Soil characteristics of rattan agroforests in Katingan district, Central Kalimantan

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Abstract. Rattan agroforest is a swidden cultivation systems, which apply slash-burning and fallow rotation in its development. This system is commonly practised by local farmers of Dayak in Central Kalimantan. The objective of the study was to assess soil characteristics of 5 land use types, namely forest, secondary forest (baliang), young rattan agroforest (bahu), complex ruber-rattan agroforest (CRR), and simple rubber agroforest (SR) in two villages in Katingan. The method used in the study was regular methods of soil analysis, such as pH (H2O &KCl), Corganic (Walkley & Black), Pavailable (Bray), Ntotal (Kjeldahl), and soil texture. The result showed that in the top layer (0-10 cm depth), forest has the highest C/N ratio, but the lowest ratio of Corg/Cref compare to others. Forest has the lowest P content (4.02 ppm), while SR has the highest P content (12.06 ppm). CRR and SR tends to have higher clay content than sand content. In general, farming systems determine characteristics of the soils. Forest conserves soil characteristics, while management that applied by farmers in the agroforestry system may improve soil fertility.

1. Introduction
Forest area in Indonesia declining fast owing to over exploitation and change to other land use types, such as monoculture plantations, agroforests, shrubs, grassland, and annual crops. In the Indonesia Forest State, deforestation in 2016-2017 is reported declined from 630 million ha in 2016 to 93.6 million ha in 2017 [1]. This could be achieved through actions on the grounds, such as law enforcement, and the increase of planted forest, such as plantation forest and farm forestry. In the forest transition theory, it is mentioned that the dense land cover (e.g. forest) declines to non-forested area; and after some time, land cover steadily increases from active afforestation, reforestation, and agro-reforestation [2,3,4]. Agroforestry is a complex cultivation system which consisted of several tree species grow in a farm. The multi strata agroforestry system consisted of multi species, which produce multi litter and play role as a habitat of animals, produce multi products, micro climate and conserve soil properties [5,6].

Soil is a medium for plant to growth, whose characteristics have resulted from the integrated effect of climate and living matter acting upon parent material, as modified by relief over periods of time [7, 8]. The characteristics of the soils determine growth of the vegetation, owing to their ability to support water and nutrients for plants [7, 8]. Thus, soil is an important part in the cultivation system [7]. Vegetations that grows in the natural ecosystem and man-made ecosystems, such as agroforestry systems, influence the litter dynamics [9], soil organic matters, and soil properties [8-10]. In the agroforestry system, there is an interaction among tree - soil – crops interaction [5, 10], which can be
in a positive or negative interaction [5]. Rattan agroforestry is commonly developed in Central Kalimantan, where the rattan is cultivated by traditional farmers in the integration with other trees as a climber tree. Agroforest rattan was developed in a fallow and shifting cultivation system, which allow natural regeneration occurs in the farm land [11-13]. In the development of rattan agroforest, farmers practice slash and burning in the land preparation. Four years after land preparation when the trees have been grown, rattan seedlings are planted. Farm management is usually extensive e.g. low intensity of management [12]. The rattan cultivation and tree diversity of rattan agroforest in Central Kalimantan have been reported elsewhere [12,14], however very limited information about soil properties from different type of rattan farming systems in Central Kalimantan.

The objective of the study was to describe the soil properties of four land use types dominated by rattan, e.g. ‘baliang’, ‘bahu’, abandoned complex rubber-rattan agroforest (CRR) and simple productive rubber agroforest (SR) in comparison with natural forest, in Central Kalimantan.

2. Materials and Methods

2.1. Study site

The study was carried out in Katingan district, Central Kalimantan, which covers an area of 17,800 km². Katingan also refers to a river’s name. Two villages were selected as study sites, namely Tumbang Malawan and Tumbang Runen. Tumbang Malawan is located in the upper stream of Katingan river (01° 04’- 01° 05’ S and 112°44’ – 112°45’ E), positioned at the altitude of 50-500 m above sea level (asl). The geographic condition in Tumbang Malawan is undulating, somewhat steep to very steep. Soil type is dominated by Latisol soil. Tumbang Runen is positioned in the lower stream of Katingan river (02° 16’ – 02°17’ S and 113° 26’ E), at the altitude of 17-50 m asl. The geographic condition in Tumbang Runen is relatively flat, and soil type is consisted of Inceptisol and Latisol soils [15]. The study site is shown in Figure 1.

