil would be hardened and the soil structure would become broken (Members of the college of Faculty of Pedology, KU, 2005)

3.) Particle density

Ingestion of soil by the earthworms caused changes in the soil particle sizes to become smaller. Generally, sand particles have the highest density, followed by silt and clay particles. Particle density is the proportion of dried soil mass to soil volume, not including the volume of air. The increase or decrease of various particles in the soil would thus result in changes in particle density. When the proportion of smaller particles in the soil increase and that of the large particles decreased, the particle density would likely decrease.

However, this study found that the earthworms could not decrease the density of soil particles, as observed results from the fact that the soil from the treatment added 30 earthworms had the highest particle density. This could be related to the increased amount of positive charge in the soil, as the soil particle density would depend on composition of elements in the soil.

4.) Soil texture

Although the number of earthworms had no statistically significant effect on the changes in clay, silt, and sand particles, but the *Polypheretima elongata* earthworms could digest the large soil particles to be smaller through the ingestion process, comparing to the soil particles that did not undergo ingestion. A study by Borssard et al.(1996) found that there was a significant difference in particle size in the soil which underwent ingestion and did not undergo ingestion. The soil which underwent ingestion, i.e. in the cast, consisted of particles of smaller size than the soil which was not

Comparing among the control groups which soil was added only earthworms, it found that, addition of 30 earthworms caused the large particle, the sand particles, decreased in size the most. Silt particles, which were of smaller size than sand particles, also had decreased in size while the clay particles, which were the finest and smallest particles, had the highest percentage increase in the treatment added 30 earthworms (Figure 4-8).

4.) Porosity

The study found that the soil from soil from all treatments which added earthworms had higher porosity than the bare soil control (without earthworms added treatment). Normally, earthworms could increase soil porosity by making cavity throughout the soil which they inhabited. endogeic and anecic earthworms can cause to soil to be porous from the earthworm cavity, which are continuous and stable macropores that allow water and air to pass through (Shipitalo & Bayon, 2004).

For *Polypheretima elongata* earthworms, it was found that there was uncontinuous cavity and the cavity of this earthworm was filled with cast (Friend & Chan, 1995) and the study of Balance et al. (2004) found that the presence of *Polypheretima elonagta* had an effect on increased number of macropores in the soil.

5.) Exchangeable Na^+ and ESP

Exchangeable sodium value in the soil from the treatment added 30 earthworms was higher than those from the treatments added 20 and 10 earthworms. The increased sodium content in the soil came partly from the excretion of the earthworms, from the mucus secreted through the dorsal pore which of similar composition to cytosol in the earthworm's body. In addition, the study of ions in the blood of the Pheretima earthworms showed that the blood consisted of Na^+ 43 mMI-, K^+ 7 mMI$^-$, Ca^{++} mMI$^-$, and Mg^{++} mMI$^-$. Another source of increased sodium is the excretion of the earthworms, which consists of water, ammonia, urea, uric acid, and positive soluble ions of Na^+ , K^+ , Ca^{2+} and Mg^{2+}, 80% of which is re-absorbed to the body, while the rest would be excreted (Wallwork, 1983).

The use of large number of earthworms caused the soil to have high ESP value, which was associated with the increased sodium from the earthworms.

6.) NH_4-N

The earthworms had an effect on the increase in the amount of ammonia nitrogen, as the excrement of the earthworms consisted of water, ammonia, urea, and uric acid (Wallwork, 1983) and was also associated with the soil that underwent ingestion by the earthworms. A study by Aira et al. (2002) compared the cast of earthworms with bare soil found in grass pasture and found that the cast had higher content of NH_4^+ and carbohydrate compounds than the surrounding soil. For *A. caliginosa* earthworm, the contents of NH_4^+ in the cast and in bare soil were 70.41 µg/g and 6.52 µg/g, respectively. While for *A. molleri* earthworm, the contents of NH_4^+ in the cast and in bare soil were 53.65 µg/g and 17.57 µg/g, respectively. In addition, the mentioned study also indicated that the activity of microbes in the cast was higher than in bare soil, as the content of protease and urease from the release of ammonia in the cast was higher than those in the bare soil, which was consistent with the amount of ammonia released.

The increased ammonia was also related to the decomposition process of organic material in the soil and the organic material that was added into the soil through mineralization, which was the process of converting organic-N to mineral-N (NH_4^+) by microbial processes (Rowell, 1994).

7.) NO3-N

The use of higher number of earthworms caused the soil to have higher nitrate nitrogen than the use of lower number of earthworms, and higher than the treatment without earthworms, which concurred with Willems et al.(1996), who studied the effect of earthworms of mineralization of nitrogen and found that both the studied soil structures, unchanged structural and underwent sieving soil, they had higher concentration of NO3-N with the addition of *Lumbricus terrestris* and *Aporectodea* earthworms.

8.) Phosphorus

According to the fact that earthworms could increase soil phosphorus content, it was associated with the soil decomposition process through the digestive tract of the earthworms. The high amount of secreted mucous in the digestive tract of the earthworms, which release carboxyl group from carbohydrate compounds that could compete for adhesive space with, or replace, phosphorus, allowing for higher content of water-soluble phosphorus (Lopez- Hernandez, 1993). In addition, a study by Brossard (1996) compared the cast of *Polypheretima elongata* with the soil that did not undergo digestion and found that there was a higher content of usable phosphorus in the soil which underwent digestion or in the excreted cast of the earthworms, which was associated with the number of earthworms. Review of previous studies on the effect of the earthworms on changes in phosphorus content also showed that the increase in phosphorus content in the soil was also related to the mucus of the earthworms in the tunnel and the cast of the earthworms. The phosphorus in the earthworm tunnel was lower than that in the cast and the soil surrounding the cast. The lining of the tunnel released phosphorus in a relatively high amount with the concentration of approximately 1 mg PO_4-P-L^{-1} in a short period of 5 minutes - 1 hour. In addition, the detection of alkaline phosphate in earthworm tunnels could be related to the activity of enzymes from microflora in the digestive tract of the earthworms (Ranée-Claire & Roxane, 2009)

5.1.2 Effect of the type and amount of organic material on soil quality

1.) Treatments added 30 earthworms

Addition of 30 earthworms with 5% organic material showed that addition of manure caused the soil to have better chemical properties, i.e. CEC, OC, OM, Na, NH_4-N, NO_3-N, Total-N, phosphorus and potassium (except for Na, which the treatment with manure had higher value, and was a negative outcome). Addition of 30 earthworms with 10% organic material showed that the type of organic matter had a significant effect on the mean values of physical properties of the soil, i.e. bulk density and porosity. Addition of 10% rice straw manure caused the soil to have higher bulk density and porosity than addition of 10% dried rice straw, Besides addition of rice straw manure caused the chemical properties of the soil, i.e. CEC, OC, OM, Na, NH_4-N, NO_3-N, total-N, phosphorus and potassium to be better than addition of dried rice straw (except for Na, which the treatment added rice straw manure had higher values and considered as a negative outcome).

From the above stated results, it could be reported that in treatments which added 30 earthworms, the type of organic material had an effect on changes in soil quality. Rice straw manure, at 5% and 10% concentration, yielded better soil quality than dried rice straw (except for the high Na and bulk density, which were negative outcomes).

The amount of rice straw manure in the treatments which added 30 earthworms was tested on changes in soil quality, it was found that addition of 10% rice straw manure caused the soil to have significantly better properties, i.e. porosity, Na, NH4-N, total-N and potassium than addition of 5% rice straw manure. However, addition of 5% rice straw manure caused the soil to have better CEC and bulk density than addition of 10% rice straw manure. From the mentioned results, it could be concluded that in the treatments added 30 earthworms, the amount of organic materials had an effect on differences in soil quality.

2.) Treatments added 20 earthworms

Addition of 20 earthworms with 5% organic material showed that addition of rice straw manure caused the means of ECe, OC, OM, Na, NH4-N, NO_3-N, total-N to be higher than addition of dried rice straw while the ESP value was lower than the treatment added dried rice straw, and was considered to be better soil quality, except the value of Na which addition of dried rice straw caused the soil to have lower Na than addition of rice straw manure, thus indicating better outcome for the former.

Addition of 10% organic material showed that addition of rice straw manure caused the soil to have higher means of ECe, OC, OM, Na, NH_4-N, NO_3-N and total-N higher than addition of dried rice straw, and lower ESP than the treatment added dried rice straw which could be considered as better soil quality (except for Na, which the addition of rice straw manure caused the soil to have higher Na, was considered as negative soil outcome). From the stated results, it could be concluded that in treatments which added 20 earthworms, the type of organic material had an effect on changes in soil quality. Rice straw manure yielded better soil quality than dried rice straw (except for Na).

The amount of rice straw manure with 20 earthworms was tested on changes in soil quality, it was found that addition of rice straw manure at different quantities had an effect on the means of particle density and phosphorus. Additon of 5% rice straw manure caused the soil to have lower particle density and phosphorus than addition of 10% rice straw manure, which were positive outcomes. On the other hand, addition of 10% rice straw manure caused the soil to have higher ECe, CEC, ESP, Na, NH_4-N, NO_3-N and total-N than addition of 5% rice straw manure, which were positive outcomes except for the values of Na and ESP, which the higher value had bad effect on soil quality. In addition, the phosphorus content in the treatment which added 5% rice straw manure was higher than in the treatment added 10% rice straw manure, and was considered as better soil quality. From the mentioned results, it could be concluded that in the treatments which added 20 earthworms, the quantity of rice straw manure had an effect on changes in soil quality. Addition of 10% rice straw manure yielded soil to have quality than addition of 5% rice straw manure.

3.) Treatments added 10 earthworms

Addition of 10 earthworms with 5% organic material showed that addition of rice straw manure and dried rice straw had no effect on difference in physical properties of the soil, but chemical properties i.e. ESP, Na, NO_3-N, total-N and phosphorus of the soil added rice straw manure was higher than the means of the treatments added dried rice straw (except for the values of Na and ESP were lower) and were considered to be good soil qualities. Addition of 10 earthworms with 10% organic material showed that addition of rice straw manure or dried rice straw caused the soil to have significantly different particle density. The treatment which added dried rice straw had lower value, and was considered to be positive outcome. The mean values of chemical properties of the soil, i.e. ECe, Na, NO3-N, total-N, phosphorus and potassium of the soil which added rice straw manure were higher, which were considered to be positive soil qualities (except for the values of Na and potassium, which addition of dried rice straw yielded better soil qualities). From the stated results, it could be concluded that the treatments added 10 earthworms, with addition of 10% rice straw manure caused the soil to be better quality than addition of dried rice straw (except for the values of Na and potassium, for which addition of 10% dried rice straw yielded better qualities of Na and potassium).

4.) Treatments Added Only Organic Materials and without Earthworms

At 5% level of organic material, addition of dried rice straw or rice straw manure had no statistically significant differences in physical properties, but had an effect on chemical properties of the soil. Addition of rice straw manure caused the soil to have higher CEC, ESP, NO3-N, total-N and phosphorus than the treatments added dried rice straw, and were considered as good soil qualities (except the value of ESP).

At 10% level of organic material, it was found that the type of organic material had no statistically significant effect on physical properties but had an effect on chemical properties of the soil. The pH, ECe, and SAR values of the treatment added dried rice straw was lower than the treatment added rice straw manure, but the CEC and potassium values were higher, and were considered as positive outcomes (except the value of ECe). The ESP and Na values of manure-added soil were lower than those in the rice straw-added soil, and were considered as good soil qualities. The NH_4-N, NO_3-N, total-N and phosphorus values of the soil which added rice straw manure were higher than the soil added dried rice straw, and were considered as good soil qualities.

Addition of rice straw manure at different quantities had no effect on the means of physical property values of the soil, but had an effect on the chemical properties of the soil, i.e. the values of ECe, CEC, Na, NO_3-N, NH_4-N, total-N, phosphorus and potassium differed significantly. Addition of 10% rice straw manure caused the means of the soil to be higher and better than addition of 10% rice straw manure, except for the values of CEC, Total-N, and phosphorus, for which addition of 5% rice straw manure yielded better results.

Addition of dried rice straw at different quantities caused the soil to have significantly different bulk density and porosity. Addition of 10% dried rice straw caused the soil to have lower bulk density and higher porosity. The different quantities of dried rice straw caused the soil to have significantly different pH, ECe, CEC, Na, NO_3-N, total-N, and potassium values. Addition of 10% dried rice straw caused the chemical property value means of soil to be higher than addition of 5%

dried rice straw, which were considered as good soil qualities, except for the value of Na which was higher and was considered as bad soil quality.

Addition of rice straw manure and dried rice straw caused the soil to have changes in chemical properties due to the effect of the rice straw manure and the dried rice straw. The rice straw manure used in this study had the chemical properties as the following values: CEC 94.45 cmol/kg, OC 18.96%, OM 32.68%, Na 7.14 cmol/kg, phosphorus 1915.27 mg/kg and potassium 380.82 mg/kg. The dried rice straw had the following values: CEC 3.24 cmol/kg, OC 47.47 %, OM 81.84 %, Na 3.24 cmol/kg, phosphorus 42.96 mg/kg and potassium 529.47 mg/kg

5.1.3 Quality of abandoned shrimp farm soil after improvement with earthworms and organic material

Soil chemical properties from the treatment added 30 earthworms with 10% rice straw manure was compared with the standards and yielded the best overall soil quality, it was found that the CEC was higher than 40 cmol/kg, which was at a very high level (Hezelton and Murphy, 2007, cited in Metson, 1961) that it associated with the fine texture of the soil. The soil with high level of clay particles could absorb high quantity of positive charges. The organic carbon content less than 2% was at a very low level (Landon,1984). The organic matter value was at the low and medium levels (Arnon, 2004) The Na value was higher than 2 meq/100 g soil (Landon, 1984, cited in Holford and Culis, 1983).

