Faculty of Resource Science and Technology

Characterizing Soils under Various Cash Crops Farming in the Upland Areas of Sarawak-A Case Study at Kruin Area, Sabal

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Bachelor of Science with Honours
(Plant Resource Science and Management)
2012

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ACKNOWLEDGEMENT

First and foremost, I would like to express my sincere gratitude to the following individuals and organizations upon their kindness and unconditional support throughout my study.

The deepest gratitude and thankfulness to my principal supervisor, Dr Mohd Effendi bin Wasli, Senior Lecturer at Faculty of Resource Science and Technology, University Malaysia Sarawak (UNIMAS) for his untiring guidance, kind assistance, valuable suggestions and constant encouragement throughout this project. Such gratitude also dedicated to Mdm Hafsah Nahrawi, for her guidance and kind assistance throughout the project.

Special thanks also dedicated to Ekin ak Empati and family and the people at Kruin Village, Sabal (rumah Dingin, rumah Ijau, rumah Niah, rumah Baong, and rumah Rendak) for their very kind assistance, constant encouragement, untiring help and warm hospitality during field sampling in Kruin Village, Sabal.

I would like to thank Syafiq, laboratory assistant of Faculty of Resource Science and Technology, University Malaysia Sarawak (UNIMAS) for preparing the laboratory equipments and field equipments during my field sampling and laboratory analysis.

My laboratory mates, Nurhanani Hanis and Alissee Sherryln Bagol, thank you very much for your assistance and help during the laboratory works and analysis. To all my friends who are willing to extent their help in every possible way, thank you very much.

My beloved siblings, Soo Shyan, Soo Jin, Chia Yen, Wei Haw and Wei Ren for their love and support. Special thanks to Chin Kian Tap for his love, support and encouragement

throughout the project. Finally, I would like to thank my parents, Ho Chin Lim and Tan Kwee Bee for their countless sacrifices, love, support and encouragements making me believe that where there is a will, there is a way. To my parents and my family, I dedicated my dissertation.

To all that mentioned above, thank you very much.

DECLARATION

No portion of the work referred to in this dissertation has been submitted in support of an application of another degree of qualification of this or any other university or institution of higher learning.

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LIST OF ABBREVIATIONS

Al	Aluminium
Ca	Calcium
EC	Electrical Conductivity
Fr	Fruit Orchard
H	Hydrogen
H_2O	Water
HG	Home Garden
K	Potassium
kg	Kilogram
KCl	Potassium Chloride
Mg	Magnesium
MgO	Magnesium Oxide
N	Nitrogen
Na	Sodium
NADPH	Reduced Nicotinamide Adenine Dinucleotide Phosphate
OP	Oil palm field
P	Phosphorus
Pe	Pepper farm
Ru	Rubber field
Te	Trace elements
USDA	United States Department of Agriculture
cm	Centimeter

$cmol_c kg^{-1}$	centimole charge per kg
gmL^{-1}	gram per millimeter
ha^{-1}	per hectare
mm	millimeter
μScm^{-1}	microsiemen per centimeter
°	Degree
°C	degree Celcius
%	Percentage

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ABSTRACT

Population expansion and the need of cash income result in intensified upland agricultural practices globally. Even though efforts are progressing towards sustaining the agricultural practices in upland areas, however, limited studies discuss on the present condition of upland agricultural practice. This study discusses present soil fertility status and condition under various kinds of perennial cash crops farming (rubber, *Hevea brasiliensis*; pepper, *Piper nigrum*; oil palm, *Elaeis guineensis*; vegetables and fruits) in an upland area of Sarawak, Malaysia towards providing fundamental information and future perspective of the current farming practice. The study was conducted at Kruin village in Sabal, Serian. Soil samples were collected in each type of agricultural lands at the depths of 0-10cm and 30-40cm for soil physicochemical analysis. The results showed that the soils are sandy in texture with acidic nature which results in high Al saturation. The clay content is low with approximately 13.8 % at the study area. At different agricultural lands, soil exchangeable bases and total C were low and did not varied widely although some sites especially in the home garden showed significantly high level of exchangeable Ca. High level of exchangeable Ca in home garden probably due to the external input of soil with different parent material and ash effect from addition of burnt materials and left over unburned materials such as charcoal from household waste. At pepper farm, bulk density and soil hardness were high, indicating regular farming practices such as harvesting and weeding have resulted in considerable soil compaction. Based on the soil analysis, it can be concluded that current farming practice does not show much impacts to the soil, the chemicals levels in the soils were low, indicating little use of agrochemicals in the farming practice. However, technologies such as intercropping and crop rotation should be integrated into current farming practice to conserve soil fertility towards a more sustainable upland agriculture in the future.

