Research article

Soil Quality Assessment for Coffee Production in Pakxong District, Champasak Province of Lao People's Democratic Republic

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Abstract Soil properties and soil types suitable for coffee production have not been well researched in Lao People's Democratic Republic. The objectives of this study were to determine the basic physical and chemical properties of the soils planted to coffee at different elevations and to identify the soil types that are suitable for coffee production. Nine coffee growing sites located in nine villages of Pakxong district, Champasak province were selected as representatives of major coffee growing areas in Laos including Lak 35, Lak 40, Nongbone, Lak 43, Kapheu, Nonglouang, Phoumaknao, Phou Oy and Phoumako. Trenches were created in these coffee plantations to study soil profiles and soil samples were analyzed physically and chemically in laboratory. Soils in all sites were classified in the great group of Acrisols. These soils were mostly highly acidic, and lime amendment was necessary to sustain coffee yield. Deficiencies of phosphorus and potassium occur in some sites but nitrogen was abundant in most soils. Soil physical and hydraulic properties favor the production of coffee and it can be grown successfully in all soils without severe limitations. Phoumaknao and Phoumako were identified as the most productive sites for coffee because of high organic mater, high cation exchange capacity and high soil nitrogen content. Fertilizer recommendations and lime requirement are site-specific and should be based on plant and soil analysis. Maintaining high organic matter should result in sustaining coffee productivity in these areas.

Keywords acrisols, coffee production, lime amendment, soil profile, soil properties

INTRODUCTION

Coffee (*Coffea spp*) is an economically important crop of many countries including Laos and it is a key export commodity of the country. The areas planted to coffee are mostly in the southern region particularly in Champasak province where 72% of the national production is produced. Arabica and Robusta botanical types are commonly cultivated in this region (Vilavong, 2004). Although coffee is economically important information on soil suitability for coffee production is still lacking and further investigations are urgently required. The objectives of this study were to determine the basic physical and chemical properties of the soils planted to coffee at different elevations and to identify the soil types that are suitable for coffee production. This information is important for sustaining coffee production in Laos.

METHODOLOGY

Preliminary study

A survey of coffee production areas was conducted by selection of 9 production sites in 9 villages of Pakxong District; these were considered to be representative of production areas for the purposes of

this research. Farms were studied in the villages of Ban Lak 35, Ban Lak 40, Ban Nongbone, Ban Lak 43, Ban Kapheu, Ban Nonglouang, Ban Poumaknao, Phou Oy and Ban Poumako. The selection of production sites was mainly based on elevation including low (910-978 m above sea level (asl)), medium (1005-1185 m asl) and high (1294-1313 m asl). Each elevation included three sites. Basic information on coffee production was obtained by a survey, verbal interview and questionnaire interview. The exact position of each site was marked and a trench was used to make a soil profile study. The project was conducted during March to June 2009.

The trench with a dimension of 1x1x1.5 m was created at each site. Soil morphology and environmental factors surrounding the trench were recorded. These included crops, vegetations, weeds, livestock and other. Classification of the soil profile was performed vertically from the soil surface to the bottom of the trenches and each soil horizon in the soil profile was named accordingly. The order of the soil horizons was used to determine the basic taxonomy of the soil profile. Soil samples of all soil layers were collected for soil analysis in laboratory.

Soil analysis

Soil physical properties were analyzed for bulk density by core method, soil texture by hydrometer method, saturated hydraulic conductivity (Ksat) by falling head permeameter apparatus, soil moisture content at saturation (θ Sat) (Klute, 1965), field capacity (FC) by pressure cooker, permanent wilting point (PWP) by pressure plate and available moisture capacity (AMCA) (Trelo-ges, 2002).

Soil chemical properties were analyzed for soil reaction (pH; 1:2.5 H_2O) by pH meter, organic matter content by Walkley-Black titration (Walkley and Black, 1934), total nitrogen by Kjeldahl method (Jackson, 1965), extractable phosphorus by Bray II (Bray and Kurtz, 1945), water soluble K_2O extracted by 1N NH_4OAc (pH 7) and measured by flame photometry method (Pratt, 1965) and cation exchange capacity (CEC) which leached cation by ammonium acetate (1N NH_4OAc (pH 7)).

Data analysis

Results of the soil physical and chemical laboratory analyses were assessed to evaluate soil fertility and quality level including soil capability classification for coffee cultivation following the Land Development Department (Land Use Planning Section, 1999; Ta-oun and Srinarong, 2009).

