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# SEASONAL DYNAMICS OF NITROGEN IN CULTIVATED SOIL AT GIAO THUY DISTRICT, NAM DINH PROVINCE

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## ABSTRACT

This paper focuses on evaluating the nitrogen mineralization and $NH_4^+$ and $NO_3^-$ leaching from the root zone in cultivated soils of Giao Thuy district, Nam Dinh province using Synthetic accumulation (SIA) method. Main findings reveal that total N content in vegetable fields and rice-vegetable-rotational fields ranges from 17.68 – 113.68 kgN ha$^{-1}$, and from 14.64 – 132.59 kgN ha$^{-1}$, respectively. Total N is also significantly different between saline paddy-fields and fresh-water fields, varies between 16.33 – 82.12 kgN ha$^{-1}$ and from 23.89 – 74.04 kgN ha$^{-1}$, respectively. $NO_3^-$ accounts for a larger proportion in vegetable fields and accumulated higher during the dry season; $NH_4^+$ predominates in paddy fields and accumulated mainly in rainy season. The N leaching losses decreased in the following order: vegetable, rice-vegetable rotation, non-saline and saline soil.

*Keywords*: fertilizer application, nitrogen fertilizer, leaching.

## 1. INTRODUCTION

The role of soil nitrogen (N) mineralization is essential for the plant uptake in all agricultural systems [1]. The N cycle is complicated but it's process generally consists of assimilation, mineralization/immobilization, nitrification, denitrification, ammonia volatilization, nitrate leaching, runoff and erosion. Potential N loss from ecosystems was calculated based on the ratios of nitrification to N mineralization (relative nitrification) and ammonium immobilization to N mineralization (relative ammonium immobilization) [2].

Number of research demonstrated that rates of mineralization and nitrification correlate positively with soil bulk density, but negatively with soil pH. Net N mineralization and nitrification were strongly regulated by land use, precipitation, soil water and temperature [1]. Land use types (LUTs) can profoundly impact soil N cycling through the alteration of abiotic and biotic characteristics of soils and soil organic matter quality [3].

This study was conducted to provide more scientific evidences for N-balance in intensive coastal agriculture in Giao Thuy. In particular, the analysis focused on the accumulation of N minerals in the soil and N leaching during two cultivating seasons. The research results can be used as the basis for proposing solutions to manage the use of nitrogen fertilizers in a rational manner, thus contributing to raising the efficiency of cultivation and environmental protection towards the sustainable development of the Red River Delta.

## 2. RESEARCH METHODS

### 2.1. The study site

This study was conducted in Giao Thuy District, Nam Dinh Province. The district lies in the corridor of the Red River Delta, between 2 estuaries, with a total of 23,776 ha (Giao Thuy district people committee, 2017). The average annual temperature is 23.7 $^{o}$C (T-min = 7.3 $^{o}$C, T-max = 33.2 $^{o}$C) [4]. There are two main seasons, rainy and dry seasons. The rainy season usually lasts from May to October, and the dry season lasts from November to April. The annual average rainfall is about 1,650 mm [4].

This study focused on 4 main LUTs: paddy rice with salinity intrusion (SRR), fresh water paddy rice (FRR), intensive vegetables (AV), and rice-vegetable rotation (RV). Three fields per each LUT were selected for field experiments on the dynamic leaching of N. Total vegetable experimental fields were about 1 hectare while the rice fields were about 6 hectares.

### 2.2. Research methodology

*2.2.1. Survey*

Household survey was applied to collect data on fertilizer application. The survey was conducted at two communes: Giao Phong and Giao Lac as representatives of intensive vegetable production and mono rice production, respectively. Four household groups who have their fields located within AV, RV, SRR and FRR were identified. In each group, 30 households were randomly selected. The amount of urea and NPK applied were converted to nitrogen based on the ratio written in the fertilizer bags.

*2.2.3. Soil sampling and analysis*

A total of 72 soil samples were taken cross over four LUTs. During the year of 2016, intervals were scheduled 2 times every month. Soil samples were taken at 0 – 10 cm depth, following TCVN 4046:1985; and analysis of $NH_4^+$ and $NO_3^-$ in soil by potassium extraction with KCl 1M according to TCVN 6179-1:1996 and TCVN 6180:1996.