Keywords: cash crop farming, upland agriculture, Sarawak, soil physicochemical properties.

ABSTRAK

Perkembangan populasi dan peningkatan dalam pendapatan telah mendorong kegiatan pertanian yang intensif, terutamanya tanah tinggi di kawasan tropika. Walaupun pelbagai usaha telah dilakukan untuk mengamalkan aktiviti pertanian yang mampan, tetapi informasi semasa tentang aktiviti pertanian di kawasan tanah tinggi masih terhad, terutamanya di Sarawak, Malaysia. Kesuburan tanah semasa di bawah tanaman tunai (getah,, Hevea brasiliensis; lada hitam, Piper nigrum; kelapa sawit, Elaeis guineensis; sayur-sayuran dan buah-buahan) di Kampung Kruin, Sabal, Sarawak telah dikenalpasti untuk memberikan informasi dasar dan perspektif masa depan tentang perkembangan semasa amalan pertanian di kawasan tanah tinggi. Sampel tanah dikutip pada kedalaman 0-10cm dan 30-40cm untuk analisis sifat fizikal dan kimia tanah. Kajian menunjukkan tanah di kawasan Kruin adalah jenis pasir dan berasidyang menyebabkan tanah di kawasan tersebut mempunyai ketepuan Al yang tinggi. Kawasan pertanian yang berbeza menunjukkan kandungan alkali dan jumlah C yang rendah serta tidak banyak berbeza di kawasan yang berlainan. Kawasan sayur-sayuran menunjukkan kandungan Ca yang sangat tinggi, mungkin disebabkan oleh kesan abu akibat dari pada pembakaran dan sisa arang. Di kawasan lada, kekerasan tanah adalah lebih tinggi tetapi masih dalam keadaan terkawal menunjukkan kekerapan dalam pengawalan rumpai dan penuaian. Kajian menunjukkan amalan pertanian semasa tidak memberi impak yang nyata terhadap tanah di kawasan tersebut. Kandungan alkali dalam tanah adalah rendah menunjukkan input baja yang terhad dalam amalan pertanian. Namun demikian, teknologi seperti penanaman campuran dan penanaman bergilir perlu diamalkan untuk menjamin kemampan dan kesuburan tanah di kawasan tanah tinggi pada masa yang akan datang.

***Kata kunci**: tanaman tunai, kawasan tanah tinggi, Sarawak, analisis sifat fizikal-kimia tanah.*

1.0 INTRODUCTION

1.1 Background of the Study

Recently, one of the crucial problems faced globally is food crisis where the food produced is not sufficient for the growing population throughout the world (Mung'ong'o, 2000). Ramakrishnan (1994) reported that continuous increase in the world population throughout the years has brought considerable pressure on the existing land and water resources. Therefore, most agriculturists, mainly subsistence farmers have been putting various efforts in looking for larger agriculture lands, particularly in uplands areas (Padoch et al., 2001). Especially in the upland areas of Asian region, the local indigenous communities still depend largely on traditional form of shifting cultivation practices as their major source of livelihood for subsistence (Kleinman et al., 1995; Watanabe et al., 2004). This has accelerated land clearing processes in large forest areas to accommodate various forms of agricultural activities for their subsistence (Klienman et al., 1995). Such phenomenon will lead to environmental problems such as soil degradation and loss of biodiversity if these resources are not managed properly.

Furthermore, increase in population pressure and influence of commercialism leads to the increasing of human impact of agricultural use on naturally forested areas in humid tropics and subtropics (Funakawa et al., 1997). Although shifting cultivation was formerly the central agricultural activity, however, due to the changes in socio-economic with industrialism development, such agricultural practices have changed into a more diversified upland farming system (Cramb, 1993). Especially in the Asian countries, the agricultural sectors have become commercialized when government offered various kinds of agricultural subsidy schemes and

advices to current agricultural management practices (Lim & Douglas, 2000). This involves the shortening of fallow cycles and several years of continuous cropping with significant fertilizer application (Boonyanuphap et al., 2007).

In Sarawak, agricultural lands cover three different types of areas namely coastal lowland, central lowland and interior upland areas (Teng, 2003). As reported by Aminuddin et al. (1990), 1.81 million hectares of interior upland areas in Sarawak are marginally suitable for agricultural practices which, including steep slopes. This is due to the type of soil that covers the upland areas of Sarawak is Ultisols which formed in association with non-basic geological formations (Soil Survey Staff, 1999). Agricultural practices in Sarawak are mainly characterized by shifting cultivations (Padoch et al., 2001). Successful rotation of soil fertility normally requires considerable fallow period for sufficient restoring soil fertility lost during cropping period (Sanchez, 1995).

