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Changes to Some Physical Properties due to Conversion of Secondary Forest of Peat into Oil Palm Plantation

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Abstract

The purpose of this study was to study how the physical properties of peat change due to the conversion of secondary forest into oil palm plantations. It was done by comparing the three conversion stages of the secondary forest into shrubs and oil palm plantations. The study was conducted in Ogan Komering Ilir District, South Sumatera Province, about 100 km south of Palembang, Indonesia from August to December 2016. Data collection was done randomly at all sites, each of five points for field sampling, observation of soil profile and measurement of hydraulic conductivity and water table depth. The samples were collected at a depth of 0-30 cm, both for undisturbed cores and bulk samples. The hydraulic conductivity was measured in the field using the auger holes method. The peat strength was determined by using the hand operated cone penetrometer. Data analysis was done descriptively and regression correlation test. The results showed that conversion of secondary forests into oil palm plantations has led to the decline in the quality of some of the physical properties of peat by decreasing total porosity, water table depth, hydraulic conductivity, organic matter content, moisture content and increasing the bulk density and peat strength.

Keywords: *land degradation; oil palm; peat; physical properties*

*A*bstrak (Indonesian)

Penelitian bertujuan untuk mengkaji bagaimana sifat fisik gambut berubah akibat konversi lahan hutan menjadi perkebunan kelapa sawit. Penelitian dilakukan dengan membandingkan tiga tipe lahan: hutan sekunder, semak belukar dan perkebunan kelapa sawit. Penelitian dilakukan di Kabupaten Ogan Komering Ilir, Propinsi Sumatera Selatan, sekitar 100 km sebelah Selatan kota Palembang, Indonesia dari bulan Agustus sampai dengan bulan Desember 2016. Pengumpulan data dilakukan secara acak, masing-masing lima titik baik untuk pengambilan contoh tanah maupun pengamatan profil tanah serta pengukuran keterhantaran hidrolik dan kedalaman muka air tanah. Contoh tanah diambil pada kedalaman 0-30 cm. Pengambilan contoh tanah utuh menggunakan silinder logam dan pengambilan contoh tanah terganggu menggunakan bor. Contoh tanah utuh digunakan untuk menentukan berat volume, porositas total, dan kadar air, sedangkan contoh tanah terganggu digunakan untuk menentukan kandungan bahan organik tanah. Keterhantaran hidrolik diukur di lapangan dengan menggunakan metode lubang bor. Kekuatan penetrasi permukaan gambut diukur dengan menggunakan penetrometer saku. Analisis data dilakukan secara deskriptif dan uji regresi korelasi. Hasil penelitian menunjukkan bahwa konversi hutan sekunder menjadi perkebunan kelapa sawit telah menyebabkan penuruan kualitas beberapa sifat fisik gambut dengan menurunya nilai porositas total, kedalaman muka air tanah, keterhantaran hidrolik, kandungan bahan organik, kadar air dan meningkatkan berat volume dan ketahanan penetrasi.

Kata Kunci: *degradasi lahan; gambut; kelapa sawit; sifat fisik*

1. Introduction

Regarding soil taxonomy, peat soils can be classified as Histosol, where the land is formed from the organic material with thickness > 40 cm [1], with 50-60% organic material content [2]. This land has an average porosity of 90% so that it can store large water. Therefore, it has a function as a hydrological buffer for the surrounding area, which can prevent flooding in a rainy season, water suppliers in the dry season, and prevent sea water intrusion [3]. In the tropics, peat swamps can be found in lowland areas such as river basins, watersheds, and coastal areas [4] up to more than 200 km to the inland [5].

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Indonesia has potential peat lands. Around 14.9 million ha [6] of which 29.5% consists of degraded forests that overgrown with shrubs, but it is potential for agriculture. Around 55.4% are forests that must be maintained as conservation areas, and 15.1% have been cultivated as agricultural land for food crops, plantations and industrial crops [7], with has good results although they indicate that they need an improvement of management.

