Agriculture, Ecosystems and Environment 129 (2009) 293–301

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

Soil characteristics under cash crop farming in upland areas of Sarawak, Malaysia

Sota Tanaka [a,*], Sayaka Tachibe [b], Mohd Effendi Bin Wasli [a], Jonathan Lat [c], Logie Seman [c], Joseph Jawa Kendawang [c], Kozo Iwasaki [b], Katsutoshi Sakurai [b]

[a] Graduate School of Kuroshio Science, Kochi University, Nankoku, Kochi 783-8502, Japan
[b] Faculty of Agriculture, Kochi University, Nankoku, Kochi 783-8502, Japan
[c] Forest Department Sarawak, Kuching 93660, Malaysia

ARTICLE INFO

Article history:
Received 19 June 2008
Received in revised form 27 September 2008
Accepted 2 October 2008
Available online 11 November 2008

Keywords:
Para rubber
Black pepper
Oil palm
Soil fertility
Sarawak
Upland farming

ABSTRACT

This study discusses soil fertility under perennial cash crop farming (para rubber, *Hevea brasiliensis*; black pepper, *Piper nigrum*; oil palm, *Elaeis guineensis*) conducted by local farmers and an oil palm estate in an upland area of Sarawak, Malaysia, in comparison with the surrounding secondary forests. In the farmlands of the local farmers, rubber farming was conducted without fertilizer application, while 2–5 t ha^{-1} of NPK compounds were applied annually on pepper farms. Soils under rubber farming were acidic with poor nutrient contents, resembling soils in secondary forests. In pepper farms, soils were less acidic and showed high nutrient contents, especially with respect to available P and exchangeable Ca. This trend became stronger with increasing farming duration. Fertilizers applied around pepper vines appeared to migrate and spread across the fields. Bulk density and hardness of surface soils were higher in pepper farms than in secondary forests, indicating soil compaction due to field works. In the oil palm estate, annual fertilizer application rates were moderate at 0.4–0.8 t ha^{-1} of NPK compound fertilizers. However, the soil properties in the oil palm estate were similar to those of the small-scale pepper farms. Close to the bases of the palms where fertilizers usually are applied, the contents of exchangeable Ca and available P were high. Nutrient uptake by the dense root systems of the palms seemed to prevent excessive loss of nutrients through leaching. Loss of soil organic matter and deterioration of soil physical properties were brought about by terrace bench construction, but the soils seemed to recover to some extent over time. In conclusion, technologies such as intercropping and the appropriate allocation of different crops to specific locations as well as the proper selection and dosage of fertilizers should be developed and adopted to improve fertilizer efficiency and prevent water pollution due to fertilizer wash-off from farmlands.

1. Introduction

In the upland of Sarawak, Malaysia, local farmers grow para rubber (*Hevea brasiliensis*) and black pepper (*Piper nigrum*) as perennial cash crops in addition to upland rice as their staple food by shifting cultivation practices. According to Crumb (2007), rubber farming was introduced at the beginning of the 20th century. It was adopted preferentially by farmers applying shifting cultivation, as it could easily be incorporated into cropping/fallow systems by planting its seedlings simultaneously or in sequence with upland rice. On the other hand, pepper farming began in the 1870s but became widespread only after the Second World War because of the high requirements for labor and agrochemical input. One characteristic of rubber and pepper production in Sarawak is that it has been conducted mainly by smallholders supported by the government's agricultural policies. Recently, with increasing need for cash income in a monetary economy, the significance of cash crop farming has increased. As a result, the shifting cultivation for rice production, formerly the most important agricultural activity and consequently, the central element of traditional local farming societies (Jensen, 1965; Freeman, 1970), changed into a mere component of a more diverse upland farming system (Crumb, 1993). This tendency toward commercialization was strengthened by various kinds of subsidy schemes provided by the Department of Agriculture of the state since the 1970s. Meanwhile, since the 1970s and 1980s, large-scale oil palm (*Elaeis guineensis*) plantations have been developed rapidly by public agencies of the federal and state governments as well as by private companies

* Corresponding author at: Graduate School of Kuroshio Science, Kochi University, B202 Monobe, Nankoku, Kochi 783-8502, Japan.
Tel.: +81 88 864 5183; fax: +81 88 864 5183.
E-mail address: sotatnk@kochi-u.ac.jp (S. Tanaka).

0167-8809/$ – see front matter © 2008 Elsevier B.V. All rights reserved.
doi:10.1016/j.agee.2008.10.001

(Ngidang, 2002; Crumb, 2007). Some local farmers possess their own small-scale oil palm farm, sometimes supported by subsidies.

The total areas under perennial cash crops in Sarawak were estimated to be 156,731 ha for rubber, 12,930 ha for pepper, and 508,307 ha for oil palm in 2004, which accounted for 16.8, 1.4, and 54.5% of the total agricultural land, respectively (Department of Statistics, Malaysia). The areas covered by rice (excluding fallow land) amounted to 60,354 ha for lowland and 66,065 ha for upland varieties. The area used for oil palm farming expanded from 116,036 ha in 1995 to 508,307 ha in 2004 while those of other crops stagnated or declined slightly.

The farmlands utilized for rice and cash crops as well as oil palm farming tend to be located along roadsides or rivers because of easy access and transportation (Hansen and Mertz, 2006), resulting in an increasing intensity of land use at such favorable sites. In the traditional shifting cultivation, upland rice was grown only once after slashing and burning of secondary forest that was more than 10–15 years old; afterwards, the field was turned to fallow. Nowadays, the fallow period is around 5 years and upland rice is cultivated two to three times in a row (Kendawang et al., 2005). Chemical fertilizers are widely used, especially in pepper and oil palm farming. This transformation from traditional shifting cultivation with low external input toward more sedentary farming practices with high input may affect soil fertility and, in consequence, the sustainability of the upland agricultural system.