However, due to population expansion and depletion in available land resources for agricultural purposes in Sarawak, the traditional form of landuse practices have slowly being abandoned by the local farmers (Lim & Douglas, 2000). In the meantime, these areas are most likely to decline due to gradual changes in various aspects such as the social structure, political and national policies, environmental and cultural aspects (Food and Agriculture Organizations, 2003). These have much influenced the modification of swidden traditional land use practices towards a sedentary form of agricultural practices involving use of agrochemicals. Without proper management of agrochemicals applications and its interventions, such cause may lead to environmental degradation (Padoch et al., 2001).

1.2 Problem Statement

Various studies have been conducted mainly on the effect of shifting cultivation to soil ecosystems, physical properties and fertility in the upland areas in the tropics (Cramb, 1989a; Watanabe et al., 2004; Kendawang et al., 2004; Hattori et al., 2005; Tanaka et al., 2009). Regarding site suitability for agriculture as well as vegetation condition in fallow lands, limited studies have been carried out in the interior upland areas of Sarawak and fallow shifting cultivation land (Bruun et al., 2006; de Neegard et al., 2008; Wasli et al., 2009). Limited attention has been paid on the current situation of intensive upland agricultural practices in the Sarawak. Moreover, although government paid attention to the need to sustain upland agricultural practices, still, limited information is available on the outcome of such scenario in the current upland farming system.

1.3 Objectives

Without information and evidence on the current conditions in the upland farming systems, the sustainability of agricultural practices in the upland areas is at stake. Environmental problems still exist if proper management is not implemented, and this goes against the mission in sustaining the upland agriculture. The objective of this study is to characterize soils under different types of perennial cash crops farming which are rubber (*Hevea brasiliensis)*, pepper (*Piper nigrum*), oil palm (*Elaeis guineensis*), vegetables and fruits in order to provide fundamental information and perspectives about upland agricultural practices of Sarawak, using a case scenario of Kruin area, Sabal. Such information is vital as a guideline for research purposes in the future to improve the farming systems towards

sustainable upland farming system in the upland areas of Sarawak where the economic, environment, social and cultural values are to be well-managed.

2.0 LITERATURE REVIEW

2.1 Information on Cash Crops Farming Practices in Sarawak

Tajima (2004) proposed that uplands areas have been providing foods and livelihoods to the millions of people in Asia. The type of soil that covers the upland areas of Asia, including Sarawak is Ultisols (Soil Survey Staff, 1999) which is derived from cretaceous sandstones and Pleistocene unconsolidated coastal sediments which is also characterized by high acidity, low nutrient status as well as low fertility unless with proper management (Orimoloye et al., 2010). It can be further defined as strongly acidic, highly weathered soil of tropical and subtropical climates (Soil Survey Staff, 1999).

Nutrients may leached out or washed away especially during high precipitation, long cropping period at permanent sites may result in poor yield due to the limitation of nutrients availability (Soil Survey Staff, 1999). Tajima (2004) reported that at the steeper slopes, crop yield is lesser than the non - steep slopes. Most steep land in Sarawak is low in cation exchange capacity (CEC) and water holding capacity (Sanchez et al., 1985). Therefore, such soil is unfavourable for continuous, long term cultivation of most food crops as few readily available soil nutrients are rapidly depleted. The composition of basic cations such as potassium and magnesium are particularly low due to leaching as a result of high precipitation annually (Soil Survey Staff, 1990).

Local indigenous farmers for many generations practiced shifting cultivation, particularly in cultivation of hills rice as their staple food (Ramakrishnan, 1994). A study conducted by Wasli et al. (2009) claimed that traditional shifting cultivation involved a relatively short cropping period with long forest fallow phase as a rotational system in space

and time. Perera (2009) reported that the local farmers also try to improve their food security by cultivating vegetables and fruits in or nearby their home gardens, gathering jungle products such as fern and fruits. Previous studies proposed that majority of the population in Sarawak still depended on shifting cultivation few decades ago but the precise data on the area under swidden Sarawak are hard to come by (Mertz et al., 1999; Nielson et al., 2006).