Currently, the most prominent peat land use is for oil palm plantations, other land uses are for industrial plantations such as Acacia that used for pulp and paper production [8]. The development of oil palm on peat lands in Indonesia has reached more than 1.7 million ha where most of them are spread on the Sumatra and the Borneo islands [9]. Some of the reasons for the rapid use of peat lands for oil palm development are among others; the high demand and high prices of fuel and cooking oil and other derivatives produced by oil palm [10], the existence of government programs to seek alternative energy by utilizing palm oil as biofuel [11], and this plant is capable of earning up to 25 years [12].

The clearance of peat lands that are less concerned with environmental biophysical characteristics, land clearance and clearing activities, drainage, and improper management lead to degradation

Figure 1. Study site: A (secondary forest); B (Shurbs); C (oil palm plantation)

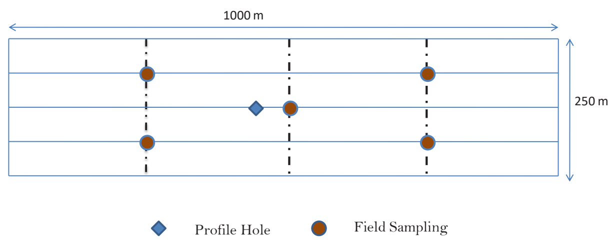

Figure 2. Field sampling and measurement site

of peat lands. Some authors state that there is a relationship between peat land management and changes in the properties of peat. Changes in the composition of peat are able to decrease of peat ability to hold water, to speed up the level of peat humification, to stimulate the irreversible drying and subsidence, and to reduce in soil fertility [13-16]. These changes need to be identified as the basis for peat land management for oil palm development, so that degradation of peat lands can be minimized. The purpose of this study was to explore changes in some physical properties of peat due to changes in land use from secondary forests to oil palm plantation.

2. Experimental Section

2.1. Study Sites

The study was conducted at Pedamaran Timur Sub-District, Ogan Komering Ilir District, South Sumatera Province, 100 km Southern of Palembang, Indonesia. Based on Koppen climate classification system, the sites are identified as a tropical rain forest. The environment of the study site belongs to Type B2 by the Oldman climate classification system. Wet season usually occurs from October to May with average monthly precipitation more than 200 mm and the dry season is from June to September with average monthly rainfall less than 100 mm. The average annual rainfall for the last decade was 2510 mm, the highest precipitation of 3827 mm (2011) and the lowest precipitation of 1576 mm (2015). The mean annual air temperature is relatively similar all year of 28 ^{0}C. Field sampling was determined purposively with consideration the site was on peat land. Three land use classes were selected, secondary forest, shrubs and palm oil plantation (Figure 1).

2.2. Peat Profile Description, Field Sampling, and Measurement

Peat profile description, peat sampling, hydraulic conductivity measurements, peat strength measurement and water level measurement on each site were shown in Figure 2. Before field sampling, peat profiles description were done by checking the thickness of the peat layer, peat color (Soil Munsell Color Card), peat humification level (van Post method), and water table height.

Five-peat samples were collected randomly at 0-30 cm depth from study sites plot with the size of 250,000 m^2. Undisturbed cores were collected by using a metal cylinder for analysis of bulk density and moisture content, and bulk samples were collected by using peat auger for analysis of organic matter content. Measurements of hydraulic conductivity were carried out using auger hole method, water table height measurements using a measuring tape, and peat strength using hand operated cone penetrometer [17].

2.3. Soil Analysis

Soil analysis was conducted at the Soil Science Laboratory of Sriwijaya University and Soil Physics Laboratory and Mineralogy of the University of Jambi. Undisturbed cores were determined for bulk density, total porosity, and moisture content, while bulk samples were determined for organic matter content. Bulk density was derived using oven-dried mass and known volumes. Total porosity was determined by standard procedures from an average particle density and bulk density [18]. Moisture content was assessed by oven drying the sample at 105 ^{0}C for two nights. Organic matter contents were quantified using the loss on ignition methods [19].

2.4. Statistical analysis

Data analysis was done descriptively. The relationships among the peat physical properties were assessed by using regression analysis.

