（様式５）(Style5)

学位論文全文に代わる要約
Extended Summary in Lieu of Dissertation

氏名：　Khairul Hafiz bin Mohd Yusoff
Name

学位論文題目：
Title of Dissertation

Influences of Agricultural Landuse on Soil Morphological and Physicochemical Properties on Sandy Beach Ridges Interspersed with Swales in East Coast of Peninsular Malaysia.
(半島マレーシア東海岸における浜堤砂質土壌の断面形態と理化学性への農業活動による影響)

学位論文要約：
Dissertation Summary

Introduction

At east coast of Peninsular Malaysia, succession of parallel beach ridges formed beach-ridge plains which consist of two or occasionally three ridges separated by shore-parallel swales and often subdivided into sets of ridges that differ in the altitude of their ridge crests or are limited by erosive discontinuities and prominent ridges/swales. These soils are locally known as beach ridges interspersed with swales (BRIS). Beach ridges are defined as shore parallel, swash aligned, swash or storm-wave built landforms composed of sand, pebbles, cobbles or boulders that are formed above the normal spring high tide level (Hesp 1999). The BRIS area in Peninsular Malaysia is estimated about 162,000 hectares and covers 1.23% of the 13.2 million hectares of the total land area (Zahari et al. 1982). The nearest ridge was located at 50 meter from the shoreline (Roslan et al. 2010). While Spodosols are distributed on the ridges located inland, Entisols are found on the ridges close to the shoreline (Zainuri 1981). In addition, Histosols or closely-related peaty soils are sometimes found in the swales. In Peninsular Malaysia, BRIS soil is referred as one of the problematic soils in Malaysia because of its high sand content (82-99%), acidic nature (pH 4.3-4.4), and low cation exchange capacity (CEC) (Zahari et al. 1982; Chen 1985). In terms of water availability, the soils on the ridges can be characterized by low water holding capacity and excessive drainage (Roslan et al. 2010).

Because of their intrinsic infertility due to sandy texture, these soils are usually regarded as unsuitable for agricultural use, and therefore left under forest or grassland vegetation (Thompson et al. 1996; Sommer et al. 2001; Perez et al. 2011). Unlike other regions, the BRIS land in the Malay Peninsula has been settled and used for agriculture, although the soil is recognized as problematic lowland soil for farming. In fact, there is various sizes of agricultural activities by local farmer, from small-scale farming such as *Citrullus lanatus* (watermelon) and *Nicotiana sp* (tobacco) to large-scale farming such as *Cocos nucifera* (coconut) were found in the BRIS area. Regarding to its naturally nutrients deficiency and water permeability, the agricultural activities in this soil fronting a challenges and high risk. Other than commercial farming, local farmers have been using the ridges for homegardens for supporting their livelihood. In general, homegardens have been admired as a sustainable agroforestry system, which are composed of multi-storey combinations of various plants with the least input of agricultural materials and can provide daily necessities such as food, materials, and medicines (Fernandes & Nair 1986; Kumar & Nair 2004). Other than supporting people livelihood, homegarden is also important for ecological conservation (Kumar and Nair, 2004).

The earlier studies of BRIS soils focused mainly on mapping and classification (Lim 1989; Nossin 1964, 1961; Soo 1975; Zainuri 1981). Although several studies have been conducted on BRIS soils under farmland areas and forests, only a few study were concerned with influences of forest degraded or agricultural activities so far. Most of the studies on agricultural activities on BRIS have been conducted from agronomic viewpoints to

increase crop production. This study, however, was conducted from a soil science viewpoint at two different soil management which are intensive farming and homegarden system. A comprehensive study on soil nutrient dynamics and the influence on the surrounding environment will be required at local farmlands to develop sustainable and eco-friendly cropping systems for BRIS. Thus, to contribute to developing such system for BRIS soils, this study evaluated the influences of agricultural activities on BRIS soils with special reference to the contrasting farming practices, which are; 1) Conventional fruit gardens with a relatively intensive managements; and 2) Homegardens managed by local people.