However, population expansion at the Sarawak creates pressure on resource such as land, water and food and the increasing need for cash incomes through years, local farmers practice cash crop agriculture in the upland areas in Sarawak (Tanaka et al., 2009). Various types of cash crops are cultivated with shorter fallow length with agrochemicals applications such as herbicides and fertilizer (Padoch et al., 2001). This shows that cash crops are the main source of income and livelihood for the indigenous farmers in the upland areas of Sarawak. Three main crops that play important role in cash crops farming of local farmers in Sarawak are rubbers, peppers and cocoa at the 19^{th} century (Ngidang, 2002).

Rubber cultivation is the most common in upland agriculture practices. This is because the market price of rubber is considered stable and less fluctuation compare to other cash crops market price (Orimoloye et al., 2010). According to Ngidang (2002), rubber cultivation was chosen by local indigenous who practices shifting cultivation because it can be easily incorporated into cropping system. The seedlings are planted simultaneously or together with upland rice. This is also one of the indigenous soil fertility maintenance by intercropping to improve the nutrient availability and soil fertility. Also, rubber is incorporated in the swidden-fallow cycle as they may earn incomes while waiting for suitable period to harvest upland rice (Klienman et al., 1995).

Study conducted by Lemmens et al. (1995) showed that rubber grows best in well-drained, clayey and deep clay soil. However, Rantala (2006) discovered that rubber can withstand different type of soil ranging from stiff clay with poor drainage to well drained sandy loam. Also, physical environment and climate also plays an important role in rubber cultivation. Rubbers prefer well-drained, acidic soil with pH ranging from 5 to 6 (Lemmens et al., 1995). de Jong (2011) pointed out that rubber cultivation in upland area encouraged and stimulated forest reconstruction. They argued that the introduction of rubber has not only affected the deforestation by Dayak farmers but also their reforestation activities, where the Dayak farmers transformed non-forested land into forest (de Jong, 1997).

Pepper farming is also among the important cash crops in upland areas of Sarawak (Padoch et al., 2001). According to Paulus (n.d.), an officer of Agriculture Research Center Sarawak (ARCS), pepper is one of the most important cash crops supporting the livelihood of about 67,000 rural dwellers in upland areas of Sarawak. Most of the farmers are smallholders with the areas of approximately 0.2 hectares, concentrate in certain district of Sarawak such as Kuching, Samarahan, Betong, Sri Aman and Sarikei (Paulus, n.d.). Pepper is a plant of humid tropics which require 2000mm to 3000mm rainfall annually, tropical temperature, and high relative humidity with little variation in day length throughout the year (Sivaraman et al., 1999). Mathew et al. (1995) proposed that soil with near neutral pH, high organic matter and high base saturation with calcium and magnesium enhanced the productivity. However, soil in upland areas is Ultisols which usually lack of basic cations needed by the plants to grow. Therefore, it is important to apply agrochemical fertilizer to enhance the yield of black pepper. Water logged soil are not suitable for black pepper cultivation (Nambiar et al., 1965; de

Waard, 1979), but well drained loamy soil rich in humus nourish the crops well (Sivaraman et al., 1999).

According to Capistrano and Marten (1986), home gardens in Southeast Asia typically occupy an area of about 1000 square meters or less immediately surrounding the house or land tenured by each household. Terra (1958) reported that home gardens are usually domesticated or semi-domesticated plants with a variety uses such as food, fuel, construction materials, herbal medicine, ornamentation and shade purposes. Home gardens consists of various kinds of cultivated plants such as fruit trees, domestic vegetables and others which are often in continuous production throughout the year either as subsistence or as source of food (Midmore et al., 1996). Practically, kitchen wastes and well water are often used to fertilize the vegetables and fruit crops in the home gardens (Mung'ong'o, 2000).

Nowadays, with the high demand and higher market price for oil palm, oil palm cultivation becomes more preferable than cocoa (Mutert, 1999). Recently, especially in Sarawak, with higher demand for palm oil products and limitations of agricultural lands, oil palms are introduced to the upland agricultural practices by smallholders and local farmers (Ngidang, 2002). Ngidang (2002) stated that farmers at both Sabah and Sarawak are currently facing increased pressure from local government and joint venture companies to convert most of the upland agricultural area into large scale commercial crop plantations, especially oil palm. One of the reasons that oil palm are cultivated in upland areas is because oil palm can withstand in a range of soil (Basiron, 2007). It may even grow well in poor soil if it is well-managed. Mutert (1999) reported that a wide range of soils derived from igneous and

sedimentary rocks, peat and volcanic ash are commonly planted with oil palm in Southeast Asia.