Figure 1. Study sites in Tumbang Malawan village and Tumbang Runen village of Katingan district, Central Kalimantan (Source: Bapemdalda)
The sampling plot for soil collection were established at five typologies of land use, namely (i) forest;(ii) secondary forest or locally known as ‘Baliang’ (which is selectively logged and have been naturally regenerated); (iii) ‘Bahu’ is a young rattan agroforest but abandoned; (iv) Complex rubber rattan agroforest (CRR), which is old and abandoned agroforest; and (v) Simple rubber agroforest (SR), which is productive rubber agroforest. The typologies of forest, ‘baliang’ and bahu were located in Tumbang Malawan. Different land use types were found in Tumbang Runen, e.g. abandoned complex rubber-rattan agroforest (CRR) and simple productive rubber agroforest (SR)[14].

2.2. Soil sampling and analysis
The sampling plots were established at five typologies of rattan agroforests in Tumbang Runen and Tumbang Melawan. The soil samples were taken five replicates in every sampling plot that have been established for vegetation analysis [14] Tata, 2019, in press). The soil sample at each layer was taken using soil ring sampler in diameter of 5 cm and length of 5 cm. Soil core was dug up in three layers of soil depth, e.g. 0-10 cm, 10-20 cm, and 20-30 cm.

The soil samples were analysed in the Soil Research Institute in Bogor with standard soil physical and chemical laboratory methods. The soil samples were analysed for texture (sand, silt, clay), pH (in a 1:2.5 soil:solution extract with water or 1 N KCl, available P_Bray1, C organic (Walkley and Black), N total (Kjeldhal). The reference organic C (C ref) content for forest soils was calculated using a regression equation derived from a large data set for Sumatra [16].

\[
C_{\text{ref}} = \text{SampleDepth}_{\text{cm}}/7.5^{-0.42} \times \exp(1.333 + 0.00994 \times \text{clay}\% + 0.00699 \times \text{silt}\% - 0.156 \times \text{pH(KCl)} + 0.000427 \times \text{elevation}_{\text{masl}})
\]  

2.3. Data analysis
To study the relative effect of typologies of rattan agroforestry on soil properties, the data were analysed for (1) typology of rattan agroforest versus soil properties were assessed using General Linear Model with multivariate analysis; (2) relationship between the factor of ‘sand_minus_clay’ with P available was performed using linear regression. The software used for statistical analysis is SPSS ver 21.

3. Results and Discussion
Soil physical properties of five typologies and three layers of soil depth are shown in Figure 2. Forest and ‘baliang’ (in the three layers of soil depth) contains higher sands than clay, and very small silt, which is categorized as ‘clay loam’ soil. On the other hand, the other three typologies, e.g. ‘bahu’, CRR and SR contain higher clay than sand, which is categorized as ‘silty clay loam’ soil. Soil texture plays role in determining hydrology in the soils, such as penetration, infiltration rate, and water absorption (Harjowigeno 2003). Forest and ‘baliang’ are less intensive compare to agroforestry system, such as ‘bahu’, CRR and SR. The higher content of clay in a productive land, such as ‘bahu’, CRR and SR determine soil surface area, which affects the soil’s storability and durability to nutrient.

