NUTRIENT DYNAMICS OF TEKAM FOREST RESERVE, PENINSULAR MALAYSIA, UNDER DIFFERENT LOGGING PHASES

Amir Husni Mohd. Shariff, Mona Zakaria, Mohd. Ghazali Hasan & Rozita Ahmad

Forest Research Institute Malaysia, Kepong, 52109 Kuala Lumpur, Malaysia

Received November 1989

AMIR HUSNI MOHD. SHARIFF, MONA ZAKARIA, MOHD. GHAZALI HASAN & ROZITA AHMAD. 1989. Nutrient dynamics of Tekam Forest Reserve, Peninsular Malaysia, under different logging phases. The effects of logging on soil chemical properties under tropical rain forest ecosystem are presented. Using ANOVA, a comparison was made on soil chemical properties. A significant loss of soil nutrients was observed immediately after logging and recovery was encouraging for N and exchangeable K but not for soil pH at the topsoil and subsoil. Fertile sites showed relatively slow recovery compared to less fertile sites.

Key words: Malaysian dipterocarp forest - logging - soil chemicals

Introduction

Logging activities in the tropics are g enerally carried out with little or perhaps no consideration on the impact it may have on nutrient loss due to erosion resulting from high annual precipitation. Under Malaysian conditions, logging activities are controlled to some extent; prior to logging, a forest inventory is carried out to determine the extraction limits (Thang 1988); and logging roads are constructed with some specifications (FDPM 1988).

In this study the status of nutrients availability, loss and recovery before logging, immediately after logging, and one year after logging, in the Sungai Tekam Forest Reserve, Pahang, Peninsular Malaysia, are shown. In addition, we further discuss on the main growth limiting nutrients under tropical rain forest ecosystems.

Study site

Tekam Forest Reserve

Tekam Forest Reserve (TFR) is approximately 170 *km* to the northeast of

Kuala Lumpur, latitude 4° 15' N and 102° 37' E (Figure 1, p. 71, Abdul Rahim 1988); and covers 12400 *ha*. The study is concentrated in the Tekam hydrological basin, a 56.6 *ha* area divided into three catchment sites; these catchments have been the focus of many integrated hydrological studies conducted by the Forest Research Institute Malaysia (FRIM) over the past ten years.

The average annual precipitation in this area ranges between 2765 to 2980 $mm\,y^1$, whilst the average air temperature is between 24°*C* and 29°*C* (Dale 1963).

The rocks in the area are from upper Triassic to lower Cretaceous and associated with volcanism (Khoo 1977), and rich in tuffaceous materials (Ibrahim unpublished). The area can be described as undulating to rolling to hilly with slope extremes of 2° and 35° and elevation between 80 to 325 *m* above sea level.

Poore (1968) described the floristic composition of the area as with a prevalence of the genera *Dipterocarpus* and *Shorea* of the red meranti group. In addition, *Shorea curtisii* is found at altitudes > 300 *m* above sea level (FELDA 1967).

Soil description

A detailed soil survey, carried out by the first author, in this hydrological basin (56.5 *ha*), showed five dominating soil types: Bungor (BGR) (Typic Paleudult), Jempol (JPL) (Typic Paleudult), Jeram (JRM) (Typic Paleudult), Tajau (TJU) (Typic Paleudult) and Jengka (JKA) (Rhodic Paleudult). In addition, two soil series were found to occur in localised spots. They are Kuala Brang (KBG) (Orthoxic Tropudult) and Musang series (MSG) (Orthoxic Tropudult).

A soil pit 1.5 *m* depth was dug for each soil series and described using the Soil Survey Manual for Soil Surveyors in Malaysia (Paramananthan 1986), Soil Survey Manual (USDA 1951) and the FAO (1977) Guidelines for Soil Profile Description. A summary of the general characteristics of the soil types is given below:

Soil type	Parent material	Depth to pedological features
TJU	Highly weathered rhyolite tuff interbedded with shale material	Stony parent materials at 50 - 80 *cm* depth, comprising of 15 - 35% by volume, 7.5-25 *cm* in size
JPL	Tuffaceous sandstone with interbedded shale material	Gravelled parent materials at 80 - 90 *cm* depth, becoming pronounced with increasing depth;size ranges between 0.2 and 7.5 *cm*
BGR	Sandstone interbedded with shale	Stony material at 110 - 140 *cm* depth, size ≥ 25 *cm* in diameter
KBG	Sandstone-shale with plinthite band > 15 *cm* thick	Stony parent material at 50 - 75 *cm* depth, size 15 - 25 *cm* in diameter; saprolitic material at the lowest depth of the profile

