Variations of Soil Properties on Post Shifting Cultivation area in Primary Forest

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Abstract. Shifting cultivation in tropical forest was presumed as the major cause of soil degradation and soil nutrient depletion, and need several years --namely forest-fallow periods-- to be recovered. Soil properties dynamic monitoring has been done in the tropical forest in Central Kalimantan at one, five and ten year after abandonment, and compared to primary forest, to predict the time for soil recovery in term of Calcium (Ca), Magnesium (Mg), Potassium (K), Natrium (Na) content and cation exchange capacity (CEC). The soil properties status can be beneficial for rehabilitation activities through practicing agroforestry by the forest dwellers. The results showed that soil properties (i.e. Ca, Mg, K, CEC) were significantly different among soil depth ($P<0.05$), but not for Na. Highest value of Ca, Mg, K and Na were observed in the soil surface (0-20 cm), Soil nutrient contents were significantly changed with the time of abandonment, the highest value of CEC, Ca, K, and pH were found in five years after the abandonment. It suggested that soil nutrients were distributed in the soil surface composed from litter of pioneer trees. The research suggested that soil recovery was probably occurred during early fallows, and agroforestry can be practiced at five year after the abandonment.

1 Introduction

Shifting cultivation is a widely traditional agricultural practice in the tropics. This system has been practiced for thousands of years. It is a dominant component of the agricultural systems of upland Southeast Asia. In this practice, Farmer clear forest land by slashing and burning areas to be used for agricultural activities such as food crop production [1][2][3]. Moreover, the land of post-shifting cultivation will be abandoned for several years before replanting for agriculture crop. The land preparation of shifting cultivation causes a negative effect such as soil degradation, loss of biodiversity, emissions of carbon dioxide, etc. [4][5]. Even though, the vegetation and soil degradation recovery of post-shifting cultivation area occurs during the fallow period [6].

Shifting cultivation has been considered as one of the causes of deforestation. Sixty percent of deforestation around the tropics was caused by shifting cultivation activities [7]. In Indonesia shifting cultivation caused 50% loss of forest land [8]. Shifting cultivation also was considered a significant contributor to forest degradation in the 1990s [9]. Furthermore, along with the increase in population and land requirements, the average fallow period of shifting cultivation has become shorter from 15-20 years to 5 years over the past decade [5]. Shortening the fallow period has an impact on the low soil fertility and decreased productivity of shifting cultivation [10].

Moreover, the soil recovery process is the main factor supporting the success of forest rehabilitation or sustainable production of shifting cultivation. Sustainable shifting cultivation is based on a balance between the input and output of nutrients of the forest ecosystem. Nutrient loss during the conversion and cultivation stages is compensated by nutrient input and soil recovery during the fallow period. Fallow is the crucial stage for reestablishing conditions that guarantee the stability of shifting cultivation [11]. Therefore, the study is needed to predict the time for soil recovery over the fallow period. The objective of this study was to analyze and determine the changes in soil properties on the various fallow periods in post-shifting cultivation areas.

2 Material and methods

2.1 Study area

Our study was located in Tanjung Paku, Seruyan, Central Kalimantan Indonesia 111^{o} 39' - 111^{o} 25' E and 00 36'- 10 10' S) Fig 1. Annual Rainfall in this area is 3730 mm per year with temprature 22-28^{o}C at night and 30-33^{o}C during daytime. The type of soil is Ultisols with low pH.