Soil chemical properties were compared among land use types and soil depth. Soil chemical properties were affected by land use types and soil depth. However, there is no interaction between the two factors. ‘Bahu’ (young rattan agroforest) has the highest soil pH (both pH_H2O and pH_1KCl) among other sites. Top soil (soil depth of 0-10 cm) tends to have lower pH than deeper layer (Table 1).
The content of organic C and N total in the upper layer is higher than that of below 10 cm. Soil from ‘bahu’ has the highest organic C and N total content, but forest has the lowest C organic and N total content (Table 1). Bahu has the highest ratio of Corg and C ref (Figure 3A). The content of C organic and N total in the soil is determined by vegetation through litter production [17, 18]. ‘Bahu’ is a young but abandoned rattan agroforestry in Tumbang Malawan. Macaranga pruinosa and Macaranga triflora, which were dominated ‘Bahu’ typology [14], are fast growing tree species. The composition of vegetation affects rate of decomposition and contribution of C and N content in the soil. Leaves with high N content decompose faster [19]; however, analysis nutrient content of the litter is beyond this study.

Table 1. Soil properties in five typologies of rattan agroforestry in Katingan district.

| Parameter | Depth (cm) | Forest  | Baliang | CRR | SR  |
|-----------|------------|---------|---------|-----|-----|
| pH (H₂O)  | 0-10       | 3.96 (0.21) | 3.96 (0.18) | 4.46* (0.11) | 4.38* (0.17) | 4.16 (0.15) |
|           | 10-20      | 4.1 (0.12) | 4.26 (0.09) | 4.44 (0.05) | 4.48 (0.22) | 4.30 (0.16) |
|           | 20-30      | 4.22 (0.08) | 4.4 (0.23) | 4.36 (0.09) | 4.45 (0.13) | 4.36 (0.13) |
| pH (KCl)  | 0-10       | 3.44 (0.48) | 3.68 (0.08) | 3.86 (0.15) | 3.78 (0.1) | 3.4 (0.48) |
|           | 10-20      | 3.6 (0.07) | 3.9 (0.0) | 3.92* (0.08) | 3.90 (0.27) | 3.66 (0.07) |
|           | 20-30      | 3.54 (0.05) | 4.0 (0.13) | 3.9 (0.12) | 3.73 (0.050) | 3.54 (0.55) |

* indicates significantly different at p value 0.05 among typologies of agroforestry.
Value in brackets denotes standard deviation.
### Table 1 (Continue)

| Parameter | Depth (cm) | Forest   | Baliang  | Typology | Bahu   | CRR   | SR   |
|-----------|------------|----------|----------|----------|--------|-------|------|
| C organic (%) | 0-10      | 2.0 (0.38) | 3.03 (0.27) | 3.96* (0.77) | 3.37 (1.23) | 2.92 (1.78) |
|           | 10-20     | 1.32 (0.38) | 1.81 (0.11) | 2.50 (1.11) | 1.7 (1.14) | 1.44 (0.93) |
|           | 20-30     | 1.11 (0.22) | 1.53 (0.23) | 1.97 (0.67) | 1.03 (0.41) | 0.74 (0.29) |
| Norganic (%) | 0-10      | 0.18 (0.02) | 0.30 (0.04) | 0.38* (0.07) | 0.30 (0.09) | 0.26 (0.17) |
|           | 10-20     | 0.13 (0.03) | 0.7 (0.01) | 0.25 (0.14) | 0.18 (0.12) | 0.12 (0.07) |
|           | 20-30     | 0.11 (0.02) | 0.13 (0.04) | 0.19 (0.05) | 0.09 (0.02) | 0.07 (0.02) |
| C/N       | 0-10      | 10.6 (1.14) | 10.6 (0.55) | 10.6 (1.14) | 11.0 (1.16) | 11.2 (2.17) |
|           | 10-20     | 10.0 (1.23) | 10.6 (0.89) | 10.2 (0.84) | 9.5 (0.58) | 11.6* (1.52) |
|           | 20-30     | 10.6 (0.55) | 10.4 (1.52) | 10.2 (1.1) | 10.0 (0.82) | 11.2 (1.1) |
| P_{2}O_{5} (ppm) | 0-10 | 5.72 (3.47) | 12.1 (5.66) | 9.62 (3.03) | 17.45 (7.09) | 18.18* (4.9) |
|           | 10-20     | 4.12 (3.26) | 7.58 (1.98) | 8.16 (3.54) | 9.98 (2.84) | 11.48 (2.12) |
|           | 20-30     | 2.32 (1.83) | 7.68 (1.55) | 4.94 (1.33) | 8.68 (3.24) | 8.22 (1.69) |
| C Ref     | 0-10      | 3.06 (0.11) | 3.46 (0.33) | 3.97 (0.61) | 4.24* (0.77) | 4.17 (0.36) |
|           | 10-20     | 3.12 (0.1) | 3.35 (0.28) | 3.99 (0.72) | 4.08 (0.58) | 4.19 (0.49) |
|           | 20-30     | 3.15 (0.03) | 3.16 (0.33) | 3.98 (0.68) | 4.22 (0.66) | 4.23 (0.58) |