JKA	Andesitic tuff with shale fragments	Parent materials with pockets of rhyolite, gravelled size materials at 150 *cm* depth
JRM	Tuffaceous shale with ferrugineous influence	Gravelled parent material, size 0.2 - 2.0 *cm* diameter occuring between 30 and 75 *cm* depth, and becoming more pronounced with increasing soil depth

A 2-*ha* plot, measuring 100 × 200 *m* and orientated in N-S direction was established on each of the three soil associations (JPL/JRM, KBG/BGR and JKA/TJU). The plots were divided into 200 (10 × 10 *m*) subplots. Using random table ten subplots from each 2-*ha* plot were chosen for soil sampling. Ten bulk samples (one bulk sample taken from five sampling points) were collected from each of the 2-*ha* plot to represent depths of 0-15 *cm* and 15-30 *cm* using a screw auger to represent soils before logging. The same plots were sampled immediately after logging and one year after logging.

Logging procedures

The Catchments, with the 2-*ha* plots, were logged in 1986. In Catchment 1 logging was carried out according to the Selection Management System (Thang 1988), and was supervised. In Catchment 2 logging was as in C1 but was not supervised. However some restrictions were enforced, namely, no machinery should cross any streams; logging roads should follow the contour lines; and 20 *m* of buffer zone should be left for streams on either side. Catchment 3 was kept as control. No logging was carried out in the higher elevation due to rugged and steep topography. All logging activities were confined to areas less than 16°, close to the access road.

Analytical procedures

All soil samples collected were thoroughly mixed to ensure uniformity and packed inside plastic bags for transportation to the laboratory for analysis. The samples were dried in the oven for 48-72 *h* at 60°*C*, rolled through the roller mill, and passed through a 2 *mm* sieve for analysis. For nutrient N determination, finer samples were used (sieved through 60 mesh size).

Soil pH was determined using the ratio of 1:2.5 (soil : water), measured using Corning 155 pH meter after shaking for an hour. Kjedahl digestion procedure was adopted for total N (%) determination (USDA 1972) followed by semi-micro distillation using Buchii apparatus. Available P was determined by Bray and Kurtz's Method Number 2 (1945), measured colorimetrically as the molybdate-blue complex formed in the presence of ammonium molybdate with stannous chloride acting as reductant. Leaching with 1N ammonium acetate buffered at pH 7 was adopted for exchangeable cation determination. Exchangeable K and Na were determined by Corning 410 flame photometer; Ca and Mg by Hitachi 170-30 atomic absorption spectrophotometer; and available P using Hilger Spekker and colour accomplished using ammonium molybdate-ascorbic acid method (Watanabe & Olsen 1965).

Results

Soil chemical properties

Before logging

Prior to logging, there was less variation in all the exchangeable nutrients between the three soil associations (Tables 1 & 2). However, high values were recorded for exchangeable Ca and exchangeable Mg in both topsoils (2.37 and 2.11 meq/100 *g* soils) and subsoils (0.30 and 0.40 meq/100 *g* soils). This observation is true for KBG/BGR association but less obvious for JKA/TJU association. Available P was low in all soil types with values not exceeding 10 ppm in the topsoils and decreasing with depth.

Again, KBG/BGR soil associations contained the highest N concentration, especially in the topsoil (0.18%). The amount of total exchangeable bases in all the three soil types paralleled the soil pH values in both horizons. The KBG/BGR association was significantly less acidic at both depths (5.09/5.01), compared to the remaining soil associations (4.35).

After logging

All soil nutrients and soil pH (Tables 1 & 2) declined upon logging except exchangeable K in both soil depths. High losses were recorded in available P (range 0.98 - 2.44 ppm), exchangeable Mg (0.20 and 1.99 meq/100 *g* soils; Table 2), and exchangeable Na (0.01 - 0.10 meq/100 *g* soils); the soil pH too declined between 0.11 and 1.03 in all types of soils. These were the trends following logging and one year after. Some recovery was seen at the later stage in exchangeable Mg and exchangeable Na in JKA/TJU and JPL/JRM associations.

