The impact of forest land use change to intensive agricultural system on the economic efficiency of nitrogen utilization

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Abstract. Identifying the dynamics of N-mineral soils in different Land Use Systems (LUS) with different levels of intensification, seven LUS were studied as well as intensive horticulture gardens. The coffee garden observed as of 7 - 10 years old. Measurements were made twice in the rainy and dry seasons. The use of forest land into coffee plantations and horticulture gardens was significantly (<0.05) to total-N, very significant (<0.01) to NO3- soil concentrations, but did not significantly affect the soil NH4+ concentration. Horticultural land has the lowest NH4+/N-mineral soil concentration ratio (0.98%) when it is compared to other LUS. The highest soil NO3+ concentration (about 1400 mg kg -1 soil) was found in intensive farming areas ie horticulture, about 5-17 times higher than in other LUS. The more intensive the land use system is followed by the increasing ratio of N-mineral/N-total soil concentration as well as the decrease in the NH4+/N-mineral soil concentration. This indicates that the more intensive the LUS will further decrease the economic efficiency of N utilization and increase the potential for loss of N through NO3- leaching, NO2 and NO evaporation, as well as run off, and potentially adverse impacts on aquatic biota due to eutrophication. This will lead to environmental damage, especially water pollution.

1. Introduction
The use of forest land into agricultural land will change the density and diversity of above ground vegetation, the level of land cover, and the quantity and quality of litter inputs. These changes eventually affect the content of soil organic matter (SOM), soil biota diversity, soil biological processes, and ultimately affect groundwater quality. The forest lands always receive an organic matter supply of about 10 Mg ha-1 year-1 through leaves, branches and twigs so that their SOM content is always maintained in dynamic equilibrium [1]. Agricultural land has more open tree canopy cover than forests, thus increasing the soil temperature fluctuation and decreasing soil moisture content [2]; [3]; [4]. Forest clearance will break the sustainability of the supply of litter, and at the same time will accelerate the decomposition of SOM and leaching nutrients that are mineralized during liver burning [5]. Therefore, plants cultivated after forest clearing often experience double cultivation [6].

Intensive agricultural cultivation is characterized by the use of excessive agro-chemical materials, continuous soil cultivation, vegetation grown by farmers only and often without the return of crop residues to the soil [7]. One of the important environmental issues that arise after the use of forest land into intensive agricultural land is nitrous contamination (NO3-) [8]. Nitrate is formed by the nitrification process causing the loss of N from both soil and N fertilizer and raises the complexity of environmental problems [9].
The nitrification process in the forest ecosystem proved to be relatively low due to the formation of allelochemical nitrification inhibitors such as tannins, polyphenols, galotanins, penicidal acids, flavonoids, chlorogenic acids, gallic acids, caffeic acid, querericin and karanjin [10]; [11]. The low NO3- in the forest ecosystem
is not only caused by the existence of allelochemical nitrification inhibitors but also due to the competition in obtaining NH$_4^+$ between nitrifying bacteria with heterotrophic microbes organic material composition (BO) and or extensive rooting of roots [10]. Another factor that can control nitrification is the abundance of BO in forest soils, which will increase the immobilization of NH$_4^+$ by heterotrophic microbes thus decreasing the amount of NH$_4^+$ remaining for the nitrification substrate. The BO decomposition process also absorbs O$_2$ in the soil so that O$_2$ competition occurs between heterotrophic microbes and nitrifying bacteria that indirectly inhibit nitrification [12].

This research aim to study the magnitude of soil nitrification in different land-use systems with different levels of intensification with the variables: N concentrations of soil minerals (NH$_4^+$ and NO$_3^-$). The more intensive the land use system will be the less the input of litter (organic matter) so as to decrease the soil organic matter content and improve the process of nitrification. The results of this study shows that the more intensive the agricultural practise, the higher rate of nitrification those the more potential loses of NO$_3^-$ in soil through leaching and denitrification.