The Total-N value was less than 0.1% and was in the range (0.1-0.2%), which was considered as the low-very low level (Landon, 1984). The value of phosphorus was higher than 25 mg/kg which was considered as the very high level (Landon, 1984, cited in Holford and Culis,1981), The value of potassium was higher than 120 mg/kg, which was considered as the very high level (Arnon, 2004, cited in Apiridee, 1999).

Improvement of physical properties and chemical properties of the soil from abandoned shrimp farm in the Ranoad soil serie by using *Polypheretima elongata* earthworms did not improve the abandoned shrimp farm soil to be at the level that met the standard criteria. Chemical properties of the soil improved in some aspects, particularly the organic components which were plant nutrients, i.e. CEC, phosphorus, and potassium. But the value of Na increased by the number of earthworms which caused the soil particles to disperse, when it contacted with water, the soil would be mushy and have the texture similar to starch paste and laminated at the soil surface. For soil with sodium content higher than 12%, when the soil dried, the structure of the soil would be broken, decreasing water infiltration and air ventilation of the soil (Bronick & Lal, 2005), and thus was the key cause for compaction and lack in structural improvement of the soil.

5.1.4 Growth rate and Survival rate of the earthworms

This study indicated that there were only 2 treatments in which the earthworms exhibited growth, the treatment added 20 and 30 earthworms with 10% rice straw manure as organic material (SW2O2 and SW2O3), which correlated with soil quality. The treatment added 30 earthworms with 10% rice straw manure (SW3O2) gave the highest soil chemical properties yield, which could be related to the activity of the earthworms. However, the earthworms in all treatments showed no increase in number, indicating that the condition of the abandoned shrimp farm soil was not suitable for the growth and proliferation of the *Polypheretima elongata* earthworms, and might relate to the increase in exchangeable sodium content in the soil, causing the earthworms to have homostasis of minerals in the body to be compatible with the external environment. In addition, the clay texture of the soil had compaction and bad water infiltration and ventilation, which were unsuitable environment for earthworm growth. However, this specie of earthworm could survival and endure soil salinity at exchangeable sodium range of 18.25-87.47 cmol/kg, which was the level that could be measured from the abandoned shrimp farm soil after the experimentation for 20 treatments.

5.1.5 Effect of type of organic material on survival rate and growth rate of the earthworms

Type of organic material had an effect on survival of the earthworms. At 5% organic material level, addition of dried rice straw caused the earthworms to have higher survival rate than addition of rice straw manure, which might relate to soil humidity as covering the soil with dried rice straw would allow the soil to hold moisture better than addition of rice straw manure. Although this study did not measure soil humidity, it could be visually observed that the soil added dried rice straw had higher humidity than the soil which added rice straw manure, and addition of dried rice straw also caused the earthworms to have lower growth rate than addition of rice straw manure.

At the 10% organic material level, addition of rice straw manure or dried rice straw caused no difference in the survival rate and growth rate of the earthworms.

5.1.6 Effect of the quantity of organic materials

Comparing among the dried rice straw treatments, addition of 10% dried rice straw caused the earthworms to have less growth retardation than addition of 5% dried rice straw, which indicated that addition of dried rice straw in higher quantity would be beneficial to the growth of the earthworms, even though the earthworms had no actual growth (the growth rates were negative).

Comparing among the rice straw manure treatments, it was found that addition of rice straw manure at 5% and 10% levels had no effect on difference in growth rates, but caused the earthworms to have different survival rates. In the treatments which added 20 earthworms, addition of 5% rice straw manure caused the earthworms to have higher survival rate than addition of 10% rice straw manure. Rice straw manure content of 10% might be too high for 10-30 *Polypheretima elongata* that were experimented over the period of 90 days. From all treatments which added 10% rice straw manure, whether 30, 20, or 10 earthworms were used, on the 90th day of the experiment, there was leftover manure on the topsoil.

5.2 Suggestions

1. The study could not be tested with MANOVA due to the limitation of number of replications and complications of the studied factors. Therefore, the number of replications should be increased, and design the experiment to be less complicated, e.g. studying each factor separately.

2. Experimentation in a shed with sunlight passing through during the day time had an effect on the activity of earthworms, a light-sensitive animal, as well as nitrogen decomposition. Therefore, the side of the experimental bottles should be covered with opaque materials, The analysis of nitrogen values should be made while the soil was still wet.

3. As the physical properties of the soil did not improve, thus the number of earthworms used in the experiment should be increased.

4. Water used in the study should be distilled or ion-free, as positively-charged ions could have an effect on changes in positive charges in the soil.

REFERENCES

กัญนัสม์ พาพล. (2548). ผลของสารปรับปรุงดินต่อคุณสมบัติของดินนากุ้งร้าง และการเติบโตของพืช. วิทยานิพนธ์วิทยาศาสตรมหาบัณฑิต มหาวิทยาลัยสงขลานครินทร์.

กรมพัฒนาที่ดิน. (2516). แผนที่ดินจังหวัดสงขลา ชุดแผนที่ดินจังหวัด ฉบับที่ 18. กองสำรวจดิน กรมพัฒนาที่ดิน กระทรวงเกษตรและสหกรณ์.

คณะสำรวจดิน กรมพัฒนาที่ดิน. (2524). รายงานการสำรวจดินจังหวัดสงขลา ฉบับที่ 156. กองสำรวจดิน กรมพัฒนาที่ดิน กระทรวงเกษตรและสหกรณ์.

กรมพัฒนาที่ดิน. (2544). วิธีการวิเคราะห์ดินทางเคมี. กรมพัฒนาที่ดิน กระทรวงเกษตรและสหกรณ์.

กรมพัฒนาที่ดิน. (2544). เอกสารคู่มือเจ้าหน้าที่ของรัฐเรื่องดินเค็ม. กรมพัฒนาที่ดิน กระทรวงเกษตรและสหกรณ์.

กรมพัฒนาที่ดิน. (2547). คู่มือการวิเคราะห์ตัวอย่าง ดิน น้ำ ปุ๋ย พืช วัสดุปรับปรุงดิน และการวิเคราะห์เพื่อตรวจรับรองมาตรฐานสินค้า เล่มที่ 2. สำนักวิทยาศาสตร์เพื่อการพัฒนาที่ดิน, กรุงเทพมหานคร.

กรมพัฒนาที่ดิน. (2548). คู่มือการวิเคราะห์ตัวอย่างดิน น้ำ ปุ๋ย พืช วัสดุปรับปรุงดิน และการวิเคราะห์เพื่อตรวจรับรองมาตรฐานสินค้า เล่ม 1. สำนักวิทยาศาสตร์เพื่อการพัฒนาที่ดิน, กรุงเทพมหานคร.

กรมพัฒนาที่ดิน. (2551). คู่มือการจัดการอินทรียวัตถุเพื่อปรับปรุงบำรุงดิน และเพิ่มความอุดมสมบูรณ์ของดิน. สำนักเทคโนโลยีชีวภาพทางดิน กรมพัฒนาที่ดิน กระทรวงเกษตรและสหกรณ์.

คณาจารย์ภาควิชาปฐพีวิทยา คณะเกษตร มหาวิทยาลัยเกษตรศาสตร์. 2544. คู่มือปฏิบัติการปฐพีวิทยาเบื้องต้น และวิทยาศาสตร์ทางดิน. คณะเกษตร มหาวิทยาลัยเกษตรศาสตร์, กรุงเทพมหานคร.

คณาจารย์ภาควิชาปฐพีวิทยา มหาวิทยาลัยเกษตรศาสตร์. 2548. ปฐพีวิทยาเบื้องต้น. สำนักพิมพ์มหาวิทยาลัยเกษตรศาสตร์, กรุงเทพมหานคร.

ประวิทย์ โตวัฒนะ, นิภา หลีระพันธ์, กัญจนัสม์ พาพล, สุชน คชาทอง และชูสิน วรเดช. (2548). รายงานโครงการวิจัยฉบับสมบูรณ์ โครงการฟื้นฟูพื้นที่นากุ้งร้างเพื่อปลูกพืชเศรษฐกิจ. มหาวิทยาลัยสงขลานครินทร์.

พัชรี ธีรจินดาขจร, อุบล หินเธาว์, พจนีย์ แสงมณี และสุรศักดิ์ เสรีพงศ์. (2550). การประเมินความอุดมสมบูรณ์ของดินโดยวิธีการวิเคราะห์ดิน. หจก. ขอนแก่นการพิมพ์, ขอนแก่น.

พิภพ ปราบณรงค์, ประวิทย์ โตวัฒนะ และสมศักดิ์ มณีพงศ์. (2537). ผลกระทบของการทำนากุ้งที่มีต่อสมบัติทางเคมีบางประการของทรัพยากรดินในอำเภอระโนด จังหวัดสงขลา. วารสารสงขลานครินทร์. 16(3): 425-436.

วิเชียร จฏุพจน์, อภินันท์ กำนัลรัตน์, นิภา หลีระพันธ์, ศักดิ์ดา โชโต และศักดิ์ชาย คงนคร. (2548). การใช้ประโยชน์ที่ดิน. รายงานฉบับสมบูรณ์โครงการจัดทำแผนแม่บทการพัฒนาลุ่มน้ำทะเลสาบสงขลา เล่มที่ 4. มหาวิทยาลัยสงขลานครินทร์ มหาวิทยาลัยทักษิณ และมหาวิทยาลัยราชภัฏสงขลา.

วุฒิชาติ สิริช่วยชู, ทรงวุฒิ หมื่นจบ และชัชวาล โชคบัณฑิต. (2534). รายงานการใช้ประโยชน์ที่ดินเพื่อการปลูกพืชเศรษฐกิจ จังหวัดสงขลา. กองสำรวจดิน กรมพัฒนาที่ดิน กระทรวงเกษตรและสหกรณ์.

สถาบันส่งเสริมการการสอนวิทยาศาสตร์และเทคโนโลยี. (มวป). เอกสารเผยแพร่การเรียนรู้เรื่องดินตามโครงการของ GLOBE. โครงการวิทยาศาสตร์และการศึกษาของ GLOBE.

สมศักดิ์ ปัญหา, Henrik Enghoff, Samuel James. (2550). ไส้เดือนและกิ้งกือ.โครงการพัฒนาองค์ความรู้และศึกษานโยบายการจัดการทรัพยากรชีวภาพในประเทศไทย. กรุงเทพมหานคร.

สมศักดิ์ มณีพงศ์, สายัณห์ สดุดี, เชาวน์ ยงเฉลิมชัย และอัจฉรา เพ็งหนู. (2542). ผลกระทบของการทำนากุ้งต่อทรัพยากรดิน และการบูรณะพื้นที่นากุ้งเสื่อมโทรมรวมทั้งพื้นที่ที่ได้รับผลกระทบจากเกลือเพื่อการเพาะปลูก. คณะทรัพยากรธรรมชาติ มหาวิทยาลัยสงขลานครินทร์.

สมศรี อรุณินท์. (2539). ดินเค็มในประเทศไทย. กรมพัฒนาที่ดิน, กรุงเทพมหานคร.

อานัฐ ตันโช. (2549). ไส้เดือนดิน. สำนักงานพัฒนาวิทยาศาสตร์และเทคโนโลยีแห่งชาติ, กรุงเทพมหานคร.

อานนท์ สุขสวัสดิ์. (2547). การประเมินความอุดมสมบูรณ์ของดินนา. โอเอส พริ้นติ้ง เฮ้าส์, กรุงเทพมหานคร.

อ้อมทิพย์ เด่นศรีเสรีกุล. (2547). การพัฒนาและฟื้นฟูดินที่ผ่านการทำนากุ้งร้างในทะเลสาบสงขลา. วิทยานิพนธ์วิทยาศาสตร์มหาบัณฑิต สาขาการจัดการทรัพยากรดิน มหาวิทยาลัยสงขลานครินทร์.

Aira, M. Monroy, F., Dominguez, J. (2003). Effects of two species earthworms (*Allolobophora* spp. On soil systems: a microfaunal and biochemical analysis. Pedobiologia, 47, 877-881.

Avnimelech, Y., and Ritvo, G. (2003). Shrimp and fish pond soils: process and management. Aquaculture, 220, 549-567.

Bhattachariee, G., and Chaudhuri, P.S. (2002). Cocoon production, morphology, hatching pattern and fecundity in seven tropical earthworm species–a laboratory-based investigation.. Journal of Biosciences, 27(3), 283-294.

Blanchart, E., Albrecht, A., Chevalliet, T., and Hartmann, C. (2004). The respective roles of roots and earthworms in restoring physical properties of Vertisol under a Digitaria decumbens pasture (Martinique, WI). Agricultural and Ecosystems Environment, 103, 343-355.

Bronick, C.J., Lal, R. (2005). Soil structure and management: a review. Geoderma, 124: 3-22.