3. Results and Discussion

Profile observation was conducted during the dry season on 20th August 2016. The observation result showed a change of profile on peat land due to the conversion of peat swamp forest into palm oil plantation. It can be seen from changes in layers and thickness of peat, color, humification level, and the water table level (Table 1).

Changes in the secondary forest into shrubs and palm oil plantation also resulted in changes in some of the physical properties of peat (Table 2). The decrease of organic matter content, total porosity, hydraulic conductivity, and water table level due to change of secondary forest into shrubs and oil palm plantation. Conversely, there is an increase in bulk density and peat strength.

There were strong relationships between the organic matter content and the physical properties of peat and peat water table level. Bulk density and peat strength were negatively related to organic matter content, whereas hydraulic conductivity and moisture content were positively related to organic matter content (Figures 3A, 3B, 3C, and 3D). Bulk density was positively related to peat strength (Figure 3E) and negatively related to total porosity and hydraulic conductivity (Figures 3F and 3G).

The decrease in water table level caused the change of humification level of peat on the surface (0-10 cm) of oil palm plantation into humification level of sapric from humification level of hemic on secondary forest and shrubs. This decline affects the decomposition of organic matter which results in changes in humification level and color of peat [20]. Water table level is a major factor affecting peat humification level [21].

The decrease in organic matter content occurs from secondary forest to shrubs and oil palm plantation (Table 2). The change from secondary forest to oil palm plantation was caused by deforestation, soil tillage, and drainage. Drainage channels on shrubs and oil palm plantation produced increasing the thickness of the aer-

Table 1. Changes in peat profile in oil palm areas

Layer Depth (cm)	Soil Colour	Humification Level	Water Table Level (cm)
Secondary Forest			
0-20	reddish black	hemic	45
20-45	very dark red	hemic	
Shrubs			
0-20	very dark brown	hemic	54
20-35	reddish brown	hemic	
35-54	reddish black	hemic	
Oil Palm Plantation			
0-10	dark brown	sapric	75
20-Oct	dark reddish brown	hemic	
20-37	dark reddish brown	hemic	
37-75	dark reddish brown	hemic	

Table 2. Changes in some physical properties of peat due to land conversion

Variables	Mean value		
	Secondary Forest	Shrubs	Oil Palm Plantation
Bulk density (g cm^{-3})	0.11±0.02	0,14±0.03	0,16±0.04
Total porosity (%)	91,60±1.21	88.99±2.01	87.30±2.81
Organic matter content (%)	96.73±2.44	92.75±1.79	89.61±1.08
Peat strength (N cm^{-2})	32.40±1.82	36.60±3.44	38.60±2.07
Hydraulic conductivity (cm $hour^{-1}$)	43.20±2.46	19.63±2.17	12.42±2.89
Moisture content (%)	650±34	520±37	430±27

ation zone so that the activity of aerobic microorganisms is more active than the activity of anaerobic microorganisms that are below the surface of water table level, consequently the decomposition of organic matter increases [17]. In addition logging in secondary forests and switching to a monoculture of oil palm plantation and shrub plants in the bushes decrease the total of biomass so that the input of organic matter will reduce [2]. The combination of increased decomposition of organic matter and the lower number of biomass resulted in the decline of organic matter both in shrubs and in oil palm plantation. The lower content of organic matter in the oil palm plantation compared to the organic matter content in the shrubs caused by the fertilization, soil tillage, and the opening of the ground surface at the beginning of oil palm cultivation resulting in the decomposition of organic matter getting faster.

The content of organic matter affects some of the physical properties of peat such as bulk density, peat strength, and hydraulic conductivity. There was a negative relationship between soil organic matter content and bulk density and peat strength (Figures 3A and 3B), while hydraulic conductivity and moisture content were positively related to organic matter content (Figures 3C and 3D).