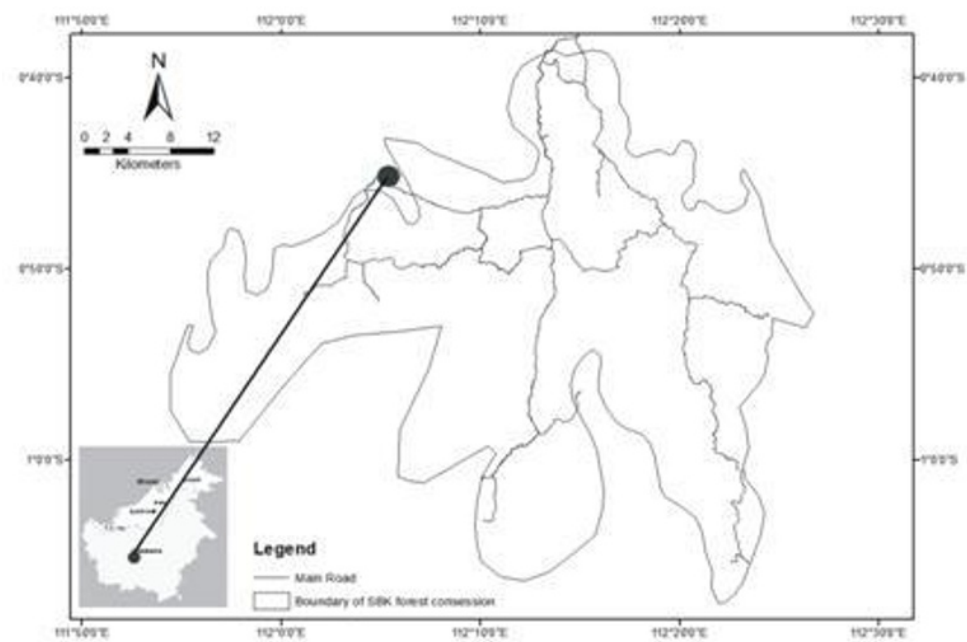

Fig. 1. Map of study area (Tanjung Paku Seruyan Central Kalimantan Indonesia)

2.2 Data collection and analysis

The Study was carried out in 3 areas with different fallow periods at 1-year (A1), 5-years (A5), and 10-years (A10) and compared to primary forest (PF). In each area, a plot 100 x 100 meter was made for soil sampling. Three sampling points were made for each plot, with three replication. At each replication, soil samples were taken at 4 depths. 0-2 cm, 2-10 cm, 10-20 cm, and 20-30 cm (Fig 2). And then, the soils properties such as, pH-H_2O, bulk density, CEC, Exchanged K, Ca, Mg and Na were analyzed in the laboratory.

Data were analyzed using two way ANOVA where the treatments were the ages after shifting cultivation, soil depths and their interactions using SPSS software for windows with a significance differences at $P \leq 0.05$ level, then the means of each treatments were compared with Tukey's HSD test to test the difference between treatments

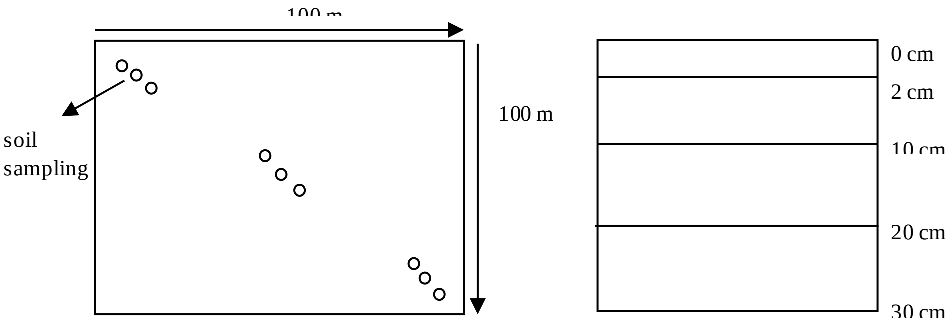

Fig. 2. Soil sampling plot and replication

3 Results and discussion

Physical and chemical soil properties provide the indicators for evaluating the impact of shifting cultivation [12]. Burning activities during the clearing land of shifting cultivation have a positive effect on nutrient supply at the beginning of the phase in shifting cultivation activities. However, it also cause a contradictive effect such as the amount of nutrients losses by volatilisation and ash-particle transfer is also quite high[13]. Nutrients easily evaporate into the atmosphere through the combustion process. Percentage of above-ground nutrients from burned vegetation that can be returned to the soil as ash, around 3% N, 49% P, 50% Ca, and 57% K [14].