Brossard, M., Lavelle, P., and Laurent J.Y. (1996). Digestion of a vertisol by the endogenic earthworm *Polypheretima elongata*, megascolocedae, increases soil phosphate extractability. European Journal Soil Bioogyl, 32(2), 107-111.

Mr & Mrs Smith (2010) Earthworms. Retrieved January 10, 2010, from Mr & Mrs Smith' s Life Science Website: http://www.smithlifescience.com/SciWormObservationNotes.htm.

Edwards, C.A. (1998). Earthworm Ecology. St. Lucies Press, Washington D.C.

FAO AGL. (2000). Land and plant nutrition management service global network on integrated soil management for sustainable use of salt-affected soil. Retrieved January 10, 2009, from FAO website: http://www.fao.org/AG/AGL/aglI/spush/topic2.htm.

Francis, GS, Fraser, PM. (1998). The effect of three earthworm species on soil macroporosity and hydraulic conductivity. Apply Soil Ecology, 10: 11-19.

Friend, J.J., Chan, K.Y. (1995) Influence of cropping on the population of a native earthworm and consequent effects on hydraulic properties of Vertisols Australian Journal of Soil Research, 33, 995-1006.

Gates, G.E. (1972.) Burmese Earthworms: An Introduction to the Systematics and Biology of Megadrile Oligochaetes with Special Reference to Southeast Asia. Transactions of the American Philosophical Society, Philadelphia.

Hezelton, P., & Murphy, B. (2007). Interpreting soil test results what do all the numbers mean? CSIRO Publishing, Collingwood.

Huerta, E., Fragoso, C., Barois, I. And Lavelle, P. (2005). Enhancement of growth and reproduction of the tropical earthworm *Polypheretima elongata* (Megascolecidae) by addition of *Zea mays* and *Mucuna pruriens* var. *utilis* litter to the soil. European Journal of Soil Biology,41(1-2), 45-53.

Sims, F.W. and Easton, E.G. (1972). A numerical revision of the earthworm genus Pheretima auct. (Megascolecidae: Oligochaeta with the recognition of new genera and an appendix on the earthworms collected by the Royal Society North Borneo Expendition. British Museum (Natural History), London.

John, A.W. (1983).Earthworm Biology. (The institude of Biology's Studies in Biology no. 161).The Camelot Press Ltd, Southampton.

Jury, W. and Horton, R. (2004). Soil Physics. Wiley, New York.

Katerina,D. and Darrell, L. N. (1999). Effects of exchangeable Ca:Mg ratio on soil clay flocculation, infiltration and erosion. In: D.E. Stotte, R.H. Mohtar and G.C. Steinhardt (eds) 2001. Sustaining the Global Farm, 580-585.

Keeney, D.R. and Nelson, D.W. (1982). Nitrogen-inorganic forms. In: A.L. Page, R.H. Miller and D.R. Keeney, Editors, Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties (second ed.), American Society of Agronomy–Soil Science Society of America, Madison, WI (1982), pp. 643–698.

Katrina, M. Miranda,1 Michael G. Espey, and David A. Wink (2001) A Rapid, Simple Spectrophotometric Method for Simultaneous Detection of Nitrate and Nitrite. NITRIC OXIDE: Biology and Chemistry. (Vol. 5), No. 1, pp. 62–71.

Landon, J.R. (1984). Booker Tropical Soil Manual, A hand book for soil survey and agricultural land evaluation in the tropics and subtropics. Booker Pitman Press Limited, Great Britain.

López-Hernández, D., Lavelle, P., Fardeau, JC., Niño, M. (1993). Phosphous transformations in two P-sorbtion contrasting tropical soil during transit through Pontoscolex corethrurus (Glossoscolecidae, Oligocheta). Soil Biology and Biochemistry, 25, 789-792.

Ranée-Claire, L.B. and Roxane, M. (2009) Effects of earthworms on phosphorus dynamics-A Review. Dynamic Soil, Dynamic Plant, (Special Issue 2), 21-27.

Rowell, D.L. (1994). Soil Science: Methods and Applications. Longman Group UK Limited, London. 350 p.

Shipitalo, M. J., and Bayon, R.L. (2004). Quantifying the effects of earthworms on soil aggregation and porosity. In Earthworm Ecology, Second Edition. Edited by Edwards, C.A., CRC press, New York & Washington, D.C., 183-199.

Pam, H. and Brain, M. (2007). Interpreting soil test results.CSIRO Publishing, Collingwood.

Towatana, P., Voradaj, C., and Panapitukkul N. (2002). Change in soil properties of abandone shrimp ponds in southern Thailand. Environmental Monitoring and Assessment, 74, 45-65.

Towatana, P., Voradaj, C., and Panapitukkul, N. (2003). Reclamation of Abandoned shrimp pond soils in southern Thailand for cultivation of Mauritius grass (Brachiaria mutica). Environmental Geochemistry and Health, 25, 365-386.

Wallwork, JA. (1983). Earthworm Biology. The Camelot Press, Southhampton.

Williem, J.J. G.M., Marinsissen, J.C.Y., and Blair, J. (1996). Effect of earthworm on nitrogen mineralization. Biology and Fertility Soil, 23 (1), 57-63.

APPENDICES

APPENDIX A

Table A-1 Descriptive Statistics of abandoned shrimp farm soil from 20 treatments.

Soil Properties	N	S-TYPE				SL_1-TYPE			
		Min	Max	Mean	SD.	Min	Max	Mean	SD.
Bulk Density	3	1.64	1.64	1.6400	.00000	1.71	1.92	1.8500	.12124
Particle Density	3	2.03	2.09	2.0521	.02977	2.04	2.16	2.1005	.05875
Porosity	3	19.28	21.39	20.0691	1.15044	6.02	18.49	11.8818	6.26948
pH	3	8.02	8.34	8.1767	.16010	7.93	8.24	8.0667	.15822
ECe	3	.09	.11	.1004	.00970	.16	.19	.1808	.01709
SAR	3	1.04	1.48	1.1944	.24346	1.13	1.38	1.2929	.13941
CEC	3	87.68	92.85	90.2580	2.58602	99.35	109.52	105.0653	5.20027
ESP	3	43.62	46.58	45.3576	1.54662	46.64	49.26	47.9991	1.31244
% OC	3	.15	.37	.2753	.11465	.18	.39	.3108	.11387
% OM	3	.25	.63	.4746	.19765	.31	.67	.5358	.19631
Na	3	40.50	41.40	40.9133	.45446	48.94	51.14	50.3867	1.25321
NH4	3	13.44	14.11	13.6734	.38170	14.21	17.23	15.4709	1.56832
NO3	3	7.10	7.73	7.4277	.31525	2.52	3.34	2.9227	.40910
Total Nitrogen	3	.03	.03	.0295	.00022	.02	.03	.0258	.00184
Phosphorus	3	2.60	3.14	2.8455	.27658	3.33	5.01	3.8873	.97312
Potassium	3	454.76	515.54	480.3467	31.51098	600.73	880.68	726.4357	142.1437
%Clay	3	57.53	57.53	57.5320	.00000	57.39	57.39	57.3880	.00000
%Silt	3	39.03	39.03	39.0280	.00000	42.14	42.14	42.1440	.00000
%Sand	3	3.44	3.44	3.4400	.00000	.47	.47	.4680	.00000
Texture	3	1.00	1.00	1.0000	.00000	2.00	2.00	2.0000	.00000
Mg^{2+}	3	15.84	19.87	18.01	2.03	15.27	19.27	17.92	2.29
Ca^{2+}	3	3.91	4.18	4.03	0.14	5.15	5.66	5.40	0.25
Mg : Ca	3	-	-	4.47	-	-	-	3.32	-
Survival	3	.00	.00	.0000	.00000	.00	.00	.0000	.00000
Average daily growth rate	3	.0000	.0000	.000000	.0000000	.0000	.0000	.000000	.000000

Table A-1 Descriptive Statistics of abandoned shrimp farm soil from 20 treatments. (continued)

Soil Properties	N	SL_2-TYPE				SO_1-TYPE			
		Min	**Max**	**Mean**	**SD.**	**Min**	**Max**	**Mean**	**SD.**
Bulk Density	3	1.53	1.65	1.5900	.06000	1.44	1.77	1.6033	.16503
Particle Density	3	2.07	2.09	2.0786	.01260	2.11	2.18	2.1489	.03607
Porosity	3	20.31	26.17	23.5033	2.96682	16.10	33.97	25.2885	8.94312
pH	3	8.45	8.64	8.5733	.10693	7.90	8.60	8.1867	.36679
ECe	3	.01	.09	.0566	.03944	.16	.16	.1572	.00040
SAR	3	1.14	1.31	1.2409	.08833	1.35	1.72	1.4849	.20534
CEC	3	127.95	135.58	131.4753	3.84587	136.26	140.13	137.7620	2.07276
ESP	3	49.32	54.13	51.2805	2.52958	31.83	33.98	32.7945	1.09116
% OC	3	.41	.51	.4484	.05664	.40	.65	.5106	.12501
% OM	3	.70	.88	.7731	.09765	.69	1.11	.8803	.21552
Na	3	63.10	70.86	67.4267	3.95638	43.58	46.30	45.1733	1.41878
NH4	3	16.08	17.25	16.8364	.65819	16.11	17.80	16.7758	.90105
NO3	3	4.33	5.16	4.6276	.46542	25.90	31.81	29.2842	3.04848
Total Nitrogen	3	.03	.03	.0300	.00142	.06	.07	.0645	.00491
Phosphorus	3	3.69	4.33	4.0391	.32319	71.71	81.81	76.6826	5.05820
Potassium	3	969.86	1144.22	1059.188	87.26024	609.60	657.08	630.6030	24.20476
%Clay	3	57.53	57.53	57.5320	.0000	54.42	54.42	54.4160	.00000
%Silt	3	41.93	41.93	41.9280	.0000	41.93	41.93	41.9280	.00000
%Sand	3	.54	.54	.5400	.0000	3.66	3.66	3.6560	.00000
Texture	3	2.00	2.00	2.0000	.0000	2.00	2.00	2.0000	.00000
Mg^{2+}	3	14.95	18.22	16.92	1.73	16.86	21.02	19.49	2.29
Ca^{2+}	3	5.45	4.91	5.17	0.27	5.79	5.90	5.86	0.06
Mg : Ca	3	-	-	3.27	-	-	-	3.32	-
Survival	3	.00	.00	.0000	.0000	.00	.00	.0000	.00000
Average daily growth rate	3	.0000	.0000	.0000	.000000	.0000	.0000	.000000	.0000000

Table A-1 Descriptive Statistics of abandoned shrimp farm soil from 20 treatments. (continued)

Soil Properties	N	SO_2-TYPE				SW_1-TYPE			
		Min	Max	Mean	SD.	Min	Max	Mean	SD.
Bulk Density	3	1.43	1.59	1.5000	.08185	1.53	1.59	1.5700	.03464
Particle Density	3	2.09	2.17	2.1348	.03872	1.96	2.12	2.0643	.08729
Porosity	3	25.70	31.82	29.7416	3.49879	22.09	25.05	23.9016	1.58589
pH	3	7.75	7.94	7.8533	.09609	8.27	8.42	8.3233	.08386
ECe	3	.24	.24	.2380	.00000	.08	.23	.1420	.08044
SAR	3	1.64	1.64	1.6409	.00163	.75	1.56	1.2102	.42061
CEC	3	99.62	113.71	108.9647	8.09309	100.83	102.35	101.7620	.81380
ESP	3	32.41	36.28	33.9046	2.07886	36.79	38.04	37.4818	.63772
% OC	3	.20	.75	.4573	.27438	.38	.44	.3996	.03461
% OM	3	.34	1.29	.7884	.47304	.67	.71	.6927	.02390
Na	3	36.14	37.56	36.8333	.71059	37.56	38.50	38.1400	.50715
NH4	3	20.00	22.64	21.3139	1.31712	12.49	14.64	13.7468	1.12352
NO3	3	57.53	58.94	58.1990	.71099	22.44	26.98	24.9554	2.30930
Total Nitrogen	3	.11	.11	.1113	.00243	.05	.06	.0542	.00463
Phosphorus	3	61.68	67.00	65.0934	2.96271	3.19	6.01	4.4187	1.44701
Potassium	3	767.11	776.42	770.9506	4.86691	368.25	372.68	371.0560	2.44354
%Clay	3	57.53	57.53	57.5320	.00000	60.86	60.86	60.8640	.00000
%Silt	3	41.64	41.64	41.6400	.00000	39.03	39.03	39.0280	.00000
%Sand	3	.83	.83	.8280	.00000	.11	.11	.1080	.00000
Texture	3	2.00	2.00	2.0000	.00000	1.00	1.00	1.0000	.00000
Mg^{2+}	3	16.85	21.02	19.20	2.14	21.00	21.43	19.28	3.37
Ca^{2+}	3	6.16	6.97	6.24	0.69	5.55	5.90	5.72	0.17
Mg : Ca	3	-	-	3.08	-	-	-	3.37	-
Survival	3	.00	.00	.0000	.00000	20.00	40.00	26.6667	11.54701
Average daily growth rate	3	.0000	.0000	.000000	.0000000	-.0093	-.0030	-.005500	.0033186

Table A-1 Descriptive Statistics of abandoned shrimp farm soil from 20 treatments. (continued)