RESULTS AND DISCUSSION

Soil classification

The soil profiles of the 9 sites were classified according to their specific soil layers from the soil surface to 150 cm depth. Lak 35 (lat. 15˚11' 34.7", long. 106˚05' 46.5", 910 m asl) clearly developed four layers of Ap, A1, A2, and B and was classified in the great group of Acrisols (Fig. 1). The soil had the properties of good drainage, available moisture capacity of 13.06% and medium acid to very strongly acid of soil reaction (pH 5.0-6.0). Lak 40 (lat. 15˚11' 14.6", long. 106˚08' 20.4", 978 m asl) developed Ap, A1, A2 and BC layers and was classified in the great group of Acrisols. The soil was moderately well-drained and had available moisture capacity of 12.03% and slightly acid to strongly acid of soil reaction (pH 5.5-6.5). Similarly, Nongbone (lat. 15˚16' 13.5", long. 106˚05' 9.7", 958 m asl) consisted of soil layers of Ap, A1, A2 and BC and was also categorized in the great group of Acrisols. The soil was characterized by good drainage, available moisture capacity of 10.41% and soil slightly acid to neutral of soil reaction (pH 6.5-7.0). These soil profiles are located at the lower elevation.

At moderate elevation, Lak 43 (lat. 15˚11' 28.9", long. 106˚10' 31.4", 1,005 m asl) formed Ap, A1, and BC layers and was grouped in the great group of Acrisols. The prominent characteristics were identified as relatively good drainage, available moisture capacity of 10.33 % and slightly acid to neutral of soil reaction (pH 6.5-7.0) (Fig. 2). Kapheu (lat. 15˚17' 24.0", long. 106˚11' 57", 1,159 m asl) constituted Ap, A1 and B soil layers and was placed in the great group of Acrisols.

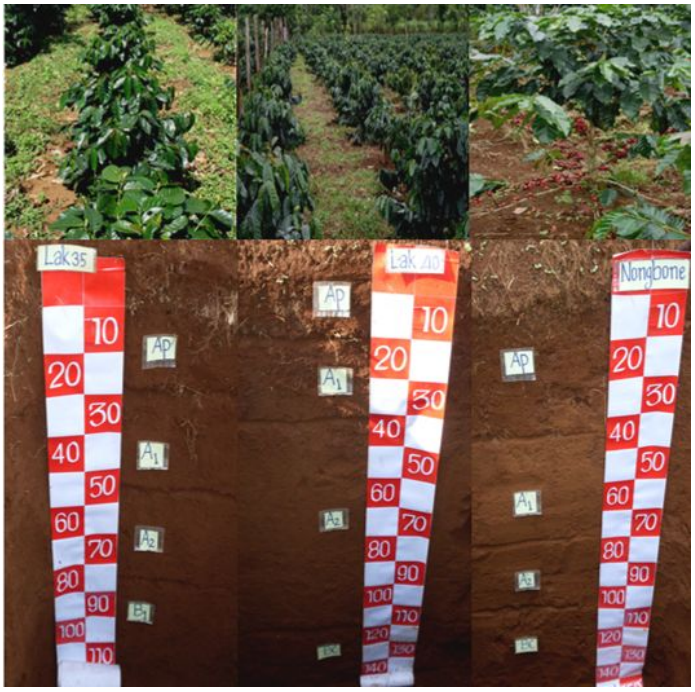

Fig. 1 Descriptions of the soil profiles and coffee plantations at Lak 35, Lak 40 and Nongbone sites, respectively

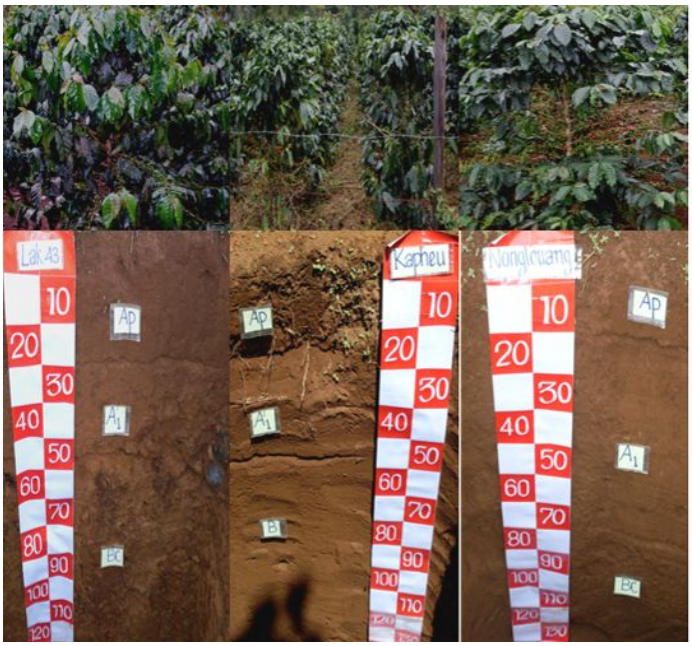

Fig. 2 Descriptions of the soil profiles and coffee plantations at Lak 43, Kapheu and Nonglouang sites, respectively

The soil is characterized by good drainage, available moisture capacity of 9.61 % and slightly acid to neutral soil reaction (pH 6.5-7.0). Nonglouang (lat. 15˚05' 38.1", long. 106˚12' 41.9", 1,185 m asl) developed Ap, A1 and BC soil layers and was classified in the great group of Alisols. The prominent characteristics were identified as good drainage, available moisture capacity of 11.22 % and medium acid to neutral of soil reaction (pH 6.0-7.0) (Fig. 2).