*2.2.4. Nitrogen leaching estimation*

This research applied Self-Integrating Accumulators – SIA to determine N leaching as this is the only method that is capable of measuring directly the amount of Nitrate –N and Ammonia–N lost from root zones under absorbing solutes of water without affecting the soil cultivation during growing season [5]. SIA measures the stimulated amount of $NO_3^-$–N and $NH_4^+$–N over crop season. SIA uses absorber materials of resin and crystal. The materials were placed in a cylinder at size of 10x10 cm and burrowed under root zone (45 cm). Water in surface containing leaching nitrogen was penetrated into the cylinder and absorbed.

The measurements were taken 2 times, from January to June (dry season) and from June to November (rainy season) in 2016 in two LUTs: AV and RV. The number of plots selected for each land type was 3, with each plot placing 3 SIA cylinder tubes. Also in each land, a spare tube was added, thus 10 pipes (3×3+1) for each land use type were designed. Tubes were buried and covered with soil for cultivation as usual and after each growing season, samples were taken. The amount of nitrogen used in the plots was the average amount applied in each type of land use. Then, the materials inside the cylinder tubes were divided into 3 layers of 5 cm, 1 cm and 4 cm respectively. If the amount on the top layer (5 cm) is higher than that of the lower layers, N is not saturated, the results can be used. If the top layer is lower or equal to the lower layers, the sample is rejected because it means that either N has either saturated or been absorbed back from the groundwater.

The 1 cm layer is used to check the results. Parameters such as $NH_4^+$–N and $NO_3^-$–N were analyzed by extraction with 1M KCl. The amount of $NH_4^+$–N and $NO_3^-$–N lost according to the monitoring point is calculated in kg N $ha^{-1}$ $year^{-1}$ based on the $NH_4^+$–N and $NO_3^-$–N concentration on the surface area of the SIA.

## 3. RESULTS AND DISCUSSIONS

### 3.1. Soil properties under different land use types in Giao Thuy district

Soil samples have been collected and analyzed for 4 different LUTs at the beginning of the study. The result shows that there are significant differences of C content and the total N between different LUTs (see Table 1).

*Table 1.* Soil physicochemical properties under cultivated lands in Giao Thuy district.

| LUT | N | Soil particles (%) | | | $pH_{KCl}$ | Bulk density ($g/cm^3$) | EC (dS/m) | TN (g/kg) | OC (g/kg) |
|---|---|---|---|---|---|---|---|---|---|
| | | Clay | Limon | Sand | | | | | |
| AV(*) | 18 | 2.6 | 14.4 | 83.0 | 7.3±0.1 | 1.09±0.11 | 3.0 ±1 | 0.43±0.04 | 3.16±0.3 |
| RV(*) | 18 | 3.9 | 15.5 | 80.6 | 7.1±0.1 | 1.12±0.08 | 1.9 ±0.5 | 0.44±0.02 | 3.43±0.3 |
| SRR | 18 | 35.1 | 11.9 | 53.0 | 7.9±0.2 | 1.06±0.06 | 5.1 ±0.6 | 0.59±0.06 | 4.64±0.2 |
| FRR | 18 | 32.3 | 15.8 | 51.9 | 7.6±0.2 | 1.06±0.05 | 3.6 ±0.1 | 0.57±0.02 | 4.27±0.4 |

(*)Source: Ly *et al*. 2018[6]

### 3.3. Variation of N mineralization in different land use types

The N variation under different LUTs during 12 months of study is shown in Figure 1. Total N minerals (including $NO_3^-$–N and $NH_4^+$–N) in the AV, RV, SRR and FRR ranged from

17.68 – 113.68 kg N $ha^{-1}$, 14.64 – 132.59 kg N $ha^{-1}$, 16.33 – 82.12 kg N $ha^{-1}$ and 23.89 – 74.04 kg N $ha^{-1}$, respectively (see Figure 1C).

$NO_3^-$–N is very low in paddy fields for nearly all year around (Figure 1A). The seasonal variation of $NO_3^-$–N is very clear in the AV and RV. It was significantly higher during the dry season and reached its peak in May with 86.11 kg ha-1 in the AV and 75.41 kg ha-1 in RV (Figure 1B); and it decreased rapidly during the rainy season.

