

The Distribution of N, P, and K in Abandoned Rubber Estate

ABSTRACT

Aims: This study will examine the distribution of N, P, and K in 30 years abandoned rubber estates in term soil fertility.

Study design: Experimental

Place and Duration of Study: The study was conducted in UPM Bintulu Campus, Sarawak at an abandoned rubber estates planted with RRIM600 and GT1 clones in 1986. The samples were collected between January to December 2016.

Methodology: Ten blocks (20x50 m) were established in 7 ha actively tapped area. Land elevation levels and coordinate for each block was recorded using GPS and classified into LE (38-43), ME (44-49), and UE (50-55) m above sea levels. Surface soil samples were collected and analysed for total organic carbon, pH, total N, available P, K, Ca, Mg, Fe, and Mn.

Results: The elevation levels showed insignificantly effect on N, P, K, Mg, Fe, and Mn. Moreover, the elevation levels were in lower range between 38-43, 44-49, and 50-55 m above sea levels and hardly to observe the effects. However, Principal Component Analysis has revealed insufficient organic carbon and N had affected the latex production.

Conclusion: Therefore, practising proper estate management such as proper fertilizer application, legume establishment and terracing conversation were recommended to improve rubber productivity.

Keywords: rubber; elevation levels; abandoned estate; RRIM600; GT1

1. INTRODUCTION

Rubber (*Hevea brasiliensis*) is a tropical tree and is regularly planted in Malaysia with a total 1,078 ha were planted by industries and small holder and contributed to RM33.33 billion gross domestic price [6]. However, the national export incomes decline respectively due to the fluctuation of latex price, synthetic rubber, and a shortage of manpower.

These problems had influence improper estate management such as abandoning estate has led to soil degradation, low crop productivity, and susceptible to pest and disease infection. Rubber tree needs a proper maintenance during the immature phase in order to shorten the period. After the immature phase (7 years), supplying adequate fertilizer will increase the yield. When the tapping process started, N is exported out from the soil [6] and K was crucial to prevent coagulation. Insufficient nutrients will give a lasting effect on the latex production.

Moreover, N will become limiting in an abandoned estate and reported to affect plant girth, latex production, and the recovery period of latex vessels [15]. However, there is a trend in converting uneconomical rubber crop into rubberwood. According to [20], the rubberwood can be processed for timber and used in furniture, sawn timber, mouldings, chipboard and others.

Therefore, practising a good soil management will help to improve and maintain soil fertility for the next crop replanting cycle in the long term. Applying a proper fertilization, planting a leguminous crop, liming, and proper terracing was necessary in order to increase rubber productivity. Thus, the objective of this study was to examine the distribution of NPK in 30 years abandoned rubber estate.

2. MATERIAL AND METHODS

This study was conducted in an abandoned rubber estate located in UPM Bintulu Sarawak Campus. The total planted area was ~25 ha and only 7 ha was actively being tapped for rubber sheet and cup lump and total harvested were summarise in Table 1. The estate was planted with RRIM600 and GT1 clones in the 1986 and actively tapped in 2002. However, the estate has been abandoned for 20 years and to date received insufficient fertilizer because of limited manpower.

According to [13], a matured rubber tree needs to be fertilized twice a year at the rate 1 kg/tree. Although the crop has passed its economic year of latex productivity but the area is still currently used for teaching purpose and soon will be harvested for rubberwood. Replanting programme for a new rubber clones which is more susceptible to pests and disease infection and high latex production will take place at the same area.

Table 1. Total harvested rubber from 2011 to 2014

Years	Latex sheet (kg)	Rubber cup lump (kg)	Total (kg)
2011	449	N.A	449
2012	1,225	N.A	1,225
2013	2,417	705	3,123
2014	1,495	N.A	1,495

N.A: not available

In order to examine the distribution of N, P, and K in actively tapped area, ten blocks (50x20 m) were established using a grid system. The distance between each block was set at ± 12 m and depending on the topography of the estate area. The surface soil sample is collected using cross sampling technique and air-dried soil was analysed for physical and chemical properties. Organic carbon was determined by loss-on-ignition method [21], soil texture by the hydrometer method [3], soil pH by water method [23], total N by Kjeldahl method [22], available nutrients (P, K, Ca, Mg, Fe, and Mn) were extracted using double acid method [18]. The extraction of available P was determine using Blue method [17] by UV-Vis Spectrometer 820 nm (Lambda 25) while others extraction were using Atomic Absorption Spectrometer (Perkin Elmer, Model AA800).

The estate elevation levels and coordinate for each block were recorded using GPS (Garmin GPS Map 76CSx) and three elevation levels were identified may substantially affect the nutrient distribution and soil fertility in the estate. The elevation levels were classified into lower, LE (38-43), middle, ME (44-49), and upper, UE (50-55) m above sea level with 5 m distance between both angles. The distribution of nutrients was analysed using analysis of variance (ANOVA) by Tukey's test at $P=0.05$ using Statistical Analysis System (SAS 9.3).