At high elevation, Phoumaknao (lat. 15˚ 10' 08.1", long. 106˚ 14' 18.5", 1,294 m asl) soil horizons of Ap, A1, A2 and B were identified and were classified in the great group of Alisols. The soil was characterized by good drainage, available moisture capacity of 10.38 % and very strongly acid to medium alkaline of soil reaction (pH 4.5-8.0) (Fig. 3). Phou Oy (lat. 15˚ 09' 20.1", long. 106˚ 14' 44.6", 1,298 m asl) developed soil horizons of Ap, A1 and B and was classified in the great group of Alisols. The soil was characterized by relatively good drainage, available moisture capacity of 11.12 % and medium acid to slightly acid soil reaction (pH 6.0-6.5). Phoumako (lat. 15˚ 06' 38.5", long. 106˚ 13' 21.7", 1,313 m asl) expressed the soil horizons in order of Ap, A1, A2 and B and was classified in the great group of Alisols. The soil was well-drained, had available moisture capacity 10.64 % and showed very strongly acid to slightly acid reaction (pH 5.0-6.5).

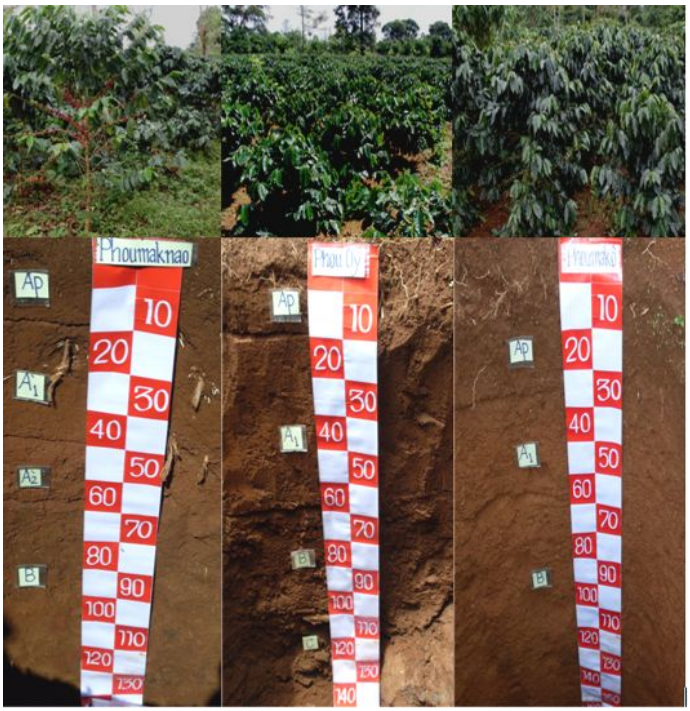

Fig. 3 Descriptions of the soil profiles and coffee plantations at Phoumaknao, Phou Oy and Phoumako sites, respectively

Soil analysis

Soils from 9 trenches were analyzed for chemical properties at 0-50 cm from the soil surface. Soil pH values were in a range of 4.4 -5.5, whereas organic matter contents were in a range of 3.10-8.58% (Table 1). The results indicated that most soils were acidic and rich in organic matter. Total nitrogen percentages of 0.095-0.32% also indicated medium soil fertility to high soil fertility. Available phosphorus contents ranging of 0.4-9.8 ppm showed phosphorus deficiency for normal production. Available potassium contents ranging from 26-110 ppm were deficient for fertility. The values of cation exchange capacity (CEC) in the range of 12.7-25.2 cmol/ kg were medium to high.

In addition to chemical properties, physical properties were also investigated. FC and PWP were in the range of 32.03-38.63 and 20.81-25.57%, respectively, and the available moisture capacity values were in the range of 9.61-13.06% (Table 2). These values were considered moderate to high. The values of saturated hydraulic conductivity were in the range of $0.77x10^{-3}$-$13.89x10^{-3}$ cm/sec and soil bulk densities were in a range of 0.767-0.942 gm/cm^3, showing well-drained properties of the soils. Soil textures in most sites were loamy sand to sandy loam except for loam texture of Lak 35 in the lower part. Soils suitable for coffee production should be moderately to highly fertile and well-drained and have soil depth at least 80 cm. Soil pH should be in a range of 4.5-6.0 (Cannell, 1985; Coste, 1992). Nitrogen is most available for plant when soil pH is in the range of 4.5-7.5 (Pomnoi, 1994). In

addition to nitrogen, phosphorus is also fixed in highly acidic soils. According to Lampaopong et al. (1985), soils for coffee production in the North of Thailand had high organic matter (2.0-11.7 %), low phosphorus (7.4 ppm) and high potassium (95 ppm). Phosphorus deficiency seems to be common for most coffee production areas in high land. This is possibly due to the sedimentation of phosphorus into unavailable forms (Sanchez, 1976; Tisdale et al., 1985).