However, for Mg recovery was poor for the highly fertile topsoils of KBG/BGR association. It is interesting to note that N showed significant recovery a year after logging (Table 2) but soil pH declined significantly at all sites, especially on fertile series soils, where the values were well below 4.35.

Between soil associations loss and recovery of nutrients varied to some extent, for example immediately after logging and one year after logging

(Table 1). However, no obvious trend was observed, except on fertile sites for total exchangeable bases content.

Table 1. Analysis of variance (ANOVA) between means of soil chemical properties in three soil associations, for topsoil and subsoil, for three logging phases [The significance is tested using t-test and LSD calculated at 5% significance level (The soil chemical values in one logging phase, in one soil associations, not sharing the same alphabets are significantly different; n.a. - not available)]

		Before logging			Immediately after logging			1 y after logging		
	Soil series	I	II	III	I	II	III	I	II	III
Nitrogen	Topsoil	0.07^a	0.18^b	0.07^a	0.06^a	0.05^a	0.06^a	0.12^a	0.16^b	n.a.
	Subsoil	0.04^a	0.06^a	0.06^a	0.04^b	0.03^b	0.04^b	0.09^a	0.10^c	n.a.
Phosphorus	Topsoil	5.84^a	6.53^a	6.91^a	3.40^a	5.55^b	4.54^c	n.a.	n.a.	n.a.
	Subsoil	3.50^a	4.46^b	4.92^b	2.10^a	3.17^b	3.18^b	n.a.	n.a.	n.a.
Potassium	Topsoil	0.13^a	0.08^a	0.26^b	0.25^a	0.21^a	0.32^b	0.22^a	0.22^a	0.30^b
	Subsoil	0.09^a	0.06^a	0.21^b	0.18^a	0.17^a	0.23^b	0.18^a	0.19^a	0.23^b
Calcium	Topsoil	0.33^a	2.37^b	0.30^a	0.29^a	0.49^b	0.32^a	0.26^a	0.58^b	0.31^a
	Subsoil	0.23^a	0.95^b	0.22^a	0.12^a	0.28^b	0.12^a	0.21^a	0.22^a	0.11^a
Magnesium	Topsoil	0.31^a	2.11^b	0.40^a	0.11^a	0.36^b	0.21^c	0.25^a	0.64^b	0.45^c
	Subsoil	0.13^a	1.41^b	0.20^a	0.07^a	0.12^a	0.13^b	0.17^a	0.41^b	0.27^c
Sodium	Topsoil	0.04^a	0.12^b	0.05^a	0.04^a	0.05^a	0.06^a	0.05^a	0.02^b	0.03^c
	Subsoil	0.04^a	0.11^b	0.04^a	0.03^a	0.07^b	0.06^b	0.04^a	0.02^b	0.03^b
Total exchangeable cations	Topsoil	0.80^a	4.68^b	1.01^a	0.69^a	1.12^b	0.89^c	0.78^a	1.47^b	1.10^c
	Subsoil	0.50^a	2.53^b	0.67^a	0.41^a	0.66^b	0.55^c	0.60^a	0.84^b	0.63^a
pH	Topsoil	4.10^a	5.09^b	4.18^a	3.99^a	4.32^b	4.00^a	4.00^a	4.06^b	4.00^a
	Subsoil	4.35^a	5.01^b	4.31^a	4.10^a	4.29^b	4.23^a	4.07^a	4.23^b	4.11^a

[Soil series: I - JPL/JRM; II - KBG/BGR; III - JKA/TJU; BGR - Bungor (Typic Paleudult), JKA - Jengka (Rhodic Paleudult), JPL - Jempol (Typic Paleudult), JRM - Jeram (Typic Paleudult), KBG - Kuala Brang (Orthoxic Tropudult), TJU - Tajau (Typic Paleudult)]

Table 2. Analysis of variance (ANOVA) between means of soil chemical properties in three logging phases, for topsoil and subsoil, for three soil associations [The significance is tested using t-test and LSD calculated at 5% significance level (The soil chemical values in one soil associations, in one logging phase not sharing the same alphabets are significantly different; n.a. - not available)]