The transformation and present situation of upland agriculture in Sarawak have been studied mostly from socioeconomic viewpoints (Best, 1988; Cooke, 2002; Ngidang, 2002; Hansen, 2005; Crumb, 2007; Ichikawa, 2007). Regarding crop production, numerous field trials have been carried out in peninsular Malaysia and Sarawak to optimize land management practices including fertilizer application (see, for example, Broughthon, 1977 for rubber, Raj, 1972 for pepper, Agamuthu and Broughton, 1985 and Khalid et al., 2000 for oil palm). The impacts of soil erosion were examined in the context of pepper farming (Hatch, 1981; de Neergaard et al., 2008), while the effects of slope terracing on soil properties were studied in rubber (Noguchi et al., 2003) and oil palm plantations (Hamdan et al., 2000). However, many of these studies have been carried out in well-controlled experimental fields of government institutions or estates and were concerned with only one particular farming practice. No attention has been paid to how different cash crop farming practices might influence soil fertility through the actual field management by local farmers.

The aim of this study was to evaluate soil fertility under different perennial cash crop farming practices (rubber, pepper and oil palm) in the Lubok Antu district of the Sri Aman division in order to provide fundamental information and perspectives for the development of appropriate and effective management systems. The hilly terrain of the study area is being used for rice and cash crop farming by local farmers. They cultivate upland rice following slashing and burning of secondary forests, and plant cash crops during or immediately after rice cropping. In addition, parts of the secondary forests have been allocated for a large-scale oil palm plantation scheme by the Sarawak Land Consolidation and Rehabilitation Authority (SALCRA) since the late 1970s. These diverse types of land use within one upland region allowed us to compare soil fertility under various farming practices to that of the surrounding secondary forests which can be regarded as a control.

2. Materials and methods

2.1. Study area and sites

This study was conducted from 2004 to 2007 at Lubok Antu district, Sri Aman division in Sarawak. The district is located near the border with West Kalimantan, Indonesia, and has been inhabited for 400 years by the Iban people, the largest tribal group of Sarawak. Except for some riverine and swampy sites suitable for lowland rice cultivation, the study area is composed of rolling hills with an altitude below 500 m ASL. The mean annual precipitation was 2926 mm from 1996 to 2005 with a drier season from June to August and a wetter season from September to December (Department of Irrigation and Drainage, 2005). The mean annual temperature is 26.4 °C (Meteorological Department, 2006). Soils originated from sedimentary rocks of the Palaeocene to Eocene periods.

Study sites were established in secondary forests and rubber, pepper and oil palm farms of three Iban longhouses, Karak (01°12′10′N, 111°40′51″E), Bak (01°13′04′N, 111°43′88″E) and Serau (01°02′46′N, 111°47′60″E) and at the Lemanak oil palm plantation estate of the SALCRA (01°10′80′N, 111°44′85″E; location of the estate office). The socioeconomic outlines of these longhouse communities are given in Kendawang et al. (2005). In these longhouses, cacao (*Theobroma cacao*) also used to be planted as a cash crop but almost all of the fields have been abandoned due to problems such as disease infestation. The Iban landowners were asked questions about farming histories of the sites and crop management. The ages of secondary forests and cash crop farms were determined based on the owners' recalling. However, the information often was ambiguous, especially in the case of old rubber farms, when answers like, for example, 'during his (her) father's or grandfather's generation' were given. In such cases, we estimated the age based on the assumption that one generation corresponded to 25 years, and on memorable incidents. Information about the oil palm estate was provided from the Lemanak regional office of the SALCRA.

In May and June 2004, a field survey was conducted at 30 secondary forest sites, including 12 sites from 2 to 5 years of age, 9 sites from 7 to 10 years, and 9 sites from 12 to 44 years. All of the secondary forests developed after one or two rice cropping cycles in a shifting cultivation scheme. According to the landowners, the sites with forests less than 10 years old were slated for cropping. Many older forests were left unused because clearing would be too laborious, although the owners believed that the soil fertility had recovered sufficiently for rice cropping. In June 2006, 25 rubber and 24 pepper farms were surveyed; the rubber farms included 8 sites 2–5 years old, 9 sites 15–35 years old, and 8 sites 50–60 years old. The pepper farms included 8 sites from 1 to 4 years old, 9 sites from 7 to 10 years old, and 7 sites from 12 to 22 years old. These farmlands had been established during or after rice cropping. Although soil fertility levels had been estimated through observation of the vegetation before rice cultivation started, a systematic assessment had not taken place at the time when pepper plants or rubber trees were planted. Except for cases in which soil fertility was obviously very low resulting in poor rice yield, pepper and rubber farms were started at any sites that were disposable at the time when planting materials and labor became available through the farmer's own efforts or the subsidy program. In older rubber farms, dead rubber trees occasionally had been replaced with naturally regenerated rubber seedlings while an improved high yielding clone had been introduced recently into newly opened farms through the subsidy program. Oil palm farms were surveyed in March 2007, but not more than nine were available because oil palms were cultivated only by the Bak community. Six of the oil palm farms were 8 years old reflecting the year when the subsidy had been provided; the other three, for which no subsidies had been provided, were 1, 4, and 17 years old.

The Lemanak oil palm estate was surveyed in March 2007. It had been established in secondary forests which belonged to longhouse territories and for which the Iban farmers asserted