All the land use, secondary forest, shrubs, and oil palm plantation show that the bulk density was within the same range of 0.1-0.2 g cm^{-3} which is relatively similar to that of previous researchers [16]-[22-23]. They indicate that these three sites have not yet been fully decomposed regarding the relatively humification level of hemic, except in the 0-10 cm layer in oil palm plantation the humification level of sapric (Table 1). However, there is a difference in bulk density between the three sites, where the highest of bulk density was found in oil palm plantation followed by shrubs and secondary forest (Table 2). They are the result of land clearing using heavy equipment which results in peat dense [24], reflected in lower total porosity and higher peat strength.

The increase in bulk density is positively related to increased of peat strength (Fig. 4e), whereas to the total porosity (Fig. 4f) and hydraulic conductivity (Fig. 4g), the increase in bulk density was negatively related. The decrease in total porosity was due to land management after several years of planting [25]. High peat strength due to increased bulk density and reduced moisture content [17]. The hydraulic conductivity of the three sites also shows differences where there is a decrease from secondary forest to oil palm (Table

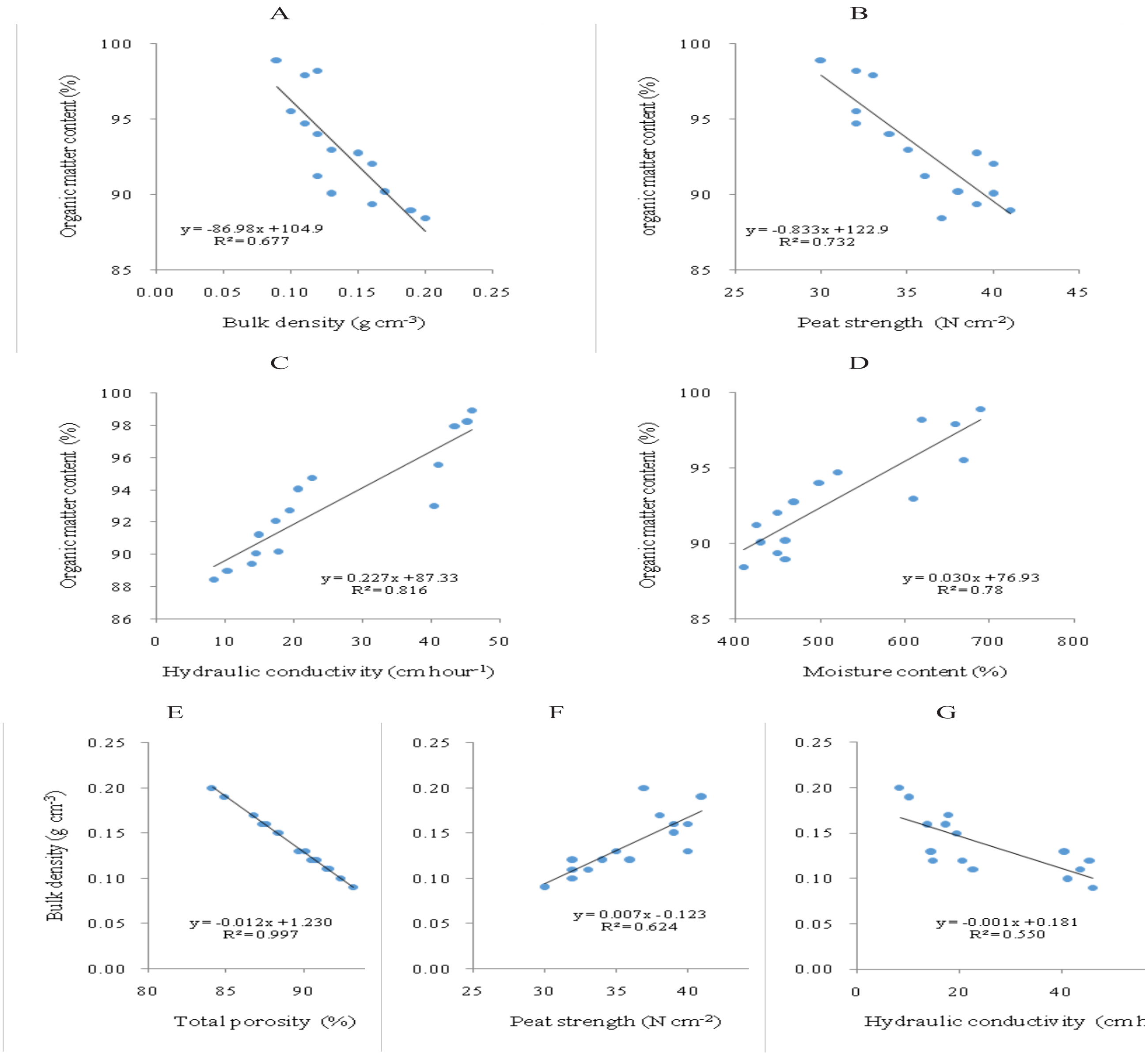

Figure 3. Relationship between organic matter content and bulk density (A); organic matter content and peat strength (B); organic matter content and hydraulic conductivity (C); organic matter content and moisture content (D); bulk density and total porosity (E); bulk density and peat strength (F); bulk density and hydraulic conductivity (G)

2). This condition occurs because of the compacting of peat due to the decomposition of coarser materials into finer materials. This compaction causes the water velocity to flow in the descending field [13].

Peat strength decreased organic matter content and increased humification levels of peat from hemic type to sapric type from secondary forest to shrubs, and oil palm plantation decreases consecutive moisture content of 650%, 520%, and 430% (Table 2). The higher the organic matter content, the higher the moisture content. Also, soil organic matter also improves physical properties such as total porosity, bulk density, peat strength, and hydraulic conductivity. The lower content of organic matter and the worsening of the physical properties of the peat, the moisture content will decrease. The higher the humification level of the peat will reduce its ability to absorb water and hold water [21].