* indicates significantly different at p value 0.05 among typologies of agroforestry.
Value in brackets denotes standard deviation.

**Figure 3.** Effect of typology of rattan agroforests and soil depth. A) Ratio of Corganic and Creference; B) Ratio of C and N
The CRR has the highest P content in the soil. It has a negative relation with high clay content. CRR is a complex rubber rattan and abandoned agroforest in Tumbang Runen. According to [20], clay content determines Phosphorus buffering capacity of the soil. However, SR has high clay content but less Phosphorus content. The SR is a young and productive rubber farm, where rattan also grows as agroforestry system.

This study shows that the soil properties of rattan agroforest were affected by land use types and soil depth, but there is no interaction between the two factors. The rattan agroforest is developed as a swidden shifting cultivation, and applied slash and burnt as prescribed burning [2,4]. Types of rattan agroforest in Katingan can be differentiated based on vegetation structure and their land management. Different typologies of rattan agroforest have different vegetation composition, which could influence the chemical properties of soil, such as C, N and P content. Composition of vegetation in the four typologies of rattan agroforestry and forest in Katingan have been reported by [14]. Forest was dominated by Shorea parvifolia; BAliang was dominated by Hydnocarpus sp., Bahu was dominated by Vitex pinnata, CRR was dominated by ‘Kambang sira’ (Unident. 3), and SR was dominated by rubber tree. The composition of vegetation affects rate of decomposition and contribution of C and N content in the soil[10, 19].

There is tree-soil-crop interaction in agroforestry system. The interaction of tree-soil-crop leading to positive and negative impact to the growth of tree and crop [5].Rattan agroforestry system in Katingan is a non-intensive cultivation. Farmers do not apply tillage and fertilizer in to their farm. ‘Bahu’ in Tumbang Malawan and the complex rubber rattan agroforest (CRR) in Tumbang Runen are abandoned farm land, while the simple rubber agroforest (SR) is still productive. The rattan agroforests in Katingan are currently abandoned by the farmers, because condition of rattan trade is weaken. Farmers are not willing to spend much effort on conducting rattan cultivation if they get less economic value[13, 21].This situation leads to positive impact on the soils of rattan agroforests, by litter fall and nitrogen inputs.

The complex rubber rattan agroforest (CRR) in Tumbang Runen has the highest C/N ratio and Phosphor content. The CRR is also an abandoned rubber rattan agroforest. In the forest, P available is very limited compare to cultivation lands. Phosphorus is often the critical nutrient in agroforestry systems with low inputs. Hence, inorganic phosphorus must be applied in soils where P is depleted.
Combining organic and inorganic sources of P may result in more effective use of nutrients. Uptake of other nutrients is determined by the soil supply which in turn is determined for each nutrient by interactions between the nutrients and the soil properties [5, 10, 18].

4. Conclusion
In conclusion, soil fertility under rattan agroforestry system is maintained, hence soil productivity can support rattan production at all rattan agroforests in Katingan district.