Soil Properties	N	SW_2-TYPE				SW_3-TYPE			
		Min	Max	Mean	SD.	Min	Max	Mean	SD.
Bulk Density	3	1.37	1.75	1.5633	.19009	1.64	1.80	1.7033	.08505
Particle Density	3	2.09	2.18	2.1419	.04326	2.089	2.466	2.24937	.194726
Porosity	3	16.46	36.31	26.9168	9.96975	13.82	33.49	23.7269	9.83890
pH	3	7.01	8.27	7.5900	.63592	7.61	7.88	7.7633	.13868
ECe	3	.15	.21	.1713	.03312	.19	.23	.2087	.02272
SAR	3	.74	1.43	1.0885	.34448	1.04	1.30	1.2015	.14019
CEC	3	107.44	113.30	111.1093	3.20084	121.70	130.53	126.0127	4.41884
ESP	3	36.96	39.09	37.7155	1.19464	37.65	42.69	40.0131	2.53801
% OC	3	.03	.39	.1798	.18884	.21	.23	.2198	.00154
% OM	3	.06	.68	.3100	.32557	.36	.39	.3789	.01989
Na	3	41.76	42.00	41.8800	.12000	47.36	51.96	50.3800	2.61633
NH4	3	16.41	17.42	16.8758	.50760	22.73	25.75	24.5546	1.60208
NO3	3	57.53	58.40	58.1026	.49814	58.72	59.04	58.9038	.16328
Total Nitrogen	3	.10	.11	.1050	.00026	.11	.12	.1168	.00217
Phosphorus	3	4.74	5.79	5.4209	.59220	2.69	4.24	3.5988	.80979
Potassium	3	390.43	395.75	392.6480	2.77072	509.78	538.21	526.6476	14.94047
%Clay	3	60.86	60.86	60.8640	.00000	57.75	62.600	62.600	.00000
%Silt	3	39.03	39.03	39.0280	.00000	32.48	42.18	37.3300	.00000
%Sand	3	.11	.11	.1080	.00000	9.78	9.78	0.0800	.00000
Texture	3	1.00	1.00	1.0000	.00000	1.00	1.00	1.0000	.00000
Mg^{2+}	3	15.92	20.60	18.60	2.41	15.89	19.62	17.78	1.90
Ca^{2+}	3	4.87	6.75	5.59	1.01	4.22	6.07	4.78	1.12
Mg : Ca	3	-	-	3.33	-	-	-	3.76	-
Survival	3	35.00	85.00	56.6667	25.65801	60.00	85.00	70.5556	12.94576
Average daily growth rate	3	-.01	-.01	-.0104	.00461	-.0086	-.0052	-.006959	.0016820

Table A-1 Descriptive Statistics of abandoned shrimp farm soil from 20 treatments. (continued)

Soil Properties	N	SW_1L_1-TYPE				SW_2L_1-TYPE			
		Min	Max	Mean	SD.	Min	Max	Mean	SD.
Bulk Density	3	1.65	2.01	1.8267	.18009	1.54	1.63	1.5867	.04509
Particle Density	3	1.95	2.11	2.0101	.08378	2.11	2.15	2.1314	.02263
Porosity	3	13.58	15.47	14.8322	1.08213	24.19	26.88	25.5655	1.34753
pH	3	8.18	8.65	8.4167	.23502	8.09	8.40	8.2867	.17098
ECe	3	.16	.23	.1910	.03627	.21	.21	.2100	.00000
SAR	3	.92	1.75	1.3435	.41656	1.15	1.30	1.2011	.08134
CEC	3	103.20	109.18	106.5427	3.05043	111.49	116.88	113.4667	2.96526
ESP	3	51.35	54.28	52.8884	1.47337	49.09	52.01	50.0696	1.67664
% OC	3	.25	.33	.2886	.04069	.21	.58	.3707	.19040
% OM	3	.44	.57	.4975	.07016	.36	.56	.4728	.10589
Na	3	56.02	56.88	56.3200	.48539	55.00	57.98	56.7933	1.57992
NH4	3	12.39	17.18	15.3592	2.59329	20.73	21.73	21.2845	.50792
NO3	3	6.38	7.12	6.7979	.37845	8.41	8.61	8.5434	.11318
Total Nitrogen	3	.03	.03	.0310	.00348	.04	.04	.0418	.00069
Phosphorus	3	2.32	3.60	2.9762	.63830	3.19	4.69	4.0391	.77084
Potassium	3	701.44	737.38	717.5623	18.25169	858.95	962.32	903.1642	53.28167
%Clay	3	54.56	54.56	54.5600	.00000	53.04	53.04	53.0360	.00000
%Silt	3	44.25	44.25	44.2520	.00000	46.42	46.42	46.4240	.00000
%Sand	3	1.19	1.19	1.1880	.00000	.54	.54	.5400	.00000
Texture	3	2.00	2.00	2.0000	.00000	2.00	2.00	2.0000	.00000
Mg^{2+}	3	15.10	19.16	17.65	2.22	15.26	19.38	17.83	2.24
Ca^{2+}	3	5.09	5.75	5.15	0.37	4.99	5.24	5.13	0.12
Mg : Ca	3	-	-	3.20	-	-	-	3.48	-
Survival	3	70.00	90.00	80.0000	10.00000	35.00	90.00	56.6667	29.29733
Average daily growth rate	3	-.0129	-.0069	-.009402	.0031312	-.0054	.0026	-.001972	.0041525

Table A-1 Descriptive Statistics of abandoned shrimp farm soil from 20 treatments. (continued)

Soil Properties	N	SW_3L_1-TYPE				SW_1L_2-TYPE			
		Min	Max	Mean	SD.	Min	Max	Mean	SD.
Bulk Density	3	1.01	1.37	1.1300	.20785	1.18	1.68	1.4267	.25007
Particle Density	3	2.12	2.23	2.1792	.05441	2.02	2.05	2.0285	.01430
Porosity	3	37.40	54.68	48.1501	9.38099	16.84	42.30	29.6172	12.72868
pH	3	7.74	8.08	7.9267	.17243	7.79	8.59	8.3067	.44814
ECe	3	.15	.19	.1707	.02148	.05	.19	.1196	.07051
SAR	3	.91	1.12	.9875	.11623	1.31	1.36	1.3431	.02755
CEC	3	115.12	126.14	120.8513	5.52381	103.65	105.21	104.4573	.77834
ESP	3	46.28	51.79	48.3879	2.97478	35.68	41.19	38.2413	2.77953
% OC	3	.25	.47	.3397	.11707	.29	.36	.3175	.03668
% OM	3	.44	.82	.5856	.20183	.51	.62	.5473	.06324
Na	3	57.12	59.62	58.3733	1.25001	36.98	43.34	39.9600	3.19881
NH4	3	23.18	24.75	23.7149	.89324	18.18	20.96	19.8139	1.45026
NO3	3	9.45	10.42	9.8713	.49660	8.16	8.64	8.4621	.26445
Total Nitrogen	3	.05	.05	.0470	.00192	.04	.04	.0396	.00238
Phosphorus	3	4.28	4.28	4.2821	.00000	2.96	3.01	2.9762	.02630
Potassium	3	1248.49	1476.98	1354.820	115.0640	1062.15	1317.26	1174.690	130.1779
%Clay	3	58.32	58.32	58.3240	.00000	57.39	57.39	57.3880	.00000
%Silt	3	41.21	41.21	41.2080	.00000	42.14	42.14	42.1440	.00000
%Sand	3	.47	.47	.4680	.00000	.47	.47	.4680	.00000
Texture	3	2.00	2.00	2.00000	.00000	2.00	2.00	2.0000	.00000
Mg^{2+}	3	17.76	20.28	17.73	2.55	14.78	19.22	17.59	2.44
Ca^{2+}	3	4.81	5.14	4.96	0.17	4.76	5.14	4.93	0.19
Mg : Ca	3	-	-	3.58	-	-	-	3.57	-
Survival	3	30.00	63.33	48.8889	17.10534	70.00	100.00	83.3333	15.27525
Average daily growth rate	3	-.0099	-.0035	-.006381	.0032488	-.0056	-.0033	-.004728	.0012207

Table A-1 Descriptive Statistics of abandoned shrimp farm soil from 20 treatments. (continued)

Soil Properties	N	SW_2L_2-TYPE				SW_3L_2-TYPE			
		Min	Max	Mean	SD.	Min	Max	Mean	SD.
Bulk Density	3	1.66	1.76	1.7133	.05033	1.47	1.56	1.5300	.05196
Particle Density	3	2.01	2.19	2.1205	.09579	2.10	2.32	2.2032	.11359
Porosity	3	14.45	24.07	19.0719	4.81777	25.62	32.85	30.4385	4.17618
pH	3	8.44	8.59	8.5000	.07937	8.16	8.33	8.2433	.08505
ECe	3	.11	.18	.1394	.03990	.14	.19	.1609	.03021
SAR	3	1.01	1.29	1.1253	.14875	1.10	1.78	1.3413	.37831
CEC	3	83.15	90.39	87.4573	3.80816	143.75	152.29	146.6447	4.88788
ESP	3	19.18	22.37	20.8580	1.59909	58.14	62.02	59.6608	2.06711
% OC	3	.37	.47	.4285	.05087	.51	.53	.5173	.01017
% OM	3	.64	.82	.7387	.08769	.87	.91	.8918	.01754
Na	3	17.04	20.22	18.2467	1.72306	83.58	89.58	87.4667	3.37024
NH4	3	23.26	23.98	23.6612	.36662	25.01	27.05	26.2557	1.08969
NO3	3	13.16	15.60	14.7719	1.39371	17.19	18.23	17.6829	.52365
Total Nitrogen	3	.05	.06	.0538	.00160	.06	.06	.0615	.00100
Phosphorus	3	2.82	4.92	4.2062	1.19689	3.92	5.01	4.2821	.63121
Potassium	3	995.15	1035.97	1019.997	21.80763	936.14	1114.94	1024.878	89.40694
%Clay	3	58.25	58.25	58.2520	.00000	59.06	59.06	59.0560	.00000
%Silt	3	41.21	41.21	41.2080	.00000	40.48	40.48	40.4760	.00000
%Sand	3	.54	.54	.5400	.00000	.47	.47	.4680	.00000
Texture	3	2.00	2.00	2.0000	.00000	2.00	2.00	2.0000	.00000
Mg^{2+}	3	15.36	18.33	17.25	1.64	15.89	19.24	17.94	1.80
Ca^{2+}	3	5.58	5.85	5.73	0.14	5.40	5.79	5.59	0.19
Mg : Ca	3	-	-	3.01	-	-	-	3.21	-
Initial weight	3	1.41	1.70	1.5187	.15755	.61	1.19	.9758	.31843
Final weight	3	.79	1.30	1.0192	.25859	.04	.78	.4703	.38332
Initial earthworm	3	20.00	20.00	20.0000	.00000	30.00	30.00	30.0000	.00000
Final earthworm	3	5.00	12.00	9.3333	3.78594	4.00	18.00	13.3333	8.08290
Survival	3	25.00	60.00	46.6667	18.92969	13.33	60.00	44.4444	26.94301
Average daily growth rate	3	-.0082	-.0016	-.005549	.0034737	-.0066	-.0039	-.005617	.0014884

Table A-1 Descriptive Statistics of abandoned shrimp farm soil from 20 treatments. (continued)

Soil Properties	N	SW_1O_1-TYPE				SW_2O_1-TYPE			
		Min	Max	Mean	SD.	Min	Max	Mean	SD.
Bulk Density	3	1.62	1.62	1.6200	.00000	1	2	1.59	.110
Particle Density	3	1.90	2.08	1.9600	.10408	1.99	2.07	2.0274	.04163
Porosity	3	14.73	22.12	17.1966	4.26632	14.52	26.80	21.5230	6.31668
pH	3	8.18	8.23	8.2033	.02517	8.21	8.30	8.2433	.04933
ECe	3	.08	.15	.1234	.03674	.10	.17	.1367	.03491
SAR	3	1.15	1.29	1.2040	.07649	1.29	1.81	1.5555	.25777
CEC	3	98.17	107.35	103.2253	4.65894	148.21	159.06	152.2407	5.93546
ESP	3	23.89	30.40	26.5031	3.43681	41.92	43.82	43.1111	1.03441
% OC	3	.31	1.01	.6564	.35088	.83	.95	.8947	.06188
% OM	3	.54	1.75	1.1316	.60491	1.42	1.63	1.5424	.10668
Na	3	24.88	29.84	27.2667	2.48526	62.66	69.70	65.6533	3.63628
NH4	3	13.30	16.60	15.2794	1.74683	18.14	18.81	18.3924	.36264
NO3	3	22.94	30.55	26.1823	3.92687	58.30	58.40	58.3586	.05493
Total Nitrogen	3	.05	.07	.0580	.00718	.11	.11	.1075	.00056
Phosphorus	3	166.64	195.24	179.0576	14.67103	148.28	192.24	172.4523	22.30594
Potassium	3	685.03	704.10	697.4492	10.76757	788.40	838.98	812.9513	25.32160
%Clay	3	53.04	53.04	53.0360	.00000	54.92	54.92	54.9200	.00000
%Silt	3	42.90	42.90	42.9040	.00000	44.61	44.61	44.6120	.00000
%Sand	3	4.06	4.06	4.0600	.00000	.47	.47	.4680	.00000
Texture	3	2.00	2.00	2.0000	.00000	2.00	2.00	2.0000	.00000
Mg^{2+}	3	16.12	21.05	18.96	2.55	16.55	20.32	18.99	2.11
Ca^{2+}	3	6.42	6.44	6.43	0.11	6.09	7.53	6.61	0.80
Mg : Ca	3	-	-	2.95	-	-	-	2.87	-
Initial weight	3	1.67	2.27	2.0003	.30584	1.75	2.07	1.9368	.16472
Final weight	3	.53	1.97	1.0606	.78870	.99	1.08	1.0359	.04514
Initial earthworm	3	10.00	10.00	10.0000	.00000	20.00	20.00	20.0000	.00000
Final earthworm	3	5.00	6.00	5.6667	.57735	16.00	20.00	17.3333	2.30940
Survival	3	50.00	60.00	56.6667	5.77350	80.00	100.00	86.6667	11.54701
Average daily growth rate	3	-.0175	-.0011	-.010442	.0084236	-.0115	-.0084	-.010011	.0015512