4. Conclusion

Changes in peat land from secondary forests to shrubs, and oil palm areas resulted in changes in some of the physical properties of peat respectively by decreasing total porosity (91.60%, 89.16%, 87.79%), moisture content (650 %, 520%; 430%), hydraulic conductivity (43.20 cm hr^{-1}; 19.63 cm hr^{-1}; 12.42 cm hr^{-1}); and organic matter content (96.73%; 92.75 %; 89.61%). However, there was an increase in bulk density (0.11 g cm^{-3}, 0.14 g cm^{-3}, 0.16 g cm^{-3}), and peat strength (32.40 N cm^{-2}; 36.60 N cm^{-2}; 38,60 N cm^{-2}).

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References

[1] Soil Survey Staff. Keys to Soil Taxonomy 12th. United States Department of Agriculture National Resources Conservation Service, 2014.

[2] G. Anshari, M. Afifudin, M. Nuriman, E. Gusmayanti, L. Arianie, R. Susana, R. Nusantara, J. Sugardjito, and A. Raflastanto. "Drainage and land use impacts on changes in selected peat properties and peat degradation in West Kalimantan Province, Indonesia". Biogeosciences, vol. 7 (11), 3403-3419, 2010.

[3] M.F. Bachia. Peat: Agroecosystem and Carbon Transformation. Gajah Mada University Press, Yokyakarta, 2006, p 2-3.

[4] M.R.C. Posa, L.S. Wijedasa, and R.T. Corlett. "Biodiversity and conservation of tropical peat swamp forest". BioScience, vol. 61 (1), 49-57, 2011.

[5] M.R.C. Posa, L.S. Wijedasa, and R.T. Corlett. "Biodiversity and conservation of tropical peat swamp forest". BioScience, vol. 61 (1), 49-57, 2011.

[6] S. Ritung, Wahyunto, K. Nugroho, Sukarman, Hikmatullah, Suparto, C. Tafakresnanto. Indonesia "Peatlands map scale 1: 250.000". Indonesian Center for Agricultural Land Resources Research and Development, Bogor, 2011.

[7] Center for Agricultural Land Resources (BBSDLP). "Sustainable Management of Degraded Peatlands Supports Agricultural Development Towards 2045". Agricultural Research Agency, Ministry of Agriculture of the Republic of Indonesia, 2014..