The organization of this study i.e. introduction, methods, results and discussion, and conclusion.

2. Methods
Measurements carried out on seven Land Use Systems (LUS), namely: (1) disturbed forest, (2) mixed coffee or multistrata, (3) coffee with sengon shade (Paraserianthes falcatoria), (4) coffee with Gliricidia sepium shading, (5) monoculture coffeees, (6) horticultural gardens, and (7) coffee with Gliricidia shade and Arachis pintoi ground cover. The criteria used to distinguish between mixed coffee systems and shade coffee systems is based on the number of tree species per area of land and the basal area (the land covered by trees).

The land use system is considered to represent a variety of intensification of land management, from natural ecosystems to intensive agricultural cultivation; from the closest land clearance level to the open, and from the highest to low litter inputs. The criteria used for the determination of coffee-based agroforestry LUS are based on basal area and number of planted tree species [3].

The retrieval points in each LUS are determined based on the stratified grid, with the number of points ranging from 12 per LUS. Soil samples for measuring the basic chemical characteristics of soil were taken at a depth of 0-30 cm. The soil from each of the 3 adjacent points is well blended for the analysis of its physical and chemical properties: pH$_{H_2O}$ (1:2.5), pH$_{KCl}$ (1:2.5), total C (Walkey and Black), total N (Kjeldahl), P available Bray II), K can be exchanged (1 M NH$_4$OAc, pH 7), soil texture (pipette method) and soil moisture (gravimetry). The results of SOM content analysis corrected with clay, dust and soil pH content (C$_{ref}$) according to the formula:

$$C_{ref} = \left(\frac{Z_{exp}}{7.5}\right) - 0.42 \exp(1.33 + 0.00994 \times %\text{clay} + 0.00699 \times %\text{dust} - 0.156 \times \text{pHKCl} + 0.000427 \times H)$$

where Z = depth of soil sampling and H = altitude of place from sea level [3].

Soil samples for measurement of NH$_4^+$ and NO$_3^-$ concentrations were taken at 3 depths of 0-10 cm, 10-20 cm and 20-30 cm from the soil surface. The sampling is minimized to avoid changes in N soil mineral composition. The soil sample weighing 5 g was extracted with 20 ml of KCl 2 M solution, shaken for 1 minute, plus 2 drops of toluene solution to prevent the mineralization and nitrification process, settled overnight, then filtered with Whatman 42 filter paper (Anderson and Ingram, 1993). N concentrations of minerals using the Flow Injection Analysis (FIA) spectrophotometer [13].

This research would like to find out the impact of forest land use on the soil N concentration of minerals with variance analysis (ANOVA) using SPSS statistical program package. To know the closeness of the relationship between each of the variables mentioned above used correlation analysis. If the result of fingerprint analysis give the value of F with P <0.05 is different and if P <0.01 is stated very different and continued by regression test [14].

3. Results and Discussion
3.1. Land Characteristic
Approximately 85% studied area was hilly predominantly steep slope to very steep (16 - >45%). In the valley, there are two kinds of parent material. The parent material which is 70% clay content forms Ultisol, while the clay content <70% forms Inceptisol. The soil texture in this area is dominated by heavy clay with clay > 30%. Mineral clay is dominated by tubular halloysite, while mineral fraction sand is dominated by silica and feldspars [15].
The results of soil characteristics analysis (Table 1 and Appendix 2) show that the soil at the study site is dominated by clay fraction having high water holding capacity because it has particle size < 2 m. The forest land has the lowest clay fraction (46.29%) than the other LUS. This result is consistent with previous research that forest soils have a coarser texture than other LUSs [16].