Study site and methods

For this study, Malaysian Agricultural Research Development Institute (MARDI), Cherating station and Sungai Ular village in the east coast of Pahang were selected as study site (Fig 1). Information on soil morphological and physicochemical properties in MARDI, Cherating research station and as well as adjacent remnant forest were collected. In the field of MARDI, a high input of chemical fertilizers and organic amendments were applied upon planting, followed by monthly application of NPK compounds and urea. Three one-kilometer transect lines from the shoreline toward inland were used for determine the influence of conventional fruit gardens with a relatively intensive management to BRIS soil in comparison with remnant forest. For influences of conventional fruit garden practice, soil profiles in MARDI and adjacent remnant forest were described in terms of soil morphology and physicochemical properties. Soil horizon stratification was also observed along 1 km from shoreline to inland. For homegardens practice, the soil profile in homegardens (HG-I) and adjacent forest of Sungai Ular village was described in terms of soil morphology and physicochemical properties. Assessment on soil fertility under different crop was also carried out to identify the difference in nutrient based on different crop management. The results of this study were interpreted by comparing with conventional fruit garden with intensively management (MARDI) and adjacent forest.

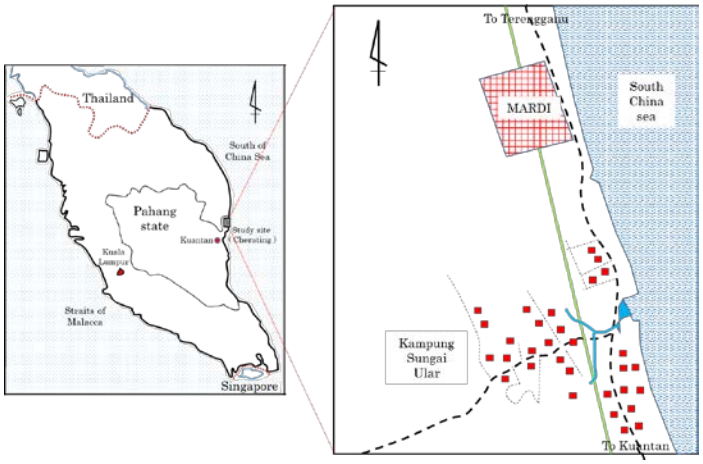

Figure 1: Study site

Study 1: Soil morphological and physicochemical properties in conventional fruit garden with intensive management

This study was conducted to characterize the BRIS soils and to evaluate the influence of agricultural activities on soil characteristics and fertility. Three one-kilometer transects from the shoreline running inland were established; two transects passed through the experimental farm of Cherating Station of the Malaysian Agriculture Research Development Institute (TrC1 and TrC2) while the other transect passed through an adjacent remnant forest (TrF). The soils located close to the shoreline and that further inland were classified as Typic Quartzipsamments and Typic Haplohumods, respectively.

The soils had a very high sand content, occasionally exceeding 95%, were acidic and had low CEC values. While soil organic matter was the determining factor for cation exchange capacity, the regression slope of CEC against soil carbon in the Bhs horizon of the Spodosols was different from that in the other horizons. Because the effective CEC value was much lower than the CEC value, the development of the negative charges on variable-charge surfaces seemed to be largely restricted under acidic conditions. For the Spodosols, the levels of Al and Fe oxides extracted with acid ammonium oxalate and those oxides with dithionite-citrate-sodium bicarbonate were negligible in the A to E horizons, but they showed sharp peaks in the Bhs horizons. Agricultural activities affected the soil in three ways. First, the A horizon of the farm soil had lower amounts of total C and N compared with the forest (Fig 2), suggesting insufficient input of plant litter to sustain original levels of soil organic matter. Second, although the levels of pH, and exchangeable Ca and Mg were higher in the farm soil than the forest, exchangeable K was occasionally not detected despite fertilizer application. This finding might be due to the preferential adsorption of divalent cations over monovalent K on the variable negative charges on soil organic matter surfaces as well as limited development of the charge sites in the sandy soil. Finally, the Spodosols under agricultural land-use had the highest peak of available P in the Bhs horizon despite its low level in the overlying A and E horizons. While phosphate is known to be immobile relative to other anions, our finding suggest the downward translocation of mineral P from fertilizer and its retention in the Bhs horizon. Based on the findings, soil organic matter was very important in BRIS soil.