Table 1 Soil pH, organic matter (OM), total nitrogen, extractable phosphorus, exchangeable potassium, cation exchange capacity (CEC), soil fertility and appropriate class
(*Soil fertility and appropriate class were evaluated by using of Land Development Department Handbook and FAO Handbook for coffee production at 0-50 cm deep of 9 coffee growing locations.*)

Site	pH	OM (%)	Total N (%)	Extr.P (ppm)	Exch.K (ppm)	CEC (cmol/kg)	Soil fertility	Appro-priate class
Lak 35	4.4	4.26	0.175	2.85	28	22.30	medium	medium
Lak 40	4.8	5.78	0.200	2.05	27	21.85	medium	medium
Nongbone	5.0	3.10	0.095	0.85	26	12.70	low	slightly
Lak 43	5.5	5.14	0.176	0.70	40	24.15	medium	medium
Kapheu	5.1	5.28	0.177	1.05	54	19.15	medium	medium
Nonglouang	4.9	5.02	0.186	5.10	32	20.80	medium	medium
Phoumaknao	4.5	8.58	0.320	4.50	37	24.55	high	high
Phou Oy	5.0	5.71	0.192	0.40	37	21.30	medium	medium
Phoumako	4.6	6.28	0.220	9.80	110	25.20	high	high

Table 2 Field capacity (FC), permanent wilting point (PWP), available moisture capacity (AMCA), saturated hydraulic conductivity (Ksat), soil moisture content (SMC), bulk density (Db) and soil texture (ST) at 50 cm depth of 9 coffee growing locations

Site	FC (%)	PWP (%)	AMCA (%)	Ksat (cm/sec)	SMC (%)	Db (gm/cm^3)	ST
Lak 35	38.63	25.57	13.06	$7.46x10^{-3}$	87.762	0.767	Loam
Lak 40	35.14	23.11	12.03	$3.31x10^{-3}$	81.551	0.818	Sandy loam
Nongbone	32.59	22.18	10.41	$9.37x10^{-3}$	84.514	0.813	Sandy loam
Lak 43	35.48	25.15	10.33	$0.77x10^{-3}$	83.044	0.836	Loamy sand
Kapheu	34.65	25.04	9.61	$9.19x10^{-3}$	79.934	0.860	Sandy loam
Nonglouang	32.03	20.81	11.22	$1.71x10^{-3}$	75.354	0.917	Loamy sand
Phoumaknao	36.44	26.06	10.38	$7.41x10^{-3}$	78.778	0.857	Sandy loam
Phou Oy	35.01	23.89	11.12	$0.96x10^{-3}$	76.360	0.843	Loamy sand
Phoumako	33.52	22.88	10.64	$13.89x10^{-3}$	68.935	0.942	Loamy sand

According to soil fertility assessment criteria (Land Use Planning Section, 1999; Ta-oun and Srinarong, 2009), most sites in this study were moderately fertile for coffee production except for three sites. Phoumaknao and Phoumako were highly fertile, whereas Nongbone was poorly fertile. Low fertility in many sites resulted from deficiency of phosphorus and potassium, whereas high fertility in Phoumaknao and Phoumako was caused mainly by high organic matter, high soil nitrogen and high CEC. Nongbone was the poorest site because most chemical properties were low.

CONCLUSION

A better understanding of soil properties and the identification of soil types suitable for crop production is important for sustainable agriculture. This study revealed that the soils planted to coffee in the major coffee production areas in Laos are mostly acidic soils, requiring lime amendment to sustain coffee productivity. Organic matter and nitrogen were mostly sufficient for coffee production, and this should reduce fertilizer costs. Low soil phosphorus and low to high potassium indicate that application of these fertilizers may be required in some areas. Moderate to high CEC should increase fertilizer use efficiency. Coarse soil, low bulk density, well drained, well aerated, high available

moisture capacity and deep soils are favorable properties for coffee production. Therefore, coffee can be grown successfully in most of these soils without severe limitations. Phoumaknao and Phoumako were readily identified as the most productive sites for coffee mainly because of high organic matter, high CEC and high soil nitrogen. However, further research is still necessary for effective use of lime amendment and fertilizer recommendations for specific sites.

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