Table 1. Part of soil fertility characteristics at depths of 1-30 cm in various LUSs (HT = undisturbed forests; AF = mixed coffee; KNS = coffee with sengon shade; KNG = coffee with Gliricidia shade; KM = coffee monoculture; HR = horticulture; KAp = coffee with Gliricidia shade and Arachis pintoi ground cover crop)

| LUS | pH | pH | Org C | Total N | C/N | Available P, mg kg⁻¹ | Exchangeable K, cmol kg⁻¹ | Sand | Silt | Clay |
|-----|----|----|--------|---------|-----|----------------------|--------------------------|------|------|------|
| HT  | 5.98 | 5.21 | 3.17h  | 0.51h   | 6.86 | 6.81kr               | 0.23r                    | 24.21 | 29.58 | 46.29 |
| AF  | 5.45 | 4.59 | 3.18h  | 0.25m   | 14.41 | 5.40el,              | 0.27l                    | 15.53 | 29.33 | 54.89 |
| KNS | 5.45 | 4.39 | 2.29m  | 0.28m   | 8.44  | 11.24d,              | 0.14d                    | 10.29 | 29.82 | 59.90 |
| KNG | 6.14 | 5.31 | 1.90l  | 0.20l   | 14.03 | 5.31el               | 0.25l                    | 22.83 | 17.44 | 59.73 |
| KM  | 5.65 | 4.60 | 3.54h  | 0.30m   | 14.36 | 6.11el               | 0.20l                    | 13.27 | 28.56 | 58.18 |
| HR  | 5.70 | 5.09 | 2.17m  | 0.39m   | 6.35  | 13.76d               | 0.25l                    | 29.55 | 19.09 | 51.36 |
| KAp | 4.91 | 4.13 | 2.80m  | 0.18l   | 17.86 | 4.51el               | 0.15l                    | 14.75 | 15.13 | 70.13 |

Description: h: high; m: moderate; l: low; el: extremely low (according to criteria of Soil and Agro-climate Research Center, 1994). The full analysis results are listed in Appendix 1b.

A general constraint of soil fertility in all LUSs studied was the availability of phosphorus (P) ranging from very low to low and potassium (K) mixed low. Plants grown on P deficiency will have low respiratory rates but photosynthesis remains normal [17]; [18].

The soil carbonaceous index (at a depth of 0-30 cm) in each LUS is measured by the multiplication value of the C-organic, N-total, P-available, K-available, Ca-exchanged and Mg-exchanged soils (Fig. 2). The higher the land's land index indicates the higher status of land occupancy in the LUS.

Figure 1. Land-land index of each LUS based on the cumulative value of Organic-C, Total-N, Available-P, Available-K, Exchangeable-Ca and Exchangeable-Mg land (HT = disturbed forests; AF = mixed coffee; KNS = coffee with sengon shade; KNG = coffee with Gliricidia shade; KM = coffee monoculture; HR = horticulture; KAp = coffee with Gliricidia shade and Arachis pintoi ground cover crop)

The most intensive horticulture gardens have the highest equity index (27.4), followed by forest (20.9) and mixed coffee AF (11.0). The lowest land-land index (2.5) contained a coffee LUS with a Gliricidia shield with Arachis pintoi ground cover (KAp). The decline in the price of coffee around Rp.3.500,- kg⁻¹ from 2002 - 2006 caused most farmers were reluctant to perform maintenance and fertilization so that the maintenance of soil fertility in each coffee garden depends only on the input and management of the litter.
3.2 Production and Thickness of Litters
The production of litter fall in forests is about 11.1 Mg ha⁻¹ th⁻¹, three times that of LUS monoculture (3.93 Mg ha⁻¹ th⁻¹), whereas in shade coffee is between 5.03 - 7.0 Mg ha⁻¹ th⁻¹. Production of litter per month varies between LUSs due to differences in leaf abortions between plant species. Leaf fraction of all LUSs ranged from 60-87% of total litter input.

In forests, mixed coffee and shade coffee, the number of fractions of twigs is about 20% of total litter input, whereas in monoculture and horticultural coffees, the fraction portion of branches and branches is only about 5%. The different types of litter input will affect the speed of decomposition. The branch fractions and twigs will be slower to decompose than the leaf fraction because they contain higher lignin and polyphenols [19]; [20]. The mixed coffee system (AF) has the highest litter production (7.7 Mg ha⁻¹ year⁻¹) compared to other coffee systems, but has a thickness of 3 th order letters (3.8 mm), which is relatively the same as the nasal shoot LUS (3.78 mm).