Table A-1 Descriptive Statistics of abandoned shrimp farm soil from 20 treatments. (continued)

Soil Properties	N	SW_3O_1-TYPE				SW_1O_2-TYPE			
		Min	Max	Mean	SD.	Min	Max	Mean	SD.
Bulk Density	3	1.21	1.70	1.4933	.25384	1.38	1.69	1.5500	.15716
Particle Density	3	2.07	2.17	2.1163	.05141	2.12	2.18	2.1521	.03398
Porosity	3	21.78	42.43	29.5026	11.26308	21.58	36.83	27.9231	7.93923
pH	3	7.77	7.95	7.8533	.09074	7.66	8.06	7.8433	.20207
ECe	3	.19	.24	.2073	.03179	.22	.27	.2430	.02390
SAR	3	1.10	1.69	1.3548	.30462	.91	1.63	1.2134	.37701
CEC	3	143.37	156.29	150.3833	6.52924	111.12	129.35	121.4407	9.35116
ESP	3	43.13	47.58	44.8068	2.42211	37.08	42.19	39.3408	2.60517
% OC	3	.56	1.00	.7792	.21978	.41	.91	.7015	.26189
% OM	3	1.38	1.71	1.5654	.17043	.70	1.56	1.2094	.45151
Na	3	66.22	68.22	67.28	1.00539	46.88	48.00	47.6133	.63540
NH4	3	21.20	22.54	21.8726	.67050	20.77	21.92	21.3298	.57538
NO3	3	57.53	58.76	58.3387	.70282	45.79	58.13	53.4613	6.69671
Total Nitrogen	3	.11	.11	.1123	.00185	.09	.11	.1047	.01..0
Phosphorus	3	110.51	175.88	153.6536	37.36586	86.46	120.13	98.1841	19.01705
Potassium	3	763.11	930.38	850.6633	83.90682	644.21	684.58	658.8500	22.35586
%Clay	3	54.20	54.20	54.2000	.00000	54.92	54.92	54.9200	.00000
%Silt	3	44.97	44.97	44.9720	.00000	44.61	44.61	44.6120	.00000
%Sand	3	.83	.83	.8280	.00000	.47	.47	.4680	.00000
Texture	3	2.00	2.00	2.0000	.00000	2.00	2.00	2.0000	.00000
Mg^{2+}	3	16.91	21.24	19.73	2.44	16.88	20.34	18.87	1.79
Ca^{2+}	3	6.99	7.48	7.27	0.25	6.19	7.53	6.77	0.69
Mg : Ca	3	-	-	2.71	-	-	-	2.79	-
Initial weight	3	.69	1.18	.9418	.24470	1.26	1.79	1.4427	.30182
Final weight	3	.29	1.32	.6778	.55893	.09	1.08	.7313	.55780
Initial earthworm	3	30.00	30.00	30.0000	.00000	10.00	10.00	10.0000	.00000
Final earthworm	3	7.00	19.00	12.3333	6.11010	1.00	8.00	5.3333	3.78594
Survival	3	23.33	63.33	41.1111	20.36700	10.00	90.00	56.6667	41.63332
Average daily growth rate	3	-.0073	.0015	-.002933	.0043993	-.0189	-.0022	-.007904	.0095443

Table A-1 Descriptive Statistics of abandoned shrimp farm soil from 20 treatments. (continued)

Soil Properties	N	SW_2O_2-TYPE				SW_3O_2-TYPE			
		Min	Max	Mean	SD.	Min	Max	Mean	SD.
Bulk Density	3	1.42	1.88	1.5933	.25007	1.80	1.80	1.80000	.00000
Particle Density	3	2.05	2.12	2.0799	.03583	1.89	2.08	2.0132	.11040
Porosity	3	8.40	33.03	23.2761	13.08955	4.55	43.47	10.4058	5.07324
pH	3	7.70	8.03	7.8733	.16563	7.72	7.98	7.8400	.13115
ECe	3	.13	.24	.1843	.05606	.17	.19	.1764	.00963
SAR	3	.73	1.32	1.1139	.33009	1.33	1.59	1.4152	.15064
CEC	3	105.29	116.66	110.6167	5.71954	94.91	100.04	96.9293	2.73392
ESP	3	33.00	43.55	36.9585	5.74814	36.79	49.94	45.4594	6.77125
% OC	3	.47	1.68	1.1877	.63958	.61	.77	.6815	.08029
% OM	3	.80	2.90	2.0476	1.10264	1.04	1.32	1.1734	.14071
Na	3	36.14	47.86	40.8333	6.19862	36.80	47.86	41.0533	5.95571
NH4	3	23.84	24.32	24.0131	.26267	24.75	28.67	26.2628	2.11072
NO3	3	58.30	58.40	58.3586	.05493	58.06	59.04	58.4650	.51509
Total Nitrogen	3	.12	.12	.1153	.00029	.12	.12	.1186	.00273
Phosphorus	3	85.60	331.18	196.0189	124.6454	101.54	11.79	104.9564	5.91764
Potassium	3	1039.96	1127.81	1085.069	43.97111	1088.77	1108.29	1099.710	9.97353
%Clay	3	54.04	54.04	54.0440	.00000	54.20	54.20	54.2000	.00000
%Silt	3	42.73	42.73	42.7320	.00000	45.40	45.40	45.4040	.00000
%Sand	3	3.22	3.22	3.2240	.00000	.40	.40	.3960	.00000
Texture	3	2.00	2.00	2.0000	.00000	2.00	2.00	2.0000	.00000
Mg^{2+}	3	14.99	21.94	19.02	3.98	16.54	20.56	19.28	2.38
Ca^{2+}	3	6.02	6.36	6.18	0.17	6.12	6.23	5.93	0.42
Mg : Ca	3	-	-	3.03	-	-	-	3.25	-
Initial weight	3	.88	1.32	1.0912	.21654	.66	1.00	.7834	.18582
Final weight	3	.33	1.06	.6996	.36353	.16	4.82	1.8847	2.55885
Initial earthworm	3	20.00	20.00	20.0000	.00000	30.00	30.00	30.0000	.00000
Final earthworm	3	12.00	18.00	14.6667	3.05505	2.00	10.00	6.6667	4.16333
Survival	3	26.67	70.00	52.2222	22.68953	6.67	33.33	15.5556	15.39601
Average daily growth rate	3	-.0083	.0019	-.004351	.0054800	-.0093	.0459	.012237	.0295259

Table A-2 Analysis results of MS and F-ratios from one way ANOVA for the influence of earthworm numbers on soil physical properties in the treatments added 10 earthworms (SW_1), 20 earthworms (SW_2), 30 earthworms (SW_3), and Control (S) after 90 days experiment.

Sources		Sum of Squares	df	Mean Square	F	Sig.
Bulk density	Between Groups	0.039	3	0.013	1.172	0.379
	Within Groups	0.089	8	0.011		
	Total	0.128	11			
Particle density	Between Groups	0.074	3	0.025	2.049	0.186
	Within Groups	0.097	8	0.012		
	Total	0.171	11			
Porosity	Between Groups	70.691	3	23.564	0.471	0.771
	Within Groups	400.077	8	50.010		
	Total	470.767	11			
Clay	Between Groups	31.253	3	10.418	.	.
	Within Groups	0.000	8	0.000		
	Total	31.253	11			
Silt	Between Groups	96.590	3	32.197	.	.
	Within Groups	0.000	8	0.000		
	Total	96.590	11			
Sand	Between Groups	186.967	3	62.322	.	.
	Within Groups	0.000	8	0.000		
	Total	186.967	11			

Remark: F-values were determined separately due to the homogeneity of variance of the data.

Table A-3 Analysis results of MS and F-ratios from one way ANOVA for the influence of earthworm numbers on soil chemical properties in the treatments added 10 earthworms (SW_1), 20 earthworms (SW_2), 30 earthworms (SW_3), and Control (S) after 90 days experiment.

Sources		Sum of Squares	df	Mean Square	F	Sig.
CEC	Between Groups	2057.320	3	685.773	73.895	.000
	Within Groups	74.243	8	9.280		
	Total	2131.562	11			
ESP	Between Groups	120.551	3	40.184	15.068	.001
	Within Groups	21.335	8	2.667		
	Total	141.886	11			
Na	Between Groups	250.724	3	83.575	45.648	.000
	Within Groups	14.647	8	1.831		
	Total	265.371	11			
NH_4-N	Between Groups	235.669	3	78.556	74.244	.000
	Within Groups	8.465	8	1.058		
	Total	244.133	11			
NO_3-N	Between Groups	5832.625	3	1944.208	1362.671	.000
	Within Groups	11.414	8	1.427		
	Total	5844.040	11			
Total-N	Between Groups	.015	3	.005	782.540	.000
	Within Groups	.000	8	.000		
	Total	.015	11			
Phosphorus	Between Groups	11.005	3	3.668	4.619	.037
	Within Groups	6.354	8	.794		
	Total	17.358	11			
Potassium	Between Groups	48307.616	3	16102.539	52.374	.000
	Within Groups	2459.615	8	307.452		
	Total	50767.231	11			

Remark: The significant level (0.05*) of F-values were determine separately due to the homogeneity of variance of the data. Table showed only significant value at the statistic significant level.

Table A-4 Analysis results of mean difference of CEC from Multiple comparison test by the way of Scheffe's test in treatments added 10 earthworms (SW_1), 20 earthworms (SW_2), 30 earthworms (SW_3), and Control (S).

Sources	Mean	S	SW_1	SW_2	SW_3
S	90.2580		-11.5040	-20.8513	-35.7547*
SW_1	101.7260	11.5040*		-9.3473*	-24.2507*
SW_2	111.1093	20.8513*	9.3473*		-14.90333*
SW_3	126.0127	35.7547*	24.2507*	14.9033*	

Remark: Significant difference , at the (0.05*)

Table A-5 Analysis results of mean difference of ESP from Multiple comparison test by the way of Scheffe's test in treatments added 10 earthworms (SW_1), 20 earthworms (SW_2), 30 earthworms (SW_3), and Control (S).

Sources	Mean	SW_1	SW_2	SW_3	S
S	45.3576	7.8758*	7.6421*	5.3445*	
SW_1	37.4818		-0.2337	-2.5313	-7.8758*
SW_2	37.7155	0.2337		-2.2976	-7.6421*
SW_3	40.0131	2.5313	2.2976		-5.3445*

Remark: Significant difference , at the (0.05*)

Table A-6 Analysis results of mean difference of Na from Multiple test comparison by the way of Scheffe's test in treatments added 10 earthworms (SW_1), 20 earthworms (SW_2), 30 earthworms (SW_3), and Control (S).

Sources	Mean	S	SW_1	SW_2	SW_3
S	40.9133		2.7733	-0.9667	-9.4667*
SW_1	38.1400	-2.7733		-3.7400	-12.2400*
SW_2	41.8800	0.9667	3.7400		-8.500*
SW_3	50.3800	9.4667*	12.2400*	8.5000*	

Remark: Significant difference , at the (0.05*)

Table A-7 Analysis results of mean difference of NH_4-N from Multiple comparison test by the way of Scheffe's test in treatments added 10 earthworms (SW_1), 20 earthworms (SW_2), 30 earthworms (SW_3), and Control (S).

Sources	Mean	S	SW_1	SW_2	SW_3
S	13.6734		-0.0734	-3.2024	-10.8812
SW_1	13.7468	0.0734		-3.1290*	-10.8078*
SW_2	16.8758	3.2024*	3.1290*		-7.6788*
SW_3	24.5546	10.8812*	10.8078*	7.6788*	

Remark: Significant difference , at the (0.05*)

Table A-8 Analysis results of mean difference of NH_4-N from Multiple comparison test by the way of Scheffe's test in treatments added 10 earthworms (SW_1), 20 earthworms (SW_2), 30 earthworms (SW_3), and Control (S).

Sources	Mean	S	SW_1	SW_2	SW_3
S	7.4277		-17.5278	-50.6749	-51.4762
SW_1	24.9554	17.5278		-33.1472	-33.9484
SW_2	58.1036	50.6749*	33.1472*		-0.8013
SW_3	58.9038	51.4762*	33.9484*	0.8013	

Remark: Significant difference , at the (0.05*)

Table A-9 Analysis results of mean difference of Total- Nitrogen from Multiple comparison test by the way of Scheffe's test in treatments added 10 earthworms (SW_1), 20 earthworms (SW_2), 30 earthworms (SW_3), and Control (S).