Mutert (1999) also proposed that highly weathered soil such as Ultisols with low fertility are successfully planted with oil palm in Southeast Asia. However, oil palm is sensitive to soil with pH above 7.5 and stagnant water (von Uexkull, 1990). According to Basiron (2007), oil palm cultivation needs frequent fertilizer application to ease growth and productivity of the fresh fruit bunches, especially in young mature state. In older or mature palm stands, they require large amount of potassium in order to increase the productivity of the palm trees (Basiron, 2007). According to Uexkull (1990), fertilizer application becomes more frequent in uplands areas as they are prone to leaching, thus nutrients in the soil can only be recovered through manuring. Weed infestation in the oil palm field are common, therefore, agrochemical herbicides and pesticides are applied widely to control the weed population and pest in the field (Watts, 2011).

2.2 Present Condition on Sustainability of Farming System in Upland Areas

Agriculture sustainability is a long term, complex and multi-faceted issue (Gorrie, 1999). The three aspects which are the environmental, social and economic sustainability dynamically interact with each other, thus, it is necessary to maintain these three components in equilibrium (Tscirley & Preety, 1996). Uplands areas play a vital role as watershed in the conservation of water resources and the maintenance of stable ecosystem (Adiningsih et al., n.d.). Appropriate and effective management in upland farming system is therefore a key issue in order to conserve the upland agricultural practices sustainably.

Population pressure and ineffective upland farming system induce problems of soil degradation such as soil erosion, agrochemical pollution, and decrease in soil fertility (Adiningsih et al., n.d; Aminuddin et al., 1990; Ramakrishnan, 1994; Tilman et al., 2002). Tscirley and Preety (1996) explained that intensive cash crops growing without effective management on soil fertility are more susceptible to soil nutrient loss which leads to the soil erosion result from ground preparation and clear cutting. As an example, black pepper cultivation on clean-weeded, relatively steep slopes with poorly constructed terraces, which are common in Sarawak local farming systems, has easily lead to soil erosion in long run (Paulus, n.d.). Even though yield and productivity are important to the farmers, however, maintaining the soil fertility is vital especially towards prolonging and effective cropping system in the upland areas (Lim & Douglas, 2000).

Royal Forest Department of Thailand (2000) introduces terracing and planting of cover crops on steep slopes at Northern region of Thailand to prevent soil erosion. Also, planting of cover crops especially legumes may provide nitrogen to the crops through nitrogen fixation. In the tropics, precipitation often ranges from 1500mm to more than 3000mm per year, thus, the uppermost top soil nutrients often being washed away by the rain water (Meteorological Department, 2010). The environmental impacts can be reduced by intercropping or mixed cropping of cash crops with other agricultural crops, as an example intercropping of rubber and oil palm with banana (Cramb, 1989a). This is done not only to minimize the risk of soil erosion but also to conserve and sustain soil fertility with multi-cropping system in upland areas (Royal Forest Department, 2000).

Various methods in terms of soil and fertilizer management have been carried out to sustain cash crops cultivation (Basiron, 2007). Fertilizer which is in combination of N, P and K fertilizers was used (Bolton, 1964). Tscirley and Preety (1996) found out that under high rainfall and highly acidic conditions of inland soils, various types of phosphatic rocks are used, which slowly release P to plants over time. Rock phosphate is a cheap source for both crops and leguminous cover crops. Rock phosphates have a high residual value therefore they benefit the crop for a long period (Middleton & Pushparajah, 1966). In oil palm cultivation, nutrients are recycled back into the soil through application of empty fruit bunches and palm oil mill effluent, this not only minimized the usage of inorganic fertilizers, but also may retained the soil fertility status through natural decomposition methods by soil microbes (Basiron, 2007).

Globalization triggered rapid population growth and increased incomes raising the demand for vegetables (Arsanti et al., 2007). According to Food Agricultural Organization (2011), the increase in production of vegetables result in sharp increase in yield and expansion of areas cultivated with vegetables. Commercial vegetable gardening therefore expanded rapidly, especially in upland areas in response to the high demand of the market (Mercado, 2008). However, inappropriate farming system and unsustainable vegetable farming systems lead to soil erosion as well as soil infertility (Midmore et al., 1996). Soil nutrient loss due to traditional farming method which is lack of proper fertilizer input practices as well as soil fertility management (Akhter, n.d.). Most of the local farmers practiced fallow systems where they will leave the areas for a period of time and re-cultivate it after a few years resulting in the soil of fallow lands that were highly acidic, nutrient poor and higher in exchangeable aluminum compared to land currently under cultivation (Midmore et al., 1996).