![Figure 2.](image)

Figure 2. The thickness and production of the annual litter (A); as well as the percentage of litter fractions in various LUS (B) {HT = disturbed forest; AF = mixed coffee; KNS = coffee with sengon shade; KNG = coffee with Gliricidia shade; KM = coffee monoculture; HR = horticulture; KAp = coffee with Gliricidia shade and Arachis pintoi ground cover crop}.

The OM composition biota encompasses the entire group of fauna, fungi and actinomycetes as well as most of the bacteria that are heterotroph biota [21] 1999; [20].

3.3 The Content of Soil Organic Matter
The measurement results at 0-30 cm depth on these LUSs did not indicate a decrease in Organic-C levels due to the conversion of forest land to agricultural land. The hypothesis is built that the higher the litter fall input will further increase the SOM content proved not fully accepted. The monoculture coffee with the lowest peak input (3.9 Mg ha⁻¹ th⁻¹) has the highest soil C-content of 3.5% .
Figure 3. Total C and Ratio of Corg/Cref ground at a depth of 0-30 cm in various LUSs {HT = disturbed forest; AF = mixed coffee; KNS = coffee with sengon shade; KNG = coffee with Gliricidia shade; KM = coffee monoculture; HR = horticulture; KAp = coffee with Gliricidia shade and cover crop Arachis pintoi}.

If the total content of soil organic-C is corrected with its clay and silt content, the C-org / C-ref difference in LUS monoculture coffee is not much different from that of forests or with mixed coffee. [3] states that the conversion of forest land into agricultural land causes a decrease in Organic-C content in the soil depth of 0 - 5 cm. The soil surface is the most dynamic layer so that the impact of litter input on SOM content will be more apparent on the surface layer than the lower layer (> 5 cm) [5]; [23].

The relationship between litter input, litter thickness and SOM content
In the quadratic model, 57% litter thickness variation on the soil surface is related to the number of lung drop inputs, but the SOM content is only 6% corresponding to the number of litter inputs. Swift et al[24] states that the SOM content depends on the interaction of 3 factors affecting the decomposition of the litter of the physical-chemical environment, the quality of the litter and the community of decomposer biota. Baon [25] adds that the thickness of litter does not always increase the level of soil C-organic unless it is carried out by littering or there is a high bios ecosystem engineer activity. Apart from litter input, the different ways of weed control and spatter management of each LUS also affect the amount of SOM content.

Figure 4. Effect of litter fall input on the thickness of the soil surface litter (A), and the influence of litter input on soil organic matter content (B).

More open ground conditions in the monoculture coffee system will increase the weed population, requiring greater weights of weeding. Weed weeding is generally followed by the implantation on the vent (rorak) thus increasing the SOM content.
Soil Nitrogen

a. N-total of soil
Nitrogen in the soil is sourced from the input of organic matter, rain-borne N atmosphere, N fertilization, and microbial activity of N2 fixers (diazotrop). The use of forest land into coffee agroforestry and horticulture garden has significant effect (p <0.05) on total N-total of soil. The results of soil characteristics analysis (Table 1) show that forests have the highest N-total (0.51%) compared to other LUSs, and the order of N-total soil concentration is HR> KM> KNS> AF> KAp. [20] state that ground litter (eg on forest land) will decompose more slowly than those immersed in the soil. Forests with the highest litter input have the highest total N reserves in Organic-N (SOM) form. Litter on the surface of the soil other than drier due to exposure to sunlight, also not reachable by most soil biota except some macrofauna and fungi. The lowest total N content (0.18%) in KAp was suspected due to high quality litter from Gliricidia shade trees and the rapidly decomposing A peat soil cover, liberating the NH4+ which was soon reabsorbed by the roots of the ground cover crops. The KAp system also has the lowest NH4+ and NO3- content compared to other LUSs (respectively 1.29 mg of NH4+ and 16 mg of NO3- kg-1 soil). The horticultural garden has N-total concentrations of 0.39% or almost 2 times greater than coffee-based LUS, due to the high number of inputs of manure and urea fertilizer by farmers.