Sources	Mean	S	SW_1	SW_2	SW_3
S	0.02954		-0.02464*	-0.07543*	-0.08730*
SW_1	0.05418	0.02464*		-0.05079*	-0.06266*
SW_2	0.10497	0.07543*	0.05079*		-0.01187*
SW_3	0.11684	0.08730*	0.06266*	0.01187*	

Remark: Significant difference , at the (0.05*)

Table A-10 Analysis results of mean difference of Phosphorus (P) from Multiple comparison test by the way of Scheffe's test in treatments added 10 earthworms (SW_1), 20 earthworms (SW_2), 30 earthworms (SW_3), and Control (S).

Sources	Mean	S	SW_1	SW_2	SW_3
S	2.8455		-1.5733	-2.5755*	-0.7533
SW_1	4.4187	1.5733		-1.0022	0.8200
SW_2	5.4209	2.5755*	1.0022		1.8222
SW_3	3.5988	0.7533	-0.8200	-1.8222	

Remark: Significant difference , at the (0.05*)

Table A-11 Analysis results of mean difference of Potassium from Multiple comparison test by the way of Scheffe's test in treatments added 10 earthworms (SW_1), 20 earthworms (SW_2), 30 earthworms (SW_3), and Control (S)

Sources	Mean	S	SW_1	SW_2	SW_3
S	480.3467		109.2907*	87.6988*	-46.3009
SW_1	371.0560	-109.2907*		-21.5919	-155.5916*
SW_2	392.6480	-87.6988*	21.5919		-133.9996*
SW_3	526.6476	46.3009	155.5916*	133.9996*	

Remark: Significant difference , at the (0.05*)

Table A-12 Analysis results from comparing. mean difference of soils properties after 90 days of the experiment derived from treatment added 30 earthworms and 5% rice straw (SW_3L_1) with addition of 30 earthworms and 5% rice straw manure (SW_3O_1).

Soil properties	Source	Mean	SD	t	Sig. (2-tail)
Clay	SW_3L_1	58.32	.000		
	SW_3O_1	54.20	.000		
Silt	SW_3L_1	41.21	.000		
	SW_3O_1	44.97	.000		
Sand	SW_3L_1	.47	.000		
	SW_3O_1	.83	.000		
CEC	SW_3L_1	120.8513	5.52381	-5.981	0.004
	SW_3O_1	150.3833	6.52924		
%OC	SW_3L_1	0.3397	0.11707	-3.057	0.038
	SW_3O_1	0.7792	0.21978		
%OM	SW_3L_1	0.5856	0.20183	-6.424	0.003
	SW_3O_1	1.5654	0.17043		
Na	SW_3L_1	58.3733	1.25001	-9.617	0.001
	SW_3O_1	67.2800	1.00539		
NH_4-N	SW_3L_1	23.7149	0.89324	2.857	0.046
	SW_3O_1	21.8726	0.67050		
NO_3-N	SW_3L_1	9.8713	0.49660	-97.549	0.000
	SW_3O_1	58.3387	0.70282		

Remark: The significant level of F-values were determine separately due to the homogeneity of variance of the data. The table showed only significant value at the statistical significant level (0.05*).

Table A-12 Analysis results from comparing. mean difference of soils properties after 90 days of the experiment derived from treatment added 30 earthworms and 5% rice straw (SW_3L_1) with addition of 30 earthworms and 5% rice straw manure (SW_3O_1) (continued)

Soil properties	Source	Mean	SD	t	Sig. (2-tail)
Nitrogen	SW_3L_1	0.04702	0.001924	-42.357	0.000*
	SW_3O_1	0.11230	0.001850		
Phosphorus	SW_3L_1	4.2821	115.06403	-6.924	0.002*
	SW_3O_1	153.6536	83.90682		
Potassium	SW_3L_1	1354.820	115.06403	6.132	0.004*
	SW_3O_1	850.6633	83.90682		
SAR	SW_3L_1	.9875	.11623	-1.951	.123
	SW_3O_1	1.3548	.30462		
ESP	SW_3L_1	.11623	2.97478	1.617	.181
	SW_3O_1	.30462	2.42211		

Remark: The significant level of F-values were determine separately due to the homogeneity of variance of the data. The table showed only significant value at the statistical significant level (0.05*).

Table A-13 Analysis results from comparing mean difference of soils from the control (SO_1) after 90 days of the experiment with treatment added 30 earthworms and 5% rice straw manure (SW_3O_1).

Soil properties	Source	Mean	SD	t	Sig. (2-tail)
%OM	SO_1	0.8803	0.21552	4.319	0.012
	SW_3O_1	1.5654	0.17043		
Na	SO_1	45.1733	1.41878	22.020	0.000
	SW_3O_1	67.2800	1.00539		
NH_4-N	SO_1	16.7758	0.90105	7.860	0.001
	SW_3O_1	21.8726	0.67050		
NO_3-N	SO_1	29.2842	3.04848	16.086	0.000
	SW_3O_1	58.3387	0.70282		
Nitrogen	SO_1	0.6448	0.004911	15.779	0.000
	SW_3O_1	0.11230	0.001850		
Potassium	SO_1	630.6030	24.20476	4.365	0.012
	SW_3O_1	850.6633	83.90682		
ESP	SO_1	32.7945	1.09116	7.832	0.001
	SW_3O_1	44.8068	2.42211		

Remarks: The significant level of F-values were determine separately due to the homogeneity of variance of the data. Table showed only significant value at the statistical significant level (0.05*).

Table A-14 Analysis results from comparing mean difference of soils after 90 days of experiment from treatment added 30 earthworms and 10% rice straw (SW_3L_2) with the treatment added 30 earthworms and 10% rice straw manure (SW_3O_2).

Soil properties	Source	Mean	SD	t	Sig. (2-tail)
Bulk Density	SW_3L_2	1.5300	0.05196	-9.00	0.001
	SW_3O_2	1.800	0.0000		
Porosity	SW_3L_2	30.4385	4.17618	5.280	0.006
	SW_3O_2	10.4058	5.07324		
pH	SW_3L_2	8.2433	0.8505	4.469	0.011
	SW_3O_2	7.8400	0.13115		
ESP	SW_3L_2	59.6608	2.06711	15.375	0.00
	SW_3O_2	42.4294	6.77125		
OC	SW_3L_2	0.1017	0.00587	4.216	0.014
	SW_3O_2	0.8029	0.4636		
OM	SW_3L_2	0.8918	0.01754	-3.516	0.025
	SW_3O_2	1.1734	0.14071		
Na	SW_3L_2	87.4667	3.37024	-3.440	0.026
	SW_3O_2	41.0533	5.95571		
NH_4-N	SW_3L_2	26.2551	1.08969	11.748	0.000
	SW_3O_2	26.2628	2.11072		
Total-N	SW_3L_2	0.06151	0.000995	-96.166	0.000
	SW_3O_2	0.11862	0.002729		
Phosphorus	SW_3L_2	4.2821	0.63121	-34.048	0.000
	SW_3O_2	104.9564	5.91764		
Potassium	SW_3L_2	1024.8777	89.40694	-29.300	0.000
	SW_3O_2	1099.7100	9.97353		

Remarks: The significant level of F-values were determine separately due to the homogeneity of variance of the data. Table showed only significant value at the statistical significant level (0.05*).

Table A-15 Analysis results from comparing mean difference of soils after 90 days of the experiment from treatment added 30 earthworms and 5% rice straw manure (SW_3O_1) with treatment added 30 earthworms and 10% rice straw manure (SW_3O_2).

Soil properties	Source	Mean	SD	t	Sig. (2-tail)
CEC	SW_3O_1	150.3833	6.52924	13.080	0.000
	SW_3O_2	96.9263	2.73392		
Na	SW_3O_1	67.2800	1.00539	7.521	0.015
	SW_3O_2	41.0533	5.95571		
NH4	SW_3O_1	21.8726	0.67050	-3.433	0.026
	SW_3O_2	26.2628	2.11072		
Nitrogen	SW_3O_1	0.11230	0.001850	-3.322	0.29
	SW_3O_2	0.11862	0.002729		
Potassium	SW_3O_1	850.6633	83.90682	-5.105	0.007
	SW_3O_2	1099.710	9.97353		

Remarks: The significant level of F-values were determine separately due to the homogeneity of variance of the data. Table showed only significant value at the statistical significant level (0.05*).

Table A-16 Analysis results from comparing mean difference of soils after 90 days of the experiment from control (SO_2) with treatment added 30 earthworms and 10% rice straw manure (SW_3O_2).

Soil properties	Source	Mean	SD	t	Sig. (2-tail)
Bulk Density	SO_2	1.5000	0.08185	-6.348	0.003
	SW_3O_2	1.8000	0.00000		
Porosity	SO_2	29.7416	3.49879	5.434	0.006
	SW_3O_2	10.4058	5.07324		
ECe	SO_2	0.23800	0.000000	11.090	0.008
	SW_3O_2	0.17637	0.009626		
ESP	SO_2	33.9046	2.07886	-2.085	0.105
	SW_3O_2	42.4294	6.77125		
NH_4-N	SO_2	21.3139	1.31712	-3.445	0.026
	SW_3O_2	26.2628	2.11072		
Total-N	SO_2	0.11132	0.002429	-3.461	0.026
	SW_3O_2	0.11862	0.002729		
Phosphorus	SO_2	65.0934	2.96271	-10.433	0.000
	SW_3O_2	104.9564	5.91764		
Potassium	SO_2	770.9506	4.86691	-51.311	0.000
	SW_3O_2	1099.710	9.97353		

Remarks: The significant level of F-values were determine separately due to the homogeneity of variance of the data. Table showed only significant value at the statistical significant level (0.05*).

Table A-17 Analysis results from comparing mean difference of soils after 90 says of the experiment from treatment added 20 earthworms and 5% rice straw (SW_2L_1) with treatment added 20 earthworms and 5% rice straw manure (SW_2O_1).

Soil properties	Source	Mean	SD	t	Sig. (2-tail)
Particle density	SW_2L_1	2.1314	.02263	3.800	.019
	SW_2O_1	2.0274	.04163		
ECe	SW_2L_1	.21000	.000000	3.636	.022
	SW_2O_1	.13670	.034914		
CEC	SW_2L_1	113.4667	2.96526	-10.122	.001
	SW_2O_1	152.2407	5.93546		
ESP	SW_2L_1	50.0696	1.67664	6.118	.004
	SW_2O_1	43.1111	1.03441		
%OC	SW_2L_1	.3707	.19040	-4.533	.011
	SW_2O_1	.8947	.06188		
%OM	SW_2L_1	.4728	.10598	-12.319	.000
	SW_2O_1	1.5424	.10668		
Na	SW2L1	56.7933	1.57992	-3.871	.018
	SW_2L_1	65.6533	3.63628		
NO3	SW_2L_1	8.5434	.11318	-685.819	.000
	SW_2O_1	58.3586	.05493		
Nitrogen	SW_2L_1	.04176	.000693	-127.408	.000
	SW_2O_1	.10745	.000563		
Phosphorus	SW_2L_1	4.0391	.77084	-13.069	.000
	SW_2O_1	172.4523	22.30594		
Growth rate	SW_2L_1	-.00197172	.004152456	3.141	.035
	SW_2O_1	-.01001057	.001551183		

Remarks: The significant level of F-values were determine separately due to the homogeneity of variance of the data. Table showed only significant value at the statistical significant level (0.05*).

Table A-18 Analysis results from comparing mean difference of soils after 90 days of experiment from treatment added 20 earthworms and 10% rice straw (SW_2L_2) with treatment added 20 earthworms and 10% rice straw manure (SW_2O_2).

Soil properties	Source	Mean	SD	t	Sig. (2-tail)
pH	SW_2L_2	8.5000	0.07937	5.910	0.004
	SW_2O_2	7.8733	0.16563		
CEC	SW_2L_2	87.4573	3.80816	-5.838	0.004
	SW_2O_2	110.6167	5.71954		
ESP	SW_2L_2	20.85	1.59909	-4.674	0.009
	SW_2O_2	36.9585	5.74814		
Na	SW_2L_2	18.2467	1.72306	-6.081	0.004
	SW_2O_2	40.8333	6.19862		
NO_3-N	SW_2L_2	14.7719	1.39371	-54.126	0.000
	SW_2O_2	58.3586	0.05493		
Total-N	SW_2L_2	0.05381	0.001604	-65.348	0.000
	SW_2O_2	0.11532	0.000292		

Remarks: The significant level of F-values were determine separately due to the homogeneity of variance of the data. Table showed only significant value at the significant level (0.05*).

Table A-19 Analysis results from comparing mean difference of soils after 90 days of the experiment from treatment added 20 earthworms and 5% rice straw manure (SW_2O_1) with treatment added 20 earthworms and 10% rice straw manure (SW_2O_2).

