The impact of converting maize to rubber (*Havea brasiliensis*) plantation on soil nutrient contents in Nan province

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**Abstract**

Recently, forest lands have been decreased and converted to agricultural lands. Therefore land use changes especially cultivation of deforested land may rapidly diminish soil quality. The objective of this study was to assess the impacts of land use changes from maize to rubber (*Havea brasiliensis*) plantation on soil organic matter, total nitrogen, phosphorus, and potassium contents and soil nutrient translocation along a slope position. The experiment was established at Nan province. This area is a slope complexes area (slope 25–35%). Six land uses were selected for this study consisting of (i) maize, (ii) Para rubber, 2–years–old intercropped with maize, (iii) Para rubber, 2–years–old, (iv) Para rubber, 3–years–old, (v) Para rubber, 5–years–old and (vi) Para rubber, 8–year–olds. Soil sample was collected from each land use at two depths (0–20 cm and 20–50 cm) from upper, middle, and lower slope. Results showed that organic matter, total Nitrogen, available phosphorus and exchangeable potassium in both soil depths were significantly affected (*p* < 0.05) by land use. Organic matter in topsoil (0–20 cm) of maize and Para rubber, 2–years–old intercropped with maize treatments were higher than monoculture rubber treatments. Moreover organic matter, total nitrogen, and exchangeable potassium in the top soil were significantly affected (*p* ≤ 0.05) by slope positions. The upper of slope had the highest organic matter, total nitrogen, and exchangeable potassium then middle slope and lower slope, respectively. An interaction between land use and slope positions was significantly influenced on organic matter, total nitrogen, and exchangeable potassium in both soil depths and also available phosphorus at top soil without at sub soil. The study of the impact of converting maize to rubber plantation can help greatly to the planning land use and land management for hillside area.

**Keywords:** Land use change, Soil nutrient content, Rubber plantation, Nan province

**Introduction**

The change of land use types in Nan province during almost 20 year period were characterized by rapid decreasing of natural forest areas and increasing of agricultural lands (Wongtui, 2014). Therefore land use change has important implications for soil degradation in the form of plant nutrient depletion is the major environmental problems in the highlands of Northern Thailand. Many researches have focused the effect of land use changes on soil properties (Bauer et al., 2002). Agricultural land use types are closely associated with soil nutrients (Kong et al., 2006) and also as well as their management practices (Duiker and Beegle, 2005). Especially, nutrient inputs for agricultural production such as nitrogen and phosphorus fertilizer can increase risk of soil nitrogen and phosphorus loss with soil loss, runoff and leaching (O’Reagain et al., 2005; Udawatta et al.,
Chen L. et al. (2011) reported that soil chemical properties were significantly affected by the different farming practice, Pamela H. T. (2005) also reported that bulk density was different in land use types with greater values in active agricultural than regenerating field.

Nowadays, Para rubber (*Hevea brasiliensis*) is a major economic crop of Thailand. Since 1989, rubber growing in Thailand has gradually shifted from its traditional area in the south to the north and northeast. The planting area has undergone more significant changes after the Thai government launched the one-million-rai (160,000 hectares) planting project. Since 2004, the new rubber planting in the north and northeast has diversified the former main crop varieties of rice, maize and cassava. In 2010, the total rubber cultivation area in northern Thailand (in 17 provinces) was 0.14 Mha (4.8%), while the expansion for new planting in the low and high land is at high rates (RRIT 2010). Today, many farmers in the uplands of Nan province, Thailand replace maize by monoculture of rubber tree plantations. Moreover, some of the original forest cover in upland areas has been cleared for agriculture including Para rubber cultivation.

Therefore, this research was to evaluate the effect of maize converting to rubber plantation on soil nutrients. The objectives this paper were (i) To assess the effects of converting maize to rubber (*Hevea brasiliensis*) plantation on soil nutrient contents and (ii) To assess nutrient translocation at different position of slope with effect of each land use type.