3. RESULTS AND DISCUSSION

3.1 Soil Characteristics

General soil properties for an abandoned rubber estates was presented in Table 2. Overall observation on soil pH was classified as acidic soil with pH 4.51 and total N, P, and K concentration has indicated about 5.51, 0.82, and 187.77 mg kg⁻¹ present in the soil (Nyalau Series), respectively. Whereas, the total Ca, Mg, Fe, and Mn was approximately 2.09, 38.00, 10.20, and 76.36 mg kg⁻¹. Moreover, the soil in this area has sandy clay loam texture with sand about 6.20-55.61%.

82 **Table 2. General results on soil physic-chemical properties in UPMKB's rubber estate**

Soil characteristics	Result (0-20 cm)
pH _{H2O}	4.51
OC (%)	0.03
Total (mg kg ⁻¹)	
N	5.51
P	0.82
K	187.1
Ca	2.09
Mg	38.00
Fe	10.20
Mn	76.36
Soil fractions (%)	
Sand	6.24 - 55.61
Clay	29.95 - 65.60
Silt	0.64 - 63.44

83
84 **3.2 Distribution of Soil Nutrients at Different Elevation Levels**

85
86 The soil has high concentrations of Fe at all elevation levels (Table 3) and results are typically
87 common found in most of Malaysian soils because of intensive weathering in tropical country [8, 1].
88 Moreover, the distribution of N, P, K, Mg, Fe, and Mn was insignificantly different compared to soil pH,
89 TC and Ca at elevation levels. The significant differences was due to insufficient lime application
90 which has affected the pH, OC, and Ca levels at the estate [4].

91
92 **Table 3. Nutrient contents in soil of an abandoned rubber estate**

Elevation (m asl)	pH	OC (%)	N mg kg ⁻¹	P	K	Ca	Mg	Fe	Mn
LE	4.42 ^b	0.03 ^{ab}	5.73 ^a	0.31 ^a	53.79 ^a	18.41 ^c	16.36 ^a	619.05 ^a	16.95 ^a
ME	4.53 ^{ab}	0.02 ^b	5.27 ^a	0.23 ^a	51.63 ^a	27.92 ^b	13.58 ^a	412.19 ^a	18.41 ^a
UE	4.57 ^a	0.03 ^a	5.62 ^a	0.26 ^a	52.36 ^a	31.03 ^a	16.09 ^a	404.16 ^a	21.36 ^a

93 Means with different alphabets within column area significantly at $P=0.05$

94
95 Generally, nitrogen has comparable amount at all elevation because the area was covered by organic
96 matter which indirectly has increased N concentration for symbiosis relationship to fixed N in the soils.
97 Moreover, N was absorb for growth and tapping activities [26]. However, the concentration of N was
98 lower than well managed estate. According to [19], the concentration of N fall between 2.5 to 4.5 g
99 kg⁻¹ when the tree aged ranged from 16 to 41 years old. This has indicated the abandoned estate only
100 received N fertilizer rarely and lower then recommended value for matured crop.

101
102 Eventually, the crop depend upon decomposed organic N that originated from rubber biomass that
103 indirectly may acts as N reservoir [25]. Lessen organic N in tropical soil is well known although even
104 the estate had produced high biomass litter because of high rate of decomposition reaction of organic
105 matter [2]. It was observed that 0.02 to 0.03% of OC was found in the estate which lower than OC
106 value that commonly found in mature estate, 0.83% [26]. However, matured tree need to be fertilize
107 twice a year to improve nutrient retention in soil and the yield itself.

108
109 The availability of P in the estate was approximately 6% and can be considered limited to fulfil the
110 crop requirements. A research conducted by [26] has demonstrated availability of P on mature rubber
111 was between 1.3 mg kg⁻¹ which is 5 times greater than found in this research study. The main reason
112 for this problem was influenced by pH (4.42 to 4.57) that enhance P fixation with soil oxides [14].

Hence, most of available P are fixed by Fe (ranged from 404.16 to 619.05 mg kg⁻¹) and become unavailable until soil pH has been alleviated in the soil [26].

Potassium was available to the plant at 28% where the other 72% was not available. Present of soil moisture will increase movement of K to plant roots which in coarse texture the soil moisture will be lower and may become evidence of lessened K in the soil. Potassium was affected by the fraction of soil though certain area in this estate have high percentage of sand (6.24 to 55.61%) and occasionally being limed, apparently, K loss was not a main problem [16]. However, in current estate there are about 51.63 to 53.79 mg kg⁻¹ K found in the estate. The value was comparable to K result found in mature estate in China at 48.0 mg kg⁻¹ was recorded [26]. Therefore has indicated the abandoned estate has retain equivalent amount of K. Nonetheless, K need to be replenished in order to increase latex flow and reduce coagulation [10].