Soil properties	Source	Mean	SD	t	Sig. (2-tail)
pH	SW_2O_1	8.2433	.04933	3.708	.021
	SW_2O_2	7.8733	.16563		
CEC	SW2O1	152.2407	5.93546	8.746	.001
	SW_2O_1	110.6167	5.71954		
Na	SW_2O_1	65.6533	3.63628	5.982	.004
	SW_2O_2	40.8333	6.19862		
NH_4-N	SW_2O_1	18.3924	.36264	-21.742	.000
	SW_2O_2	24.0131	.26267		
Total-N	SW_2O_1	.10745	.000563	-21.490	.000
	SW_2O_2	.11532	.000292		
Potassium	SW_2O_1	812.9513	25.32160	-9.289	.001
	SW_2O_2	1085.0689	43.97111		

Remark: The significant level of F-values were determine separately due to the homogeneity of variance of the data. Table showed only significant value at the statistical significant level (0.05*).

Table A-20 Analysis results from comparing mean difference of soils after 90 days of the experiment from treatment added 20 earthworms and 5% rice straw (SW_2L_1) with treatment added 20 earthworms and 10% rice straw (SW_2L_2).

Soil properties	Source	Mean	SD	t	Sig. (2-tail)
Bulk density	SW_2L_1	1.5867	0.04509	-3.247	0.031
	SW_2L_2	1.7133	005033		
ECe	SW_2L_1	0.2100	0.000000	3.064	0.038
	SW_2L_2	0.13943	0.039895		
CEC	SW_2L_1	113.4667	2.96526	9.334	0.001
	SW_2L_2	87.4573	3.80816		
ESP	SW_2L_1	50.0696	1.67664	21.837	0.000
	SW_2L_2	20.8580	1.59909		
OM	SW_2L_1	0.4728	0.10598	-3.347	0.029
	SW_2L_2	0.7387	0.08769		
Na	SW_2L_1	56.7933	1.57992	28.559	0.000
	SW_2L_2	18.2467	1.72306		
NH_4-N	SW_2L_1	21.2845	0.50792	-6.572	0.003
	SW_2L_2	23.6612	0.36662		
NO3-N	SW_2L_1	8.5434	0.11318	-7.715	0.002
	SW_2L_2	14.7719	1.39371		
Total-N	SW_2L_1	0.04176	0.000693	-11.941	0.000
	SW_2L_2	0.05381	0.001604		
Potassium	SW_2L_1	4.0391	0.77084	-3.515	0.025
	SW_2L_2	4.2062	1.19689		

Remarks: The significant level of F-values were determine separately due to the homogeneity of variance of the data. Table showed only significant value at the significant level (0.05*).

Table A-21 Analysis results from comparing mean difference of soils after 90 days of experiments from treatment added 10 earthworms and 5% rice straw (SW_1L_1) with treatment added 10 earthworms and 5% rice straw manure (SW_1O_1).

Soil properties	Source	Mean	SD	t	Sig. (2-tail)
ESP	SW_1L_1	52.8884	1.47337	12.222	.000
	SW_1O_1	26.5031	3.43681		
Na	SW_1L_1	56.3200	.48539	19.873	.000
	SW_1O_1	27.2667	2.48526		
NO3	SW_1L_1	6.7979	.37845	-8.511	.001
	SW_1O_1	26.1823	3.92687		
Nitrogen	SW_1L_1	.03102	.003483	-5.869	.004
	SW_1O_1	.05805	.007175		
Phosphorus	SW_1L_1	2.9762	.63830	-20.768	.002
	SW_1O_1	179.0576	14.67103		
Survival	SW_1L_1	80.00	10.000	3.500	.025
	SW_1O_1	56.67	5.774		

Remark: The significant level of F-values were determine separately due to the homogeneity of variance of the data. The table showed only statistical significant value at the significant level (0.05*).

Table A-22 Analysis results from comparing mean difference of soils after 90 days of the experiment from treatment added 10 earthworms and 10% rice straw (SW_1L_2) with treatment added 10 earthworms and 10% rice straw manure (SW_1O_2).

Soil properties	Source	Mean	SD	t	Sig. (2-tail)
Particle density	SW_1L_2	2.0285	0.01430	-5.809	0.004
	SW_1O_2	2.1521	0.03398		
ECe	SW_1L_2	0.11960	0.70513	-2.871	0.045
	SW_1O_2	0.24300	0.023896		
CEC	SW_1L_2	104.4573	0.77834	-3.135	0.035
	SW_1O_2	121.4407	2.77953		
Na	SW_1L_2	39.9600	3.19881	-4.065	0.049
	SW_1O_2	47.6133	0.63540		
NO3	SW_1L_2	8.4621	0.26445	-11.630	0.000
	SW_1O_2	53.4613	6.69671		
Total-N	SW_1L_2	0.03959	0.002381	-10.965	0.006
	SW_1O_2	0.10471	0.010007		
Phosphorus	SW_1L_2	2.9762	0.02630	-8.671	0.013
	SW_1O_2	98.1841	19.01705		
Potassium	SW_1L_2	1174.6903	130.17790	6.6764	0.002
	SW_1O_2	658.8500	22.355586		

Remarks: The significant level of F-values were determine separately due to the homogeneity of variance of the data. The table showed only statistical significant value at the significant level (0.05*).

Table A-23 Analysis results from comparing mean difference of soils after 90 days of the experiment from treatment added 10 earthworms and 5% rice straw manure (SW_1O_1) with treatment added 10 earthworms and 10% rice straw manure (SW_1O_2).

Soil properties	Source	Mean	SD	t	Sig. (2-tail)
Particle density	SW_1O_1	1.9600	.10408	-3.039	.038
	SW_1O_2	2.1521	.03398		
pH	SW_1O_1	8.2033	.02517	3.062	.038
	SW_1O_2	7.8433	.20207		
ECe	SW_1O_1	.12340	.036735	-4.727	.009
	SW_1O_2	.24300	.023896		
CEC	SW_1O_1	103.2253	4.65894	-3.020	.039
	SW_1O_2	121.4407	9.35116		
ESP	SW_1O_1	26.5031	3.43681	-5.156	.007
	SW_1O_2	39.3408	2.60517		
Na	SW_1O_1	27.2667	2.48526	-13.738	.000
	SW_1O_2	47.6133	.63540		
NH_4-N	SW_1O_1	15.2794	1.74683	-5.698	.005
	SW_1O_2	21.3298	.57538		
NO_3-N	SW_1O_1	26.1823	3.92687	-6.086	.004
	SW_1O_2	53.4613	6.69671		
Total-N	SW_1O_1	.05805	.007175	-6.563	.003
	SW_1O_2	.10471	.010007		
Phosphorus	SW_1O_1	179.0576	14.67103	5.832	.004
	SW_1O_2	98.1841	19.01705		

Remarks: The significant level of F-values were determine separately due to the homogeneity of variance of the data. Table showed only significant value at the statistical significant level (0.05*).

Table A-24 Analysis results from comparing mean difference of soils after 90 days of the experiment from treatment added 10 earthworms and 5% rice straw (SW_1L_1) with treatment added 10 earthworms and 10% rice straw (SW_1L_2).

Soil properties	Source	Mean	SD	t	Sig. (2-tail)
ESP	SW_1L_1	52.8884	1.47337	8.064	0.001
	SW_1L_2	38.2413	2.77953		
Na	SW1L1	56.3200	0.48539	8.758	0.001
	SW_1L_1	39.9600	3.19881		
NO_3-N	SW_1L_1	6.7979	0.37845	-6.243	0.003
	SW_1L_2	8.4621	0.2645		
Total-N	SW_1L_1	0.03010	0.003483	-3.517	0.025
	SW_1L_2	0.03959	0.002381		
Potassium	SW_1L_1	717.5623	18.25169	-6.023	0.004
	SW_1L_2	1174.6903	130.17790		

Remarks: The significant level of F-values were determine separately due to the homogeneity of variance of the data. Table showed only significant value at the significant level (0.05*).

Table A-25 Analysis results from comparing mean difference of soils after 90 days of the experiment from treatment added 5% rice straw (SL_1) with treatment 5% rice straw manure (SO_2).

Soil properties	Source	Mean	SD	t	Sig. (2-tail)
CEC	SL_1	105.0653	3.23209	-10.116	0.001
	SO_1	137.7620	3.23209		
ESP	SL_1	47.9991	9.8541	15.430	0.000
	SO_1	32.7945	9.8541		
NO_3-N	SL_1	29.227	1.77582	-14.845	0.004
	SO_1	29.2842	1.77582		
Total-N	SL_1	0.02575	0.003029	-12.789	0.000
	SO_1	0.06448	0.003029		
Phosphorus	SL_1	3.8873	2.97391	-24.478	0.000
	SO_1	76.6826	2.97391		

Remarks: The significant level of F-values were determine separately due to the homogeneity of variance of the data. The table was showed only the statistical significant value at the significant level (0.05*).

Table A-26 Analysis results from comparing mean difference of soils after 90 days of the experiment from treatment added 10% rice straw (SL_2) with treatment added 10% rice straw manure (SO_2).

Soil properties	Source	Mean	SD	t	Sig. (2-tail)
pH	SL_2	8.5773	0.10693	8.675	0.001
	SO_2	7.8533	0.09609		
ECe	SL_2	0.05664	0.039438	-7.965	0.001
	SO_2	0.23800	0.00000		
SAR	SL_2	1.2409	00883	-7.843	0.001
	SO_2	1.6409	0.00163		
CEC	SL_2	131.4753	3.84587	4	0.012
	SO_2	108.9647	8.09309		
ESP	SL_2	51.2805	51.2805	9.192	0.001
	SO_2	33.9046	33.9046		
Na	SL_2	67.4267	67.4267	13.182	0.000
	SO_2	36.8333	36.8333		
NH4-N	SL_2	16.8364	16.8364	-5.267	0.006
	SO_2	21.3139	21.3139		
NO3-N	SL_2	4.6276	4.6276	-109.191	0.000
	SO_2	58.1990	58.1990		
Total-N	SL_2	0.03005	0.03005	-50.070	0.000
	SO_2	0.11132	0.11132		
Phosphorus	SL_2	4.0391	4.0391	-35.483	0.000
	SO_2	65.0934	65.0934		
Potassium	SL_2	1059.1882	1059.1882	5.712	0.005
	SO_2	770.9506	770.9506		

Remarks: The significant level of F-values were determine separately due to the homogeneity of variance of the data.. The table showed only significant value at the significant level (0.05*)

Table A-27 Analysis results from comparing mean difference of soils after 90 days of the experiment from treatment added 5% rice straw (SL_1) with treatment added 10% rice straw (SL_2).

Soil properties	Source	Mean	SD	t	Sig. (2-tail)
Bulk density	SL_1	1.8500	0.12124	3.329	0.029
	SL_2	1.5900	00600		
Porosity	SL_1	11.8818	6.26948	-2.902	0.044
	SL_2	23.5033	2.96682		
pH	SL_1	8.0667	1.5822	-4.596	0.010
	SL_2	8.5733	0.10693		
ECe	SL_1	0.18083	0.017086	5.005	0.007
	SL_2	0.5664	0.039438		
CEC	SL_1	105.0653	5.20027	-7.072	0.002
	SL_2	131.4753	3.84587		
Na	SL_1	50.3867	1.25321	-7.112	0.002
	SL_2	67.4267	3.95638		
NO_3-N	SL_1	2.9227	0.40910	-4.765	0.009
	SL_2	4.6276	0.46542		
Total-N	SL_1	0.02575	0.001842	-3.205	0.033
	SL_2	0.03005	0.001415		
Potassium	SL_1	726.4357	142.14368	-3.455	0.026
	SL_2	1059.1882	87.26024		

Remarks: The significant level (0.05*) of F-values were determine separately due to the homogeneity of variance of the data. The table showed only the statistical significant value at the significant level.

Table A-28 Analysis results of Independent sample test for the soil properties comparing mean difference of soils after 90 days of the experiment from treatment added 5% rice straw manure (SO_1)with treatment added 10% rice straw manure (SO_2).

Soil properties	Source	Mean	SD	t	Sig. (2-tail)
ECe	SO_1	0.15723	0.000404	-346.143	0.000
	SO_2	0.23800	0.00000		
CEC	SO_1	137.7620	2.07276	5.970	0.020
	SO_2	108.9647	8.09303		
Na	SO_1	45.1733	1.41878	9.104	0.001
	SO_2	36.8333	0.71059		
NH_4-N	SO_1	16.7758	0.90105	-4.925	0.008
	SO_2	21.3139	1.31712		
NO_3-N	SO_1	29.2842	3.04848	-15.999	0.000
	SO_2	58.1990	0.71099		
Total-N	SO_1	45.1733	1.41878	-14.805	0.000
	SO_2	36.8333	0.71059		
Phosphorus	SO_1	76.6826	5.05820	3.424	0.027
	SO_2	65.0934	2.96271		
Potassium	SO_1	630.6030	24.20476	-9.846	0.001
	SO_2	770.9506	4.86691		

Remarks: The significant level of F-values were determine separately due to the homogeneity of variance of the data. Table showed only significant value at the significant level (0.05*).

Table A-29 Analysis results of MS and F-ratios from one way ANOVA for the growth rate and survival of earthworm. Independence variable is earthworm number in the treatments added 10 earthworms (SW_1), 20 earthworms (SW_2) and 30 earthworms (SW_3).

Sources		Sum of Squares	df	Mean Square	F	Sig.
Survival	Between Groups	3019.264	2	1509.632		
	Within Groups	1918.493	6	319.749	4.721	.059
	Total	4937.757	8			
Growth rate	Between Groups	.000	2	.000	1.588	.280
	Within Groups	.000	6	.000		
	Total	.000	8			

Remarks: The significant level of F-values were determine separately due to the homogeneity of variance of the data as 0.05 (*).