**Materials and methods**

**Site description**

The study area is located at Muab sub-basin of the Nan watershed (18° 54′N, 100° 54′E) in Nan province of Thailand. The trial altitude is located at an elevation ranging from 293 m to 472 m above sea level with slope gradients ranging from 20 to > 35% (Fig. 1). Data was conducted in 2005. The study area is tropical savannah climate. Annual temperatures ranged from 20° C to 32° C (average 26.8° C) in 2005. The total annual rainfall at the experimental site was approximately 1,330 mm, recorded by a self-registering rain gauge (Fig. 2). The soil profiled, carried out according to Soil Survey Staff (2014), were classified as a fine, mixed, active, isohyperthermic Typic Haplustalfs with 39.5% sand, 36% silt, a 24.5% clay in the topsoil (0–25 cm) and a bulk density (BD) of 1.3g cm⁻³. The topsoil had a pH (H₂O) of 4.5, an organic matter content (OM) of 0.3–1.8%, an available P (Bray II) content of 2.8–7.0 mg kg⁻¹ and an exchangeable K content of 99–149 mg kg⁻¹.
Soil sampling and analysis

In this study, soil samples were randomly collected from six land use types for maize and rubber production at Muab sub-basin of Nan province. They were i) only maize production, ii) 2-years-old Para rubber trees intercropped with maize, iii) 2-years-old Para rubber trees, iv) 3-years-old Para rubber trees, v) 5-years-old Para rubber trees and vi) 8-years-old Para rubber trees (Table 1).
Table 1 Land use types and management practices at Du–Phong, Santi–suk, Nan province

<table>
<thead>
<tr>
<th>Land use type</th>
<th>Management Practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>Cropping once a year, Fertilizer twice a year with 19 kg N rai, 20 kg P rai, no burn, no tillage</td>
</tr>
<tr>
<td>Maize with 2–year–old rubber</td>
<td>Maize converts to rubber for 2 years and till intercropping with maize. Fertilizer twice a year with 0.018 N kg⁻¹, 0.009 P, 0.009 K kg⁻¹.tree⁻¹.year⁻¹, for maize postharvest not burn, no tillage</td>
</tr>
<tr>
<td>2–year–old rubber trees</td>
<td>Maize convert to rubber for 2 years, no intercropping, Fertilizer twice a year with 0.018 N, 0.009 P, 0.009 K.kg⁻¹.tree⁻¹.year⁻¹</td>
</tr>
<tr>
<td>3–year–old rubber trees</td>
<td>Maize convert to rubber for 3 years, no intercropping,</td>
</tr>
<tr>
<td>5–year–old rubber trees</td>
<td>Maize convert to rubber for 5 years, no intercropping, Fertilizer twice a year with 0.018 N, 0.009 P, 0.009 K.kg⁻¹.tree⁻¹.year⁻¹, weed control 2 times</td>
</tr>
<tr>
<td>8–year–old rubber trees</td>
<td>Maize convert to rubber for 8 years, no intercropping, harvest for 3 years</td>
</tr>
</tbody>
</table>

In January 2016, a total of 36 soil samples were taken from the six land use categories along each of the three slope positions: upslope, middle slope and down slope (Fig. 3). Each sample was collected at two deep levels (surface soil at 0–20 cm and sub–soil at 20–50 cm) by using a soil auger. Soil 36 samples used for chemical analysis were air–dried in the shade area, ground and sieved through a 0.5 mm sieve to remove stone, root and large organic residues. Soil organic matter was analyzed by Walkley and Black method. Total nitrogen was converted from soil organic matter by using equation (1) (Chuchitt S., 2012).

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\text{Total Nitrogen (\%)} = \text{Organic matter} \times 0.05
\]

Figure 3 Slope positions at the site study

The samples sieved through a 2 mm sieve for available phosphorus was analyzed by Bray–II method, and the available phosphorus was determined by using Spectrophotometer. Exchangeable potassium was extracted by ammonium acetate and was analyzed by Atomic Absorption Spectrophotometry.
Statistical analysis

The variances of influence of land use and slope position on soil nutrients were statistically analysed by using one-way ANOVA, and mean comparisons were calculated by using the least significant difference (LSD) method at $p < 0.05$. The independent variables used in this study were land use types and slope aspects. Significant difference of their interactive effect was identified using GLM–MANOVA.

Results

At surface soil (0–20 cm), soil organic matter was significantly different among the six land use types and slope position. The result showed that maize and Para rubber, 2–years old intercropped with maize had the highest soil organic matter contents. In subsoil (20–50 cm), Para rubber, 3–years old had the highest organic matter contents, however, it had not significant difference with Para rubber, 8– years old (Table 1).