b. Concentrations of NH4+ and NO3- soils
The use of forest land to coffee agroforestry and horticulture garden has no significant effect on soil NH4+ content, but it has significant effect (p <0.01) on soil NO3 content.

| Source of Variety | F-calc | P-value |
|-------------------|--------|---------|
| Land Use System   | 13.909 | .000**  |
| Soil Depth        | 0.430  | 0.651   |
| LUS * Soil Depth  | 0.167  | 0.999   |

Table 2. Result of analysis of diversity of soil nitrate concentration

There were no significant differences in NH4+ and NO3- concentrations at various depths of soil. Mean N NH4+ concentration of soil at all depth and LUS ranged from 1.29 - 2.91 mg kg-1 soil. The highest mean NH4+ concentration was found in coffee LUS with sengon shading (2.91 mg kg-1) and lowest in coffee with Arachis pintoi ground cover (1.29 mg kg-1). The soil NO3 concentration varies from the highest in the most intensive horticultural LUS (283.88 mg kg-1), or about 26-fold from the forest (20.33 mg kg-1), or 5-9 times from Coffee-based LUS (AF, KNS, KNG, KM), or about 17 times that of LUS coffee shade with Arachis pintoi ground cover (KAp).

Figure 5. Concentration of NH4+ soil (A), and NO3-soil concentrations in various LUS (B) {HT = undisturbed forest; AF = mixed coffee; KNS = coffee with sengon shade; KNG = coffee with Gliricidia shade; KM = coffee monoculture; HR = horticulture; KAp = coffee with Gliricidia shooter and ground cover crop (TPT) Arachis pintoi}. 
In low rainfall, soil NH$_4^+$ concentration is much higher than in high rainfall. In low rainfall average NH$_4^+$ concentrations in the overall LUS range from 50% - 278% higher than in high rainfall. This is in accordance with the statement of [21] that in aerobic conditions (low rainfall), NH$_4^+$ mineralization and release will take place more rapidly, on the contrary to stagnant conditions (high rainfall), mineralization progresses more slowly and with incomplete decomposition. [21] states that the mineralization of N will take place at a maximum of 50-70% of the pore space filled with water, and pH 5.5-6.5 [1]. [10] stated that low NO$_3^-$ in forest ecosystems is due, among other reasons, to competition for NH$_4^+$ between nitrifying bacteria and microorganisms of organic matter (OM) compositions and / or extensive rooting diversity in forest ecosystems. The abundance of OM in forest soil can control nitrification because heterotrophic microbes will immobilize NH$_4^+$ in the soil during decomposion so as not to leave NH$_4^+$ for nitrification. OM decomposition also absorbs O2 in the soil so that O2 competition occurs between heterotrophic microbes and nitrifying bacteria that indirectly inhibit nitrification [12].

c. NH$_4^+$/ N-mineral ratio and N-mineral / N-total soil

Nitrate (NO$_3^-$) in the soil is formed from microbial NH$_4^+$ oxidation process, therefore, the NH$_4^+$/N-mineral (NH$_4^+$ + NO$_3^-$) concentration of soil represents the actual amount of nitrification in the soil. Nitrogen-total soil represents the total amount of N-organic and N-minerals in the soil, so the N-mineral / N-total ratio of soils represents the amount of N reserves that can be utilized by plants in the long run (Figure 8). The lower N-mineral / N-total ratio of soil will be the lower the N amount available but the higher the nutrient reserves in the N-organic soil. Therefore, the lower N-mineral / N-total ratios of land will be less risk of land loss through leaching, volatilization and denitrification, making it more profitable for annual crops such as coffee [20]; [10]. The lower the NH$_4^+$/ N- mineral soil ratio will be the lower proportion between the amonification process compared to nitrification in the soil or the lower efficiency of utilization of N from the soil.