		JPL/JRM			KBG/BGR			JKA/TJU		
	Logging phase	I	II	III	I	II	III	I	II	III
Nitrogen	Topsoil	0.07^{a}	0.06^{a}	0.12^{b}	0.18^{a}	0.05^{b}	0.16^{a}	0.07^{a}	0.06^{a}	n.a.
	Subsoil	0.04^{a}	0.04^{a}	0.09^{b}	0.06^{a}	0.03^{b}	0.10^{a}	0.06^{a}	0.04^{b}	n.a.
Phosporus	Topsoil	5.84^{a}	3.40^{b}	n.a.	6.53^{a}	5.55^{b}	n.a.	6.91^{a}	4.54^{b}	n.a.
	Subsoil	3.50^{a}	2.10^{b}	n.a.	4.46^{a}	3.17^{b}	n.a.	4.92^{a}	3.18^{b}	n.a.
Potassium	Topsoil	0.13^{a}	0.25^{b}	0.22^{b}	0.08^{a}	0.21^{b}	0.22^{b}	0.26^{a}	0.32^{b}	0.30^{c}
	Subsoil	0.09^{a}	0.18^{b}	0.18^{b}	0.06^{a}	0.17^{b}	0.19^{b}	0.21^{a}	0.23^{a}	0.23^{a}
Calcium	Topsoil	0.33^{a}	0.29^{a}	0.26^{a}	2.37^{a}	0.49^{b}	0.58^{b}	0.30^{a}	0.32^{a}	0.31^{a}
	Subsoil	0.23^{a}	0.12^{b}	0.21^{a}	0.95^{a}	0.28^{b}	0.22^{b}	0.22^{a}	0.12^{b}	0.11^{b}
Magnesium	Topsoil	0.31^{a}	0.11^{b}	0.25^{a}	2.11^{a}	0.36^{b}	0.64^{c}	0.40^{a}	0.21^{b}	0.45^{a}
	Subsoil	0.13^{a}	0.07^{a}	0.17^{a}	1.41^{a}	0.12^{b}	0.41^{c}	0.20^{a}	0.13^{b}	0.27^{c}
Sodium	Topsoil	0.04^{a}	0.04^{a}	0.05^{b}	0.12^{a}	0.05^{b}	0.02^{c}	0.05^{a}	0.06^{b}	0.03^{c}
	Subsoil	0.04^{a}	0.03^{b}	0.04^{a}	0.11^{a}	0.07^{b}	0.02^{a}	0.04^{a}	0.06^{b}	0.03^{c}
Total exchangeable cations	Topsoil	0.80^{a}	0.69^{a}	0.78^{a}	4.68^{a}	1.12^{b}	1.47^{c}	1.01^{a}	0.89^{b}	1.10^{a}
	Subsoil	0.50^{a}	2.53^{b}	0.67^{c}	0.41^{a}	0.66^{b}	0.55^{b}	0.60^{a}	0.84^{b}	0.63^{a}
pH	Topsoil	4.10^{a}	3.99^{b}	4.02^{b}	5.09^{a}	4.32^{b}	4.06^{b}	4.18^{a}	4.00^{a}	4.00^{b}
	Subsoil	4.35^{a}	4.10^{a}	4.07^{a}	5.01^{a}	4.29^{b}	4.23^{c}	4.31^{a}	4.23^{b}	4.11^{b}

(Logging phases: I - Before logging; II - Immediately after logging; III - 1 *y* after logging; soil series: as in Table 1)

Discussion

Effect of logging on soil chemical properties

Based on the results (Table 2), it is clear that logging activities have detrimental effects on the soil chemical properties in both topsoils and subsoils, especially immediately after logging; the effect exists even one year after logging. Detrimental effects of logging on soil nutrient changes in the tropics have been highlighted (Salleh *et al.* 1983, Phillips 1987, Abdul Rahman & Shukri 1987, under Malaysian conditions and elsewhere (Brown 1979, Kartawinata *et al.* 1981, Boonchee *et al.* 1988).