Table A-30 Analysis results of MS and F-ratios from one way ANOVA for the growth rate and survival of earthworm in the treatments added earthworms and 5% rice straw (SW_1L_1, SW_2L_1, SW_3L_1).

Sources		Sum of Squares	df	Mean Square	F	Sig.
Survival	Between Groups	1573.012	2	786.506	1.886	.231
	Within Groups	2501.726	6	416.954		
	Total	4074.738	8			
Growth rate	Between Groups	.000	2	.000	3.343	.106
	Within Groups	.000	6	.000		
	Total	.000	8			

Remarks: The significant level of F-values were determine separately due to the homogeneity of variance of the data as 0.05 (*).

Table A-31 Analysis results of MS and F-ratios from one way ANOVA for the growth rate and survival of earthworm in the treatments added earthworms and 10% rice straw (SW_1L_2, SW_2L_2, SW_3L_2).

Sources		Sum of Squares	df	Mean Square	F	Sig.
Survival	Between Groups	2222.222	2	1111.111	3.883	.083
	Within Groups	1716.667	6	286.111		
	Total	3938.889	8			
Growth rate	Between Groups	.000	2	.000	3.179	.114
	Within Groups	.000	6	.000		
	Total	.000	8			

Remarks:.The significant level of F-values were determine separately due to the homogeneity of variance of the data as the 0.05 (*).

Table A-32 Analysis results of MS and F-ratios from one way ANOVA for the growth rate and survival of earthworm in the treatments added earthworms and 5% rice straw manure (SW_1O_1, SW_2O_1, SW_3O_1).

Sources		Sum of Squares	df	Mean Square	F	Sig.
Survival	Between Groups	313.531	2	156.765	.520	.619
	Within Groups	1807.526	6	301.254		
	Total	2121.057	8			
Growth rate	Between Groups	.000	2	.000	.146	.867
	Within Groups	.000	6	.000		
	Total	.000	8			

Remarks: The significant level of F-values were determine separately due to the homogeneity of variance of the data as the 0.05 (*).

Table A-33 Analysis results of MS and F-ratios from one way ANOVA for the growth rate and survival of earthworm in the treatments added earthworms and 10% rice straw manure (SW_1O_2, SW_2O_2, SW_3O_2).

Sources		Sum of Squares	df	Mean Square	F	Sig.
Survival	Between Groups	3054.220	2	1527.110	1.844	.238
	Within Groups	4969.963	6	828.327		
	Total	8024.183	8			
Growth rate	Between Groups	.001	2	.000	1.047	.407
	Within Groups	.002	6	.000		
	Total	.003	8			

Remarks: The significant level of F-values were determine separately due to the homogeneity of variance of the data as the 0.05 (*).

Table A-34 Analysis results of Independent sample test for the growth rate and survival of earthworm after 90 days of the experiment by comparing mean difference of growth rate and survival from treatment added 5% rice straw and rice straw manure.

	Source	Mean	SD	t	Sig. (2-tail)
Survival	SW_1L_1	80.0000	10.00000	3.500	.025*
	SW_1O_1	56.6667	5.77350		
Growth rate	SW_1L_1	-.0094033	.00312833	.200	.851
	SW_1O_1	-.0104433	.00842265		
Survival	SW_2L_1	56.6667	29.29733	-1.650	.174
	SW_2O_1	86.6667	11.54701		
Growth rate	SW_2L_1	-.0019733	.00415199	3.142	.035*
	SW_2O_1	-.0100133	.00155017		
Survival	SW_3L_1	48.8867	17.10350	.506	.639
	SW_3O_1	41.1100	20.36628		
Growth rate	SW_2L_1	-.0063800	.00324906	-1.090	.337
	SW_2O_1	-.0029367	.00440024		

Remarks: The significant level of F-values were determine separately due to the homogeneity of variance of the data as the 0.05 (*).

Table A-35 Analysis results of Independent sample test for the growth rate and survival of earthworm after 90 days of the experiment by comparing mean difference of growth rate and survival from treatment added 10% rice straw and rice straw manure.

	Source	Mean	SD	t	Sig. (2-tail)
Survival	SW_1L_2	83.3333	15.27525	1.042	.356
	SW_1O_2	56.6667	41.63332		
Growth rate	SW_1L_2	-.0047300	.00122049	.571	.624
	SW_1O_2	-.0079033	.00954271		
Survival	SW_2L_2	46.6667	18.92969	-.326	.761
	SW_2O_2	52.2233	22.68765		
Growth rate	SW_2L_2	-.0055500	.00347350	-.319	.765
	SW_2O_2	-.0043533	.00548071		
Survival	SW_3L_2	44.4433	26.94494	1.612	.182
	SW_3O_2	15.5567	15.39216		
Growth rate	SW_3L_2	-.0056167	.00148561	-1.046	.405
	SW_3O_2	.0122333	.02952509		

Remarks: The significant level of F-values were determine separately due to the homogeneity of variance of the data as 0.05 (*).

Table A-36 Analysis results of Independent sample test for the growth rate and survival of earthworm after 90 days of the experiment by comparing mean difference of growth rate and survival of earthworm from treatment added 5% and 10% rice straw.

	Source	Mean	SD	t	Sig. (2-tail)
Survival	SW_1L_1	80.0000	10.00000	-.316	.768
	SW_1L_2	83.3333	15.27525		
Growth rate	SW_1L_1	-.0094033	.00312833	-2.411	.074*
	SW_1L_2	-.0047300	.00122049		
Survival	SW_2L_1	56.6667	29.29733	.497	.646
	SW_2L_1	46.6667	18.92969		
Growth rate	SW_2L_1	-.0019733	.00415199	1.144	.316
	SW_2L_1	-.0055500	.00347350		
Survival	SW_3L_1	48.8867	17.10350	.241	.821
	SW_3L_2	44.4433	26.94494		
Growth rate	SW_3L_1	-.0063800	.00324906	-.370	.730
	SW_3L_2	-.0056167	.00148561		

Remarks: The significant level of F-values were determine separately due to the homogeneity of variance of the data as 0.05 (*).

Table A-37 Analysis results of Independent sample test for the growth rate and survival of earthworm after 90 days of the experiment by comparing mean difference of growth rate and survival of earthworm from treatment added 5% and 10% rice straw manure.

	Source	Mean	SD	t	Sig. (2-tail)
Survival	SW_1O_1	56.6667	5.77350	.000	1.000*
	SW_1O_2	56.6667	41.63332		
Growth rate	SW_1O_1	-.0104433	.00842265	-.346	.747
	SW_1O_2	-.0079033	.00954271		
Survival	SW_2O_1	86.6667	11.54701	.000	1.000*
	SW_2O_2	52.2233	22.68765		
Growth rate	SW_2O_1	-.0100133	.00155017	-.346	.747
	SW_2O_2	-.0043533	.00548071		
Survival	SW_3O_1	41.1100	20.36628	1.734	.158
	SW_3O_2	15.5567	15.39216		
Growth rate	SW_3O_1	-.0029367	.00440024	-.880	.468
	SW_3O_2	.0122333	.02952509		

Remarks: The significant level of F-values were determine separately due to the homogeneity of variance of the data as 0.05 (*).

APPENDIX B
THE SOIL STANDARDS FOR INTERPRETING SOIL TEST RESULTS

Table B-1 The infiltration category

Class	Infiltration category	Basic infiltration rate (cm h^{-1})
1.	Very Slow (non-irrigable)	< 0.1
2.	Slow	0.1-0.5
3.	Moderate slow	0.5-2.0
4.	Moderately	2.0-6.0
5.	Moderately rapid	6.0-12.5
6.	Rapid	12.5-25
7.	Very rapid	>25

Source: Landon, 1984 refered to C Berryman, in liaison with FAO and MAFF worker

Table B-2 A general scale of bulk density

Bulk density (g/cm^3)	Rating
Very low	<1
Low	1-1.3
Moderate	1.3-1.6
High	1.6-1.9
Very High	>1.9

Source: Hezelton and Murphy, 2007 refered to Harte (pers.comm.)

Table B-3 Critical values of bulk density for plant growth at which root penetration is likely to be severely restrict.

Texture	**Critical bulk density (g/cm^3)**
Sandy loam	1.8
Fine sandy loam	1.7
Loam and clay loam	1.6
clay	1.4

Source: Hezelton and Murphy, 2007 refered to Jones(1983)

Table B-4 Effect of bulk density on soil condition

Bulk density (g/cm^3)	**Rating**
<0.1	Satisfactory
1-1.2	Satisfactory
1.2-1.4	Some too compact
1.4-1.6	Very compact
1.6-1.8	Highly compact
>1.8	Excessively compact

Source: Hezelton and Murphy, 2007 refered to Handreck and Black (1984) and Hunt and Gikes (1992)

Table B-5 Critical values of bulk density and porosity

Physical Properties	Critical values
Bulk density (g/cm^3)	2.65
Porosity (%)	30-70

Source: Landon,1984

Table B- 6 Classification of soil as basic soil, sodic soil, saline sodic soil and normal soil.

Value / Type of Soil	ECe (dS/m)	ESP (%)	SAR	pH
Saline soil	≥0.4	<15	<13	<8.5
Sodic soil	<0.4	>15	≥13	≥8.5
Saline sodic soil	≥0.4	>15	≥13	≥8.5
Normal soil	<0.4	<15	<13	<8.5

Source: Department staff of Pedology, Kasetsart University, 2006

Remark: Value of electrical conductivity measured from the soil solution which extracted from soil, with water saturation; 1 S/m =10 dS/m

Table B-7 Harmful from sodic

ESP	Rating
<15	Non-harmful to Slightly
15-30	Slightly to Moderate
30-50	Moderate to High
50-70	High to Very High
>70	Very High

Source: Desconap, 1990

Table B-8 Standard of soil for assessing good soil chemical properties at the level 0-25 cm from top soil.

Chemical properties	Ctitical Values
pH	5.5-7.5
Organic matter (%)	1
Cation exchange capacity (cmol/kg)	5
Available Phosphorus (mg/kg)	5
Available Potassium (mg/kg)	30
EC (ds/cm)	2

Source: Land Development Department, 1997

Table-B-9 Rating Interpreting of soil chemical properties.

Chemical Properties	Rating Interpreting						
	Very low	Low	Moderately low	Moderate	Moderately high	High	Very high
1. Organic matter (%)[a]	<0.5	0.5-1.5	-	1.5-2.5	-	2.5-4.5	>4.5
2.Organic carbon (%)[b]	<2	2-4	-	4-10		10-20	>20
3. Available Phosphorus(mg/kg)[c]	<5	5-10		10-17		17-25	>25
4. Available Potassium (mg/kg)[a]	<30	30-60		60-90	-	90-20	>120
5. Total-N (%)[b]	<0.1	0.1-0.2		0.2-0.5	-	0.5-1.0	>1.0
6. Cation exchange capacity (cmol/kg)[d]	<5	5-15	-	15-25	-	25-40	>40
7. Exchangeable cation (meq/100g soil)[c]							
Na+	0-0.1	0.1-0.3		0.3-0.7	-	0.7-2	>2
K+	0-0.2	0.2-0.3	-	0.3-0.7		0.7-2	>2
Ca^{2+}	0-2	2-5		5-10	-	10-20	>20
Mg^{2+}	0-0.3	0.3-1		1-3		3-8	>8

Source: a: Arnon,1994 refered to Apiridee,1999

b: Landon,1984 refered to Metson 1961

c: Landon,1984 refered to Holford and Culis 1981

d: Hezelton and Murphy, 2007 refered to Metson 1961

APPENDIX C
THE EARTHWORM CHARACTERISTICS

Table C-1 Characteristic of *Polypheretima elongata*

Herbarium/Reference collection	Department of Biology, Faculty of Science, Naresuan University
Herbarium No./ Reference No.	-
Collector number	1
Kingdom	Animalia
Phylum	Annelida
Class	Oligochaeta
Order	Haplotaxida
Family	Megascolecidae
Genus	Polypheretima
Species	P. elongata
Common name (in English)	-
Common name (in Thai)	-
Locality	Area beside abandoned shrimp farm pond in Tha-bon District
Province	Songkla
Latitude	N 648586
Longtitude	E 863473
CollectionDate	24/5/2008
Collector*	Jarupan Chunuang
Identifier*	Prasuk Kosavitkul
Status (in term of quantity eg. abundant, common, rare)	i
Major Characters (for example morphology, color, healthy)	length ~16-17cm, 137 segments, male pore superficial at 18, female pore absent, genital marking at 19-23, intestine lacking caecum, Holandric, testis sac unpaired and annular, serminal veicles in xi,xii, GM glands sessile in the parietes
Names of collectors and identifiers	Mr. Prasuk Kosavititkul (Ph.D) Department of Biology, Faculty of Science, Naresuan University,Thailand, 65000
	Miss Jarupan Chunuang (student)Faculty of Environment and resouce studies, Mahidol University,73170

Figure C-1 Specimen of *Polypheretima elongata* (1)

Figure C-2 Specimen of *Polypheretima elongata* (2)

BIOGRAPHY

NAME	Miss Jarupan Chunuang
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