Total nitrogen of the surface soil (0–20 cm) was significant difference compared land use types. Para rubber, 2–years old intercropped with maize and maize monoculture the highest total nitrogen in comparison to Para rubber, 2, 3, 5 and 8–years old. Moreover total nitrogen in surface soil was also significant affected by slope position and interaction between land use types and position. In the subsoil (20–50 cm), slope position had no significant effect on total nitrogen content (Table 1).

There was a significant amount of available phosphorus content in the surface soil among land use types and an interaction between land use types and slope position. However, the result showed that slope position had no significant effect on available phosphorus at the surface soil and subsoil. We found that Para rubber, 2–years old intercropped with maize had the highest available phosphorus at the surface soil, and, Para rubber–3– years old had the highest available phosphorus (table 1).

The concentrations of exchangeable potassium had ranged from the highest to lowest as following the order sequences of Para rubber, 2 years old > Para rubber, 2 years old intercropped with maize > Para rubber, 3 years old > Para rubber, 8 years old > Para rubber, 5 years old > maize in the surface layer. However, in the soil subsurface soil layer, SOC was highest in Para rubber, 2 years old intercropped with maize. The results indicated that in the surface layer and in the soil subsurface soil layer, exchangeable potassium were significantly affected by land use types, slope position and their interaction (Table 1).

Lastly, the result showed that soil nutrients under Para rubber, 2 years old, Para rubber, 2 years old intercropped with maize, Para rubber, 3 years old, Para rubber and 5 years old and maize were higher in upper slope position than in the middle and lower slope position. However, the trend of soil nutrient translocation was not clear. In contrast with Para rubber, 8 years old, the highest soil nutrients were in the lower slope position.
Discussion and conclusion

Soil nutrients in each land use of this study decrease rapidly in the sub soil similar with the previously finding of Chen L. et al., (2011). Moreover, the different soil nutrients of each land use are affected by management practice. In this study, the greatest of organic matter and total nitrogen were maize and Para rubber, 2 years old intercropped with maize treatments may be due to N and P fertilizer application and biomass from maize straw and rubber leaves. Soil nutrient enrichment in the soil surface can be caused by chemical fertilizer (Shepherd and Withers, 1999). Moreover, plant cycling from residues also has influenced to soil nutrient (Jobbagy and Jackson, 2001).

The soil nutrients in top soil always are removed by runoff and soil loss (Wang et al., 2004). For in this study, Land use types and position of slope had an effect on nutrient content, especially in the top soil. We found that in the upper position had organic matter, nitrogen, phosphorus, and potassium more than middle and lower, respectively because the groundcover might be protect intensity of rainfall corresponded with Pimentel D. (2000) reported that groundcover have an
important factor for nutrients protection that can move out from soil by runoff and soil loss. Moreover, we found that Para rubber, 8 years old in lower position had the highest soil nutrient that might be run off and soil loss. These are consistent with Ponsak W. and Pinthip T. (2012) reported para-rubber has decrease covering area density and has a canopy as impact rainfall that increasing, while intensity of rain drop are increasing also. Moreover, they reported that Para rubber, 7 years old has the most soil erosion because this year has the highest canopy density. Shine through of light down into the ground is less that cause to weed are weak, soil surface without ground cover, so soil and water loss rate are increasing. However, soil and water loss decrease rapidly with the increasing age after Para rubber, 7 years old because of competition of rubber, it is made self-stratification and more light in soil surface that weed can growth then rate of soil and water loss are decreased. Similarly previous studies in South India also (Madhu et al., 2011) suggested that canopy development of tea has a direct relationship with reduction in runoff and soil loss.

In conclusion, this study assessed the effects of converting maize to rubber plantation. Significant differences among land uses were found for most soil nutrients. Soil organic matter, total nitrogen available phosphorus and exchangeable potassium contents in the top soil had the higher levels in maize and Para rubber–2-year old intercropped with maize treatments than those in rubber–5-year old and rubber–8-year old. Moreover, the amounts of soil organic matter, total nitrogen, and exchangeable potassium are affected by slope position. The understanding of the impact of converting maize to rubber plantation can help guide land–use decisions, land use planning and land management for the area of hillside agricultural land.

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References