[8] P. Gunarso, M.E. Hartoyo, F. Agus, T.J. Killeen. "Oil palm and land use change in Indonesia, Malaysia and Papua New Guinea". Reports from the Technical Panels of the 2nd Greenhouse Gas Working Group of Roundtable on Sustainable Palm Oil (RSPO). Kuala Lumpur, Malaysia, 2013.

[9] Tropenbos International Indonesia. Study on the use of peatlands in Indonesia. Presented at the Seminar on Peatland: Maslahat or Murhadat. Jakarta, Indonesia, 2012.

[10]E.F. Lambin, and P. Meyfroidt. "Global and land use change, economic globalization, and the looming land scarcity". In Proc. NAS, vol. 108, 3465-3472, 2011.

[11]E. Widyati. "Study on optimizing peatland management and climate change issues". Tekno Hutan Tanaman, vol. 4 (2), 57-68, 2011.

[12]Kristohasi. "Analysis of peatlands development for oil palm crops in Kubu Raya District". Jurnal Teknologi Perkebunan dan Pengelolaan Sumberdaya Lahan, vol 1 (1), 1-7, 2011.

[13]M. Firdaus, S. Gandaseca, O. Ahmed, N. Majid. "Effect of converting secondary tropical peat swamp forest into oil palm plantation on selected peat soil physical properties". Am. J. Environ. Sci., vol. 6 (4), 402-405, 2010.

[14]Hooijer, S. Page, J. Jauhainen, W.A. Lee, X.X. Lu, A. Idris, and G. Anshari. "Subsidence and C loss in drainage tropical peatlands". Biogeoscience, vol. 9, 1053 – 1071,2012.

[15]M.E. Armanto. M.S. Imanudin, E. Wildayana, H.Junedi, M.Zuhdi. "Managing actual problems of peatsoills associated with soil acidity". Sriwijaya Journalof Environment, vol 1 (3), 58-63, 2016.

[16]A.J. Tonks, P. Aplin, D.J. Beriro, H. Cooper, S. Evers, C.H. Vane, S. Sjogersten. "Impacts of conversion of tropical peat swamp forest to oil palm plantation on peat organic chemestry, physical properties and carbon stocks". Geoderma, vol. 289, 36-45, 2017.

[17]N.C. Brady and R.R. Weil. The Nature and Properties of Soils. 14th Edn., Prentice Hall, USA., 2007, pp: 980.

[18]I. Bashour and A.H. Sayegh. Methods of Analysisi for Soils of Arid and Semi-Arid Regions. FAO, USA, 2007, pp:119.

[19]M. Murtedza, E. Padmanabhan, B.L.H. Mei, W.B. Soing. The Peat Soils of Serawak. STRAPEAT, 2002.

[20]Las, K. Nugroho, and A. Hidayat. "Strategy of peat land utilization for sustainable agriculture development". Jurnal Pengembangan Inovasi Pertanian, vol. 2 (4), 295-298, 2009.

[21]Suwondo, S. Sabiham, Sumardjo, B. Paramudya. "The effect of land opening on peat bio-physical characteristics on oil palm plantation in Bengkalis Regency. Jurnal Natur Indonesia, vol. 14 (2), 143-149, 2012.

[22]M.B. Prayitno, Sabaruddin, D. Setyawan, Yakup. "Estimation of Carbon peat reserves in palm oil agro-ecosystem". Jurnal Agrista, vol. 17 (3), 86-92, 2013.

[23]Susandi, Oksana, A.T. Arminudin. "Analysis of physical properties of peat in peatland forest in Tambang Sub District, Kampar Regency, Riau Province. Jurnal Agroteknologi, vol. 5 (2), 23-28, 2015.

[24]A.E. Satrio, S. Gandaseca, O.H. Ahmed, N.M.A. Majid. "Effect of logging operation on soil carbon storage of a tropical peat swamp forest". Am. J. Environ Sci., vol. 5, 748-752, 2009.

[25]Z. Yahya, A. Husin, J. Talib, J. Othman, O.H. Ahmed. 2009. "Machinery compaction effects on physical properties of bernam series in an oil palm plantation". Am. J. Applied Sci., vol. 6, 2006-2009, 2009.