Abandoned rubber estate had influence soil pH to be in acidic condition since minimum lime materials has been applied in the area. Ultimately, the concentration of Ca in the soil had depended upon weathering soil mineral and accelerate concentration of Fe. Moreover, acidic condition has increased Al, Fe, and Mn has more ability to bind on soil colloid. Additionally, OC (0.02 – 0.03%) was lesser and will increase absorption of N in soil by microorganism [26]. This may affect availability of total N in soil for plant absorption and organ metals complexation [2, 9]. To date the availability of N, P, and K in the abandoned rubber estate has revealed the crops struggle to obtained nutrient resource from the soil except for K. The insufficient nutrient may unseen as the crop not actively been tapped and passed the economic value. A proper established estate need to be done once replanting takes place such as liming to increase soil pH and follow fertilization guidelines provided by Malaysian Rubber Board.

3.3 Principal Component Analysis Levels

The principal component analysis considered the first two factors, which had an accumulated variable of 47.00% (Fig.1).

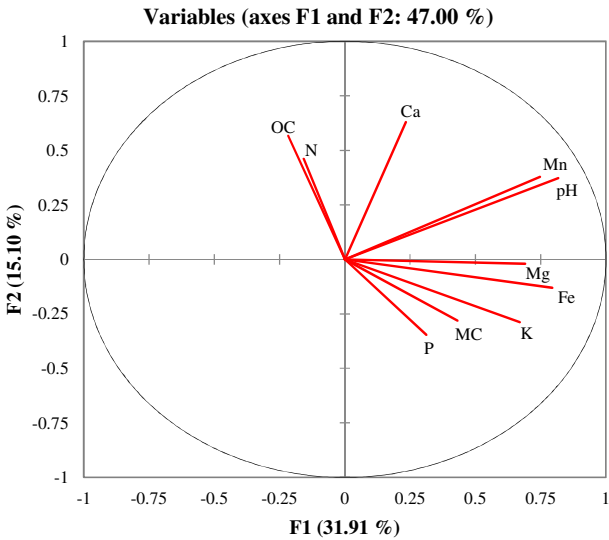


Fig. 1. Eigenvectors of soil chemical variables, where: pH: soil pH; MC: moisture content; OC: organic carbon; N: total N; P: available P; K: available K; Ca: available Ca; Mg: available Mg; Fe: available Fe; Mn: available Mn

The first component was negatively correlated with the variable OC and N. Thus, the effect of OC and N led to the reduction of its values and can be interpreted as a response related to the C and N in soil. Based on this rationale C was correlated with N because microorganisms will take up ammonium and nitrate out of the soil to accelerate decomposition [26]. Hence, the N was insufficient for the rubber to absorb.

The second component, correlations were highest between variables Mn and pH. The correlations were explained by the fact that soil pH influences Mn; hydrous Mn oxides. It was attributed to negatively charged when soil solution acidic [7]. The second component, the highest negative correlations were observed for Mg and Fe. According to [23], Mg and Fe will undergo for isomorphous substitution each other because of valence state and ionic radii was similar. Moreover, the increase in the Ca concentration will decrease Mg and Fe.

The grouping in Fig. 2 represents the relationship between all elevation levels. In G1, Ca, Mn, and pH was positive at both axes because the availability of K was limited due to replacing ion between K and Ca. According to [5] and [11], K will be depressed or replace due to stronger divalent ions in Ca.

Moreover, the availability of K was controlled by soil pH and will leach out from soil colloid as the negative ion will absorb Al and Fe in acidic condition [24]. While in G2, availability of N, P, and K was limited because of OC, MC, pH, Ca, Mg, Fe, and Mn in soil.

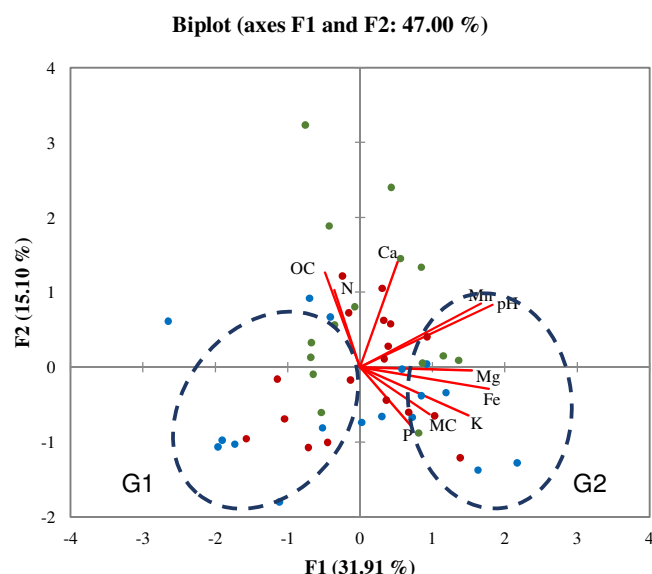


Fig. 2. Grouping of soil elevation levels based on the application of PCA for soil chemical variables

4. CONCLUSION

The distribution of major nutrients (N, P, and K) was unaffected by elevation levels as the range was lower compared to other studies. However, there is movement of N, P, and K from ME to the LE as ME located on a slopping area compared to UE which was more flat area. Proper estate management was needed to maintain and sustain the rubber growth even though the economic value was dropped down due to the age of the rubber itself (30 years). Replanting was suggested to increase productivity and also a good way to practice a good estate management in the future.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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