Figure 3 showed Cation Exchange Capacity (CEC) on 3 areas with different fallow periods of shifting cultivation area, and the primary forest was not significantly different. As shown in figure 3(c) there is no certain pattern of CEC by increasing the length of the fallow period. However, the highest value of CEC was found in 5 years fallow period. CEC in the study area ranged from 4-8 me/100g and classified as very low [15]. The value of CEC in the soil is determined by type of clay mineral. The type of soil in the study site is Ultisols that has developed further and its clay minerals are dominated by kaolinite, hematite, gutite, and gibbsite clays. Soil which were dominated by kaolinite clay, had a CEC ranging from 3-15 me/ 100g [16].

The process of burning biomass accelerates the increase in soil pH at the soil surface. In acid soil conditions, ash reduces the amount of dissolved and exchangeable Al [17][18]. According to figure 3(b) soil pH among the study area was significantly different. Soil pH in 1-year fallow period was lower than in 5-years and 10-years fallow periods but higher than the primary forest. Soil pH in the 1-year fallow period was higher than primary forest indicating direct heating [19] and ashes [12] from the burning process caused increasing soil pH. It also was caused by the condition of the site which has not been covered by vegetation resulting in leaching [20]. In other studied reported that the conversion of primary forest to shifting cultivation did not affect the soil pH [21]. It was predicted the amount of cation from burnt biomass did not enough to affect the soil pH.

Our study elucidated that bulk density in various fallow periods and primary forest were not significantly different (figure 3). The similar result was reported by Terefe [21] and Osman et al. [22], whereas they said that the shifting cultivation did not affect soil physical properties such as bulk density, water holding capacity, and soil moisture. This might be caused that the study site was only used once for cultivation with minimum soil disturbance [21]. Otherwise, Filho [12], Mukul and Herbohn [23] found that the practice of shifting cultivation caused decreasing the soil bulk density. It was caused by the ash from burnt biomass clogged soil pores [24] and destruction of soil aggregates due to fire [25]

The fallow period has a significant effect on the rate of exchanged Ca Mg and K in the soil. The highest value of Ca and K were found in 5-years fallow period following by the 1-year fallow period. The ash from land clearing can increase an enormous amount of exchanged Ca, Mg, K, Na and gradually decreasing along with cultivation and absorption by the plant during the fallow period [18][19][26]. The succession of vegetation begins to occur in the 5-years fallow period, thus supplying decomposed organic matter which can add to the exchanged cations in the soil. Furthermore, a long fallow period (10-years fallow period) and primary forest have lower cation caused nutrients such as Ca and K are contained and accumulated in the vegetation due to root pumping [27] [28]. According to Juo and Manu [29] soil nutrients on shifting cultivation areas do not only depend on ash, but also on the capacity of the soil to retain available nutrients for plants. This might cause the value of Ca, Mg, K, and Na in the 1-year and 5-years fallow period were higher than 10-years fallow period and primary forest. However, Fawnia et al [30] reported that there were no differences in nutrients at various fallow periods. The observed short fallow period (6-years fallow period) did not show a significant change in nutrients after converting into shifting cultivation. In general, the value of Ca, Mg, and K at various fallow periods did not follow a certain pattern [29][30].

According to Utomo [31], pH at the topsoil was lower than the subsoil and increase with the depth of soil. Soil organic matter was found larger at the topsoil than the lower layer. It was a source of nutrients and also adds to the acidity of the soil through decomposition. In addition, the high rainfall resulting cation leaching from topsoil to subsoil. However, the soil pH in each soil depth in this study was not significantly different (figure 4b).

Using fire for land clearing has a strong impact on the topsoil [26][32]. The low intensity of fires significantly affected the content of N, P_2O_5, K, Na, Ca, and Mg in the topsoil (0-5cm) [33]. CEC and Ca, Mg, K, Na most found at the surface soil and decrease with the soil depth. Figure 4 showed that the soil properties at various soil depths significantly different. The topsoil has more base cation than the subsoil. Cation Ca, Mg, K, Na well accumulated in on the topsoil and decrease with soil depth [29][34]. It suggested that soil nutrients were distributed in the soil surface that was probably composed of the litter of pioneer trees.