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Table Appendix 1. Variance analysis of soil properties from different typologies of rattan agroforestry and depth of soil

| Source                    | Type III Sum of Squares | df | Mean Square | F     | Sig.  |
|---------------------------|-------------------------|----|-------------|-------|-------|
| Corrected Model           |                         |    |             |       |       |
| Sand                      | 11568.100\(^a\)         | 14 | 826,293     | 5,303 | .000  |
| Silt                      | 13231.319\(^b\)         | 14 | 945,094     | 12,956| .000  |
| Clay                      | 1197.650\(^c\)          | 14 | 85,546      | .988  | .478  |
| pH\(_H_2O\)               | 2.010\(^d\)             | 14 | .144        | 6.348 | .000  |
| pH\(_KCl\)                | 1.939\(^e\)             | 14 | .138        | 4.937 | .000  |
| C                         | 58.460\(^f\)            | 14 | 4,176       | 6.544 | .000  |
| N                         | .547\(^g\)              | 14 | .039        | 6.746 | .000  |
| C/Nratio                  | 19.053\(^h\)            | 14 | 1,361       | .987  | .478  |
| P\(_2O_5\)                | 1295.554\(^i\)          | 14 | 92,540      | 7,719 | .000  |
| Cref                      | 15.226\(^j\)            | 14 | 1,088       | 4.557 | .000  |
| Sand_minus_clay           | 11733.350\(^k\)         | 14 | 838,096     | 2,061 | .028  |
| Typology                  |                         |    |             |       |       |
| Sand                      | 11349.533               | 4  | 2837.383    | 18,209| .000  |
| Silt                      | 13077.053               | 4  | 3269.263    | 44,817| .000  |
| Clay                      | 1054.183                | 4  | 263.546     | 3,042 | .024  |
| pH\(_H_2O\)               | 1.180                   | 4  | .295        | 13,046| .000  |
| pH\(_KCl\)                | 1.434                   | 4  | .358        | 12,778| .000  |
| C                         | 15.474                  | 4  | 3.868       | 6.062 | .000  |
| N                         | .163                    | 4  | .041        | 7.020 | .000  |
| C/Nratio                  | 11.986                  | 4  | 2.997       | 2.173 | .084  |
| P\(_2O_5\)                | 705.568                 | 4  | 176.342     | 14,710| .000  |
| Cref                      | 14.913                  | 4  | 3.728       | 15,621| .000  |
| Sand_minus_clay           | 11307.383               | 4  | 2826.846    | 6,952 | .000  |
| Depth                     |                         |    |             |       |       |
| Sand                      | 95.678                  | 2  | 47.839      | .307  | .737  |
| Silt                      | 74.762                  | 2  | 37.381      | .512  | .602  |
| Clay                      | 49.771                  | 2  | 24.886      | .287  | .751  |
| pH\(_H_2O\)               | .396                    | 2  | .198        | 8.756 | .000  |
| pH\(_KCl\)                | .289                    | 2  | .145        | 5.152 | .009  |
| C                         | 40.226                  | 2  | 20.113      | 31,519| .000  |
| N                         | .357                    | 2  | .179        | 30,841| .000  |
| C/Nratio                  | 2.292                   | 2  | 1.146       | .831  | .441  |
| P\(_2O_5\)                | 488.500                 | 2  | 244.250     | 20,374| .000  |
| Cref                      | .018                    | 2  | .009        | .038  | .962  |
| Sand_minus_clay           | 105.744                 | 2  | 52.872      | .130  | .878  |
| Typology * Depth          |                         |    |             |       |       |
| Sand                      | 108.817                 | 8  | 13.602      | .087  | .999  |
| Silt                      | 75.906                  | 8  | 9.488       | .130  | .998  |
|          |          |     |     |     |     |
|----------|----------|-----|-----|-----|-----|
| Clay     | 94,383   | 8   | 11,798 | .136 | .997 |
| pH_H2O   | .414     | 8   | .052  | 2,287 | .034 |
| pH_KCl   | .201     | 8   | .025  | .897  | .525 |
| C        | 3,479    | 8   | .435  | .682  | .706 |
| N        | .031     | 8   | .004  | .674  | .712 |
| C/Nratio | 5.206    | 8   | .651  | .472  | .871 |
| P2O5     | 116,385  | 8   | 14,548 | 1,214 | .308 |
| Cref     | .297     | 8   | .037  | .156  | .996 |
| Sand_minus_clay | 306,883 | 8   | 38,360 | .094 | .999 |