The use of forest land to coffee agroforestry and horticulture gardens has a very significant effect (<0.01) on the ratio of NH$_4^+$/ N-mineral soil concentrations. Soil N-minerals throughout the LUS range from the lowest (17.7 mg kg-1 soil) to coffee with the Gliricidia shoot and Arachis pintoi legume cover crop (KAp), to the highest (286.7 mg kg-1 soil) in horticulture. According to [10] N-mineral concentrations in natural ecosystems rarely exceed 100 mg kg-1 of soil, whereas [26] state that the Spanish soils contain N-minerals between 0 - 153 mg kg -1 ground.

Table 3. Results of the variation analysis of NH$_4^+$/N-mineral soil concentrations

| Sources of variety | F-calc | P-value |
|--------------------|--------|---------|
| Land Use System (LUS) | 3.89 | 0.001* |
| Soil Depth | .043 | 0.958 |
| LUS * Soil Depth | .422 | 0.952 |

Description: ** very significant; * significantly different; ns: not significantly different

The more intensive land management (ILUI land intensification index) the lower the NH$_4^+$/ N-mineral soil concentration and the higher the N-mineral / N-total soil ratio. The forest land has the lowest mean N-mineral / N-total concentration ratio (0.5%) and the highest NH$_4^+$/ N-mineral ratio (12.3%). In contrast, horticultural LUS has the highest N-mineral / N-total (8.1%) and the lowest NH$_4^+$/ N-minerals (1.0%). This indicates that although horticultural gardens have the highest equity index (27.4) but have a low utilization efficiency of N.
Figure 6. N-mineral / N-total concentration ratio and NH$_4^+$ / N concentration of soil minerals at various LUSs {HT = disturbed forest; AF = mixed coffee; KNS = coffee with sengon shade; KNG = coffee with Gliricidia shade; KM = coffee monoculture; HR = horticulture; KAp = coffee with Gliricidia shade and cover crop Arachis pintoi}.

In the quadratic model, 51% variation in N-mineral / N-total land and 19% variation in the NH$_4^+$ / N-mineral soil ratio was correlated with litter input from each LUS.

Figure 7. Effect of input litter on N-mineral / N-total ratios of soil

The increased litter input on an LUS will be the lower N-mineral / N-total soil ratio and the higher the NH$_4^+$ / N-mineral land ratio. However, the number of litter inputs did not significantly affect the NH$_4^+$ / N-mineralized soil ratio as indicated by the weak relationship of the two variables (R$^2$ = 0.241). Increased litter intake followed by a decrease in the N-mineral / N-total concentration of the soil indicated a nitrification bottleneck (actual) due to high litter input.

4. Conclusion

This research was aimed to study the magnitude of soil nitrification in different land-use systems with different levels of intensification with the variables: N concentrations of soil minerals (NH$_4^+$ and NO$_3^-$). The results of this study showed that (a) The more intensive the real land use system followed by the increase in the N-mineral / N-total soil concentration ratio and the decrease in the NH$_4^+$ / N-mineral soil concentration. The more intensive the land use system will be the higher the land soil index but the lower the utilization efficiency of N and the higher the potential for loss of N through leaching of NO$_3^-$; (b) Coffee-based agroforestry with a variety of shade trees and mixed trees has a 48% higher NH$_4^+$ / N-mineral concentration ratio (8.85%) than coffee with Gliricidia shading (NH$_4^+$ / N-mineral ratio = 5.96%); and (c) An increase in NH$_4^+$ / N-mineral concentration ratio is thought to be due to an increase in the number of low quality litter inputs.

Acknowledgement

The authors would like to thank all parties who helped in the smooth running of this research.
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