Increasing organic matter levels of the soils can improve soil fertility through enhancing cation exchange capacity and the resulting increase in basic cations. The A horizons of soils in the MARDI field had lower in T-C and T-N compared with those in the forest, suggesting loss of soil organic matter in the former due enhanced decomposition and insufficient input of organic materials to sustain the level of soil organic matter. While the levels of pH, and exchangeable Ca and Mg of the soils in the MARDI were higher than those in the forest, that of exchangeable K was occasionally under the detection limit despite of fertilizer application. This phenomenon might be ascribable to the fact that variable negative charges on soil organic matter surfaces with preferential adsorption of divalent over monovalent cations are predominant in the limited amounts of charge sites in the sandy soil. The Spodosols in the inland-ward location in the MARDI showed the highest peak of available P in the Bhs horizon despite its low level in the overlying A and E horizons suggesting the downward translocation of mineral P from fertilizer and its retention in the Bhs horizon with higher contents of Fe and Al oxides.

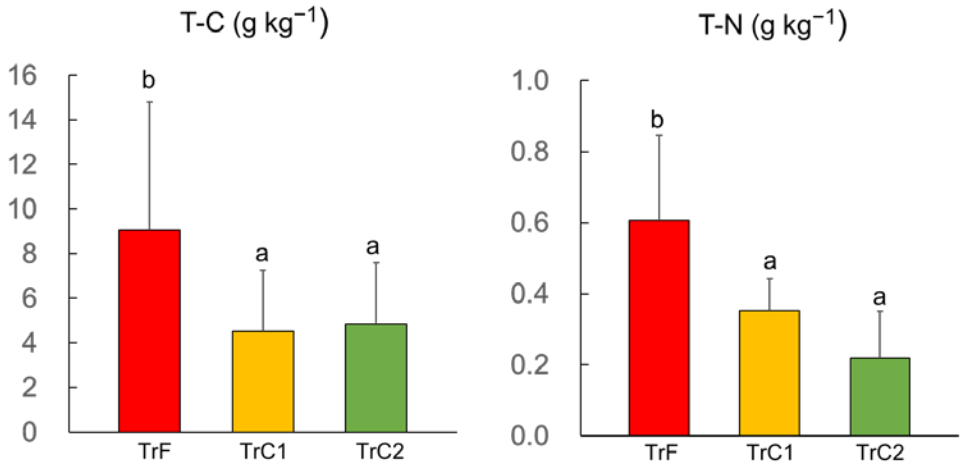

Figure 2: Average of T-C and T-N in A horizon determined at 50 m interval

Study 2: Soil morphological and chemical properties in homegardens by local people

The purpose of this study is to evaluate the morphological and chemical properties of the BRIS soils in homegardens in order to find a clue for developing sustainable agricultural management on the BRIS. A field survey and soil sampling were conducted at homegardens in Sungai Ular Village in Pahang State as well as secondary forests in the village and several fruit tree lots in the experimental farm at Cherating Station, Malaysian Agriculture Research Institute (MARDI). The village was divided into two areas: the inland-ward area occupied mainly by farmers and the shoreline area by fishermen. Chemical fertilizers as well as ash and charcoal produced from burning garbage and plant litter were applied to the homegardens in both the inland-ward area (HG-I) and in the shoreline area (HG-S). Manure was applied in HG-I and seafood waste from fish processing was buried in the soils in HG-S.

The soils were classified as Typic Haplohumods or Typic Haplorthods in HG-I and Typic Quartzipsamments in HG-S. Sand content was around 90% and a high correlation was found between total carbon (T-C) and cation exchange capacity (CEC), indicating soil organic matter was the determinant factor for CEC in the very sandy BRIS soils (Fig 3). The levels of T-C, total nitrogen (T-N), and CEC at depth 0–10 cm in HG-I tended to be high with increasing ages of homegardens, whereas no clear relationship was found in HG-S, probably due to the limited number of sites. The soils in 0–10 cm and 20–30 cm showed higher levels of T-C and T-N with higher C/N ratios in HG-I than in HG-S and the MARDI farm. It has been suggested that the cumulative effects of the combined application of charcoal and manure in the inland-ward area contributed to the augmentation of the soil organic matter pool in a relatively short duration of several decades after homegarden establishment. The levels of exchangeable Ca, Mg, and K tended to be high in HG-I compared with the MARDI farm, suggesting that improved CEC with increasing soil organic matter in HG-I could enhance the retention of basic cations supplied as chemical fertilizer, ash, and manure. The level of available P was higher in HG-S than HG-I, which could be ascribed to seafood waste application in the shoreline area. A clear difference in soil properties was not found in terms of different crops (coconuts, mango, and vegetables).