Interestingly, exchangeable K in particular showed increased concentrations after logging. This phenomenon is probably due to the parent material of the study site which is tuffaceous in origin (Gobbett & Hutchinson 1973, Khoo 1977, Amir 1989). Furthermore, nutrients in the logging residuals (branches and tree crowns) left on the forest floor are leached away by rain, releasing large amounts of K since this particular nutrient is the most mobile cation in the plant ecosystem (Ulrich *et al.* 1976, and others). Similarly Zulkifli (1989) showed high discharge of K in soils at Berembun hydrological basin, a granite country which is known to be rich in feldspar and micaceous minerals (Paramanathan 1977, Wong 1977, 1981).

The loss of nutrients after logging is high, especially on fertile topsoils of KBG/BGR association compared to less fertile sites and the recovery rate was relatively poor in the former compared to the latter (Table 2). The recovery of exchangeable bases for JPL/JRM and JKA/TJU was encouraging after the one year period but not for KBG/BGR association, especially for Ca and Mg (Table 2), the determinant of soil basicity. Ultra basic soils are known to contain high amounts of Ca and Mg (Paramanathan 1977), hence the higher pH values. Data from this study showed poor recovery of Ca and Mg in fertile topsoils (Table 2), and therefore the poor pH recovery in KBG/BGR soil association in particular, and the remaining two soil associations in general.

Effect of N, P and K availability on tree growth

Nitrogen (N)

The recovery of N, which is considered as one of the growth limiting nutrients (Miller *et al.* 1976a, 1976b, 1979, and others) was good, particularly one year after logging (Table 2). In some instances it exceeded the initial availability, which accords with the observation by Gulam & Norhayati (unpublished) under Malaysian conditions. According to Vitousek (1984), N is less limiting especially in the tropics, where rates of decomposition and mineralisation are efficient. In Tekam Forest Reserve the C:N ratio is < 12 (Amir 1989), a condition described as 'mull' type of humus (Baule & Fricker 1970). This decomposes rapidly and readily releases nutrient N. Furthermore, logging activities resulted in an increase in light reaching the forest floor, raising the temperature, which could enhance the rate of litter decay (Anderson & Swift, 1983).

Phosphorus (P)

Besides N, P has also been shown to limit plant growth (Platteborze *et al.* 1971, and others). In this study t here was significant loss of available P immediately after logging (Table 2). Logging may have enhanced leaching causing available P in the soil and those loosely tied up to the organic matter content to be washed away during rainstorm. In addition, it is postulated that P which is naturally fixed by Fe and Al (Owen 1953, and others) may require some time for weathering and release.

Potassium (K)

Under Malaysian forest conditions nutrient K has also been pointed out to be a growth limiting nutrient (Amir & Miller in preparation); similarly too for forest plantation crops (Anthony 1971, Manikam & Srivastava 1980) and agriculture perennial crops such as such as *Hevea* (Pushparajah 1969) and oil palm (Ng *et al.* 1968). Experiences on perennial agriculture crops in Malaysia indicate that a level of 0.2 meq/100 *g* of soil K is considered deficient (Pushparajah 1980). In the present study it is about 0.2 meq/100 *g* soil, except on KBG/BGR association which is slightly above 0.3 meq/100 *g* soils. According to Amir and Miller (in preparation), the availability of K, or plant growth limiting nutrient in the tropics, is an advantage.

Conclusion

Logging activities in tropical rain forest are positively detrimental to the soil fertility status. Its recovery one year after logging is slow; this is also true for soil pH. In this study, logging activities carried out in Tekam Hydrological Basin can be considered of low intensity since areas logged were confined to slopes not exceeding 16°, and logging was supervised in Catchment 2 and Catchment 3 was left undisturbed. Due to constraints in the plot layout and high variability in the soil types, a comparison between supervised and unsupervised logging is difficult. It is also observed that different soil types respond variably and this could be attributed to the soil physical properties such as clay content, bulk density and porosity (whose parameters are not quantified in this study) and also to the nature of its derived parent rocks. According to Gulam & Norhayati (unpublished) preserving the stable structure under forest soils is desirable for reducing run-off and maintaining high level of porosity. However no particular trend could be established since the soils under investigation are of associations.

Relatively fertile topsoils tended to lose more nutrients than less fertile sites and recovery was poor especially for exchangeable bases of Ca and Mg. Recovery for mineral N and exchangeable K was encouraging but soil pH deteriorated significantly even one year after logging.

Acknowledgements

We would like to thank the technical staff of Soil Chemistry Laboratory of FRIM, for carrying out the soil analyses.

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