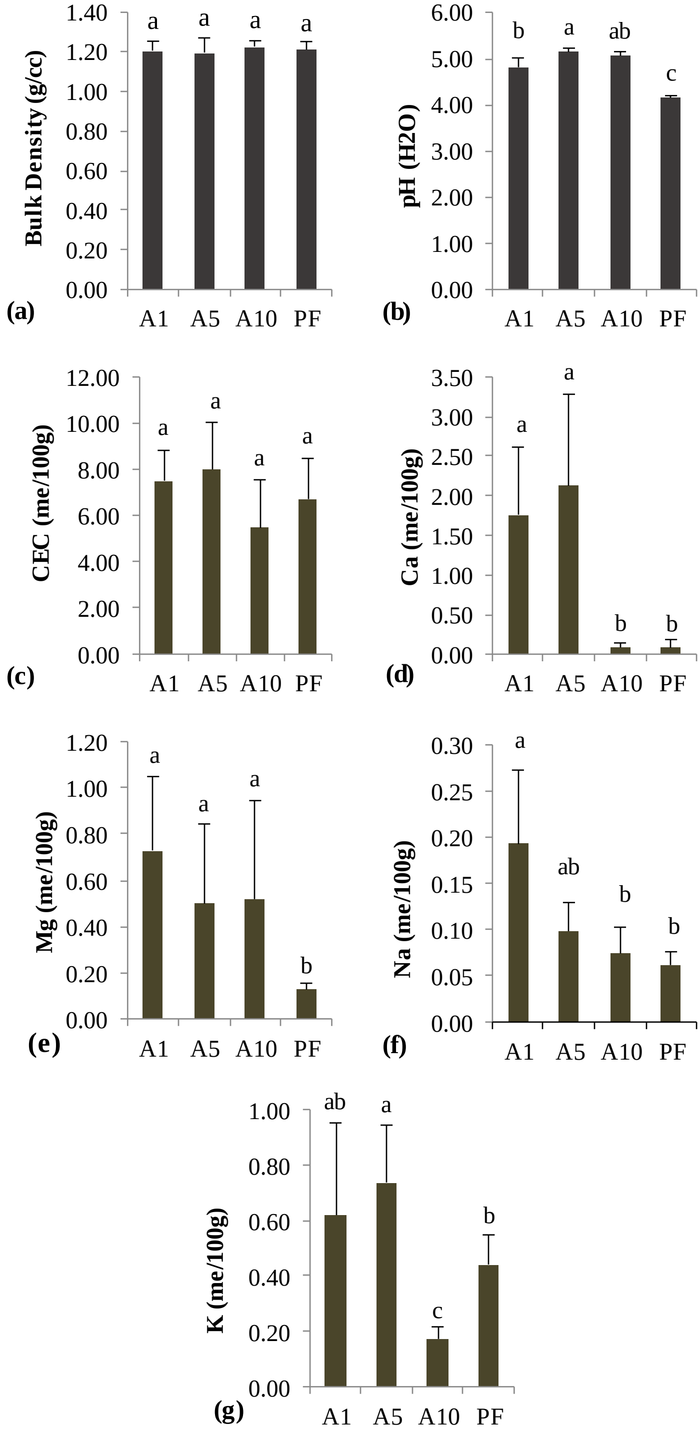

Fig. 3. Soil properties in different fallow period post shifting cultivation area and primary forest (a) Bulk density, (b) pH, (c) CEC, (d) Exchange Ca, (e) Exchange Mg, (f) Exchange Na, (g) Exchange K