Thus, on the BRIS, the levels of soil organic matter and nutrients can be sustained by the homegarden management although it cannot be regarded as a closed system compared with those in the other tropical regions because chemical fertilizer was used and a certain amounts of nutrients seemed to leach down beyond plant rooting depth.

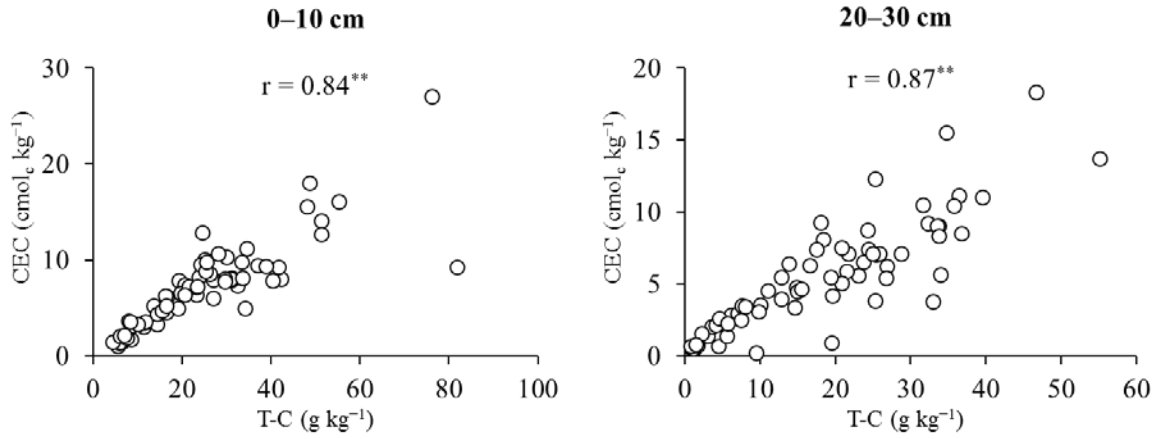

Figure 3: Relationship between T-C and CEC of HG-I and HG-S at two different depths. Left: 0–10 cm, right: 20–30 cm. n=69 for each depth. **, $p < 0.01$

General conclusion

The soil at both sites had a very high sand content, occasionally exceeding 95%. For soil classification, the soils on the ridges located close to the shoreline until 400 m was classified as Typic Quartzipsamments (Entisols) and from 400 m to further inland were classified as a Typic Haplohumods and Typic Haplorthods (Khairul et al. 2017) which belong to Spodosols.

The study on both intensive farming and homegarden revealed that the current intensive schemes by farmland cannot improve the fertility of BRIS soil. The soil under intensive farming undergo loss of organic matter through rapid decomposition. In this study, soil organic matter was the determinant factor for cation exchange capacity in BRIS soils. Hence, limited quantity of organic matter in BRIS soil will not be able to embrace soil nutrient even after rapid application of chemical fertilizer to the soil. Therefore, from this study I can conclude that increasing organic matter levels of the soils improved soil fertility through enhancing cation exchange capacity and as well as increase in basic cations. On the whole, the levels of soil organic matter and nutrients can be sustained by the homegarden management. However, it cannot be regarded as a closed system because chemical fertilizer was used and a certain amounts of nutrients seemed to leach down beyond plant rooting depth. In comparison with intensive farming systems which rely on heavy input of chemical fertilizer, management practices employed in the homegarden can be considered to be more appropriate on the BRIS.

More detailed studies should be required to elucidate the function of combined use of charcoal (Biochar) and manure employed in the homegarden management, which would be the key to sustain soil fertility levels under intensive farming activities on the BRIS.