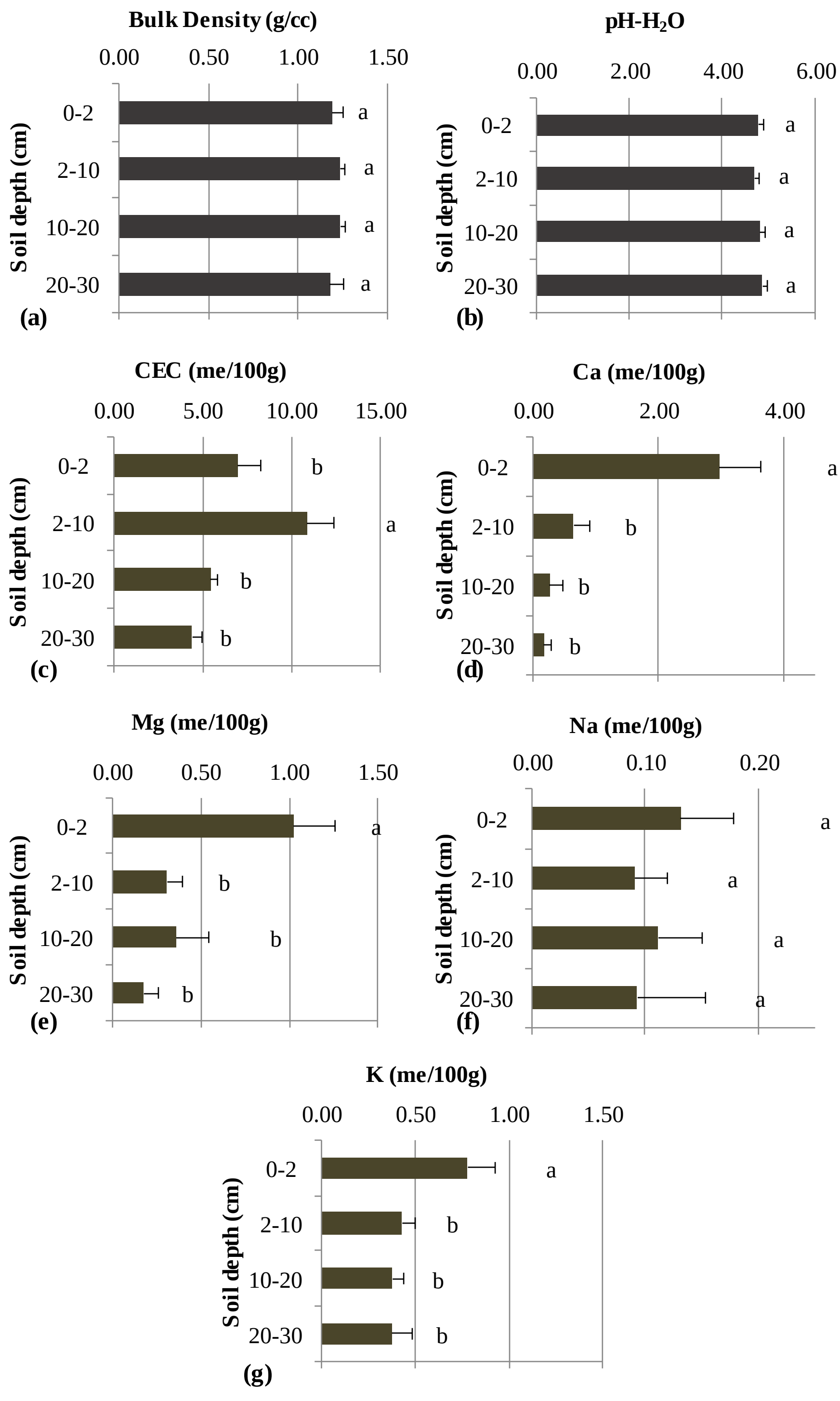

Fig. 4. Soil properties in different soil depth in post shifting cultivation area and primary forest a) bulk density, (b) pH, (c) CEC (d) Exchage Ca, (e) Exchange Mg, (f) Exchange Na, (g) Exchange K

4 Conclusion

The recovery of soil properties after shifting cultivation occurred during the fallow periods. It can be seen from soil pH and other chemical properties such as CEC and cation exchanged that began to recover during the early fallow period. Generally, the soil properties in 5-years fallow period have higher value than 1-year, 10-years fallow period, and the primary forest. The soil properties also varied among soil depths. The soil nutrient was large distributed on the surface layer and decreasing with soil depth.

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