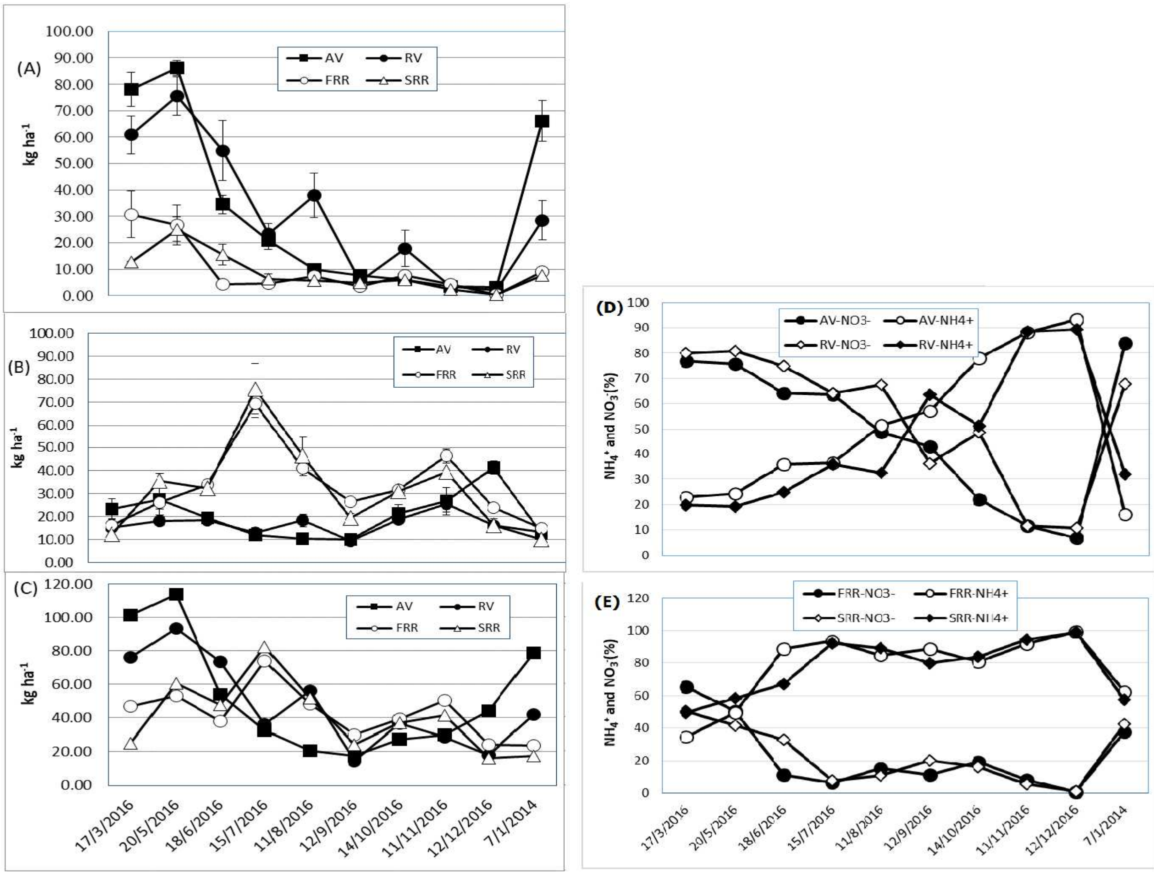


*Figure 1.* Variation of $NO_3^-$–N(A), $NH_4^+$–N (B) and TN (C) in soil depth (0-10 cm); percentage of $NO_3^-$–N and $NH_4^+$–N compared to TN in the soil in (D) AV and RV and (E) in SRR and FRR.

In contrast to $NO_3^-$–N, the amount of $NH_4^+$–N was slightly different from season to season. It was slightly higher during rainy season, ranging from 10.09 – 41.22 kg $ha^{-1}$ in AV and from 9.33 – 25.33 kg $ha^{-1}$ in RV. The $NH_4^+$–N content was much higher in paddy fields, dominating in all seasons. It was higher in rainy season and decreased during the fallow time (Figure 1B). Total $NH_4^+$–N reached the maximum in July in both SRR and FRR, which were 75.96 kg $ha^{-1}$ and 69.41 kg $ha^{-1}$, respectively. There was a statistically significant difference of $NO_3^-$–N and $NH_4^+$–N between paddy and vegetable fields and within rainy and dry season ($p < 0.05$). Figure 1C shows that TN accumulated in the soil during the dry season was greater than that of rainy season.

$NO_3^-$–N accounts for a large proportion of TN in AV and RV during dry season, ranging from 75.7 % to 83.9 % and 67.9 % to 80.7 %, respectively. In the wet season, the contents were lower, ranging from 0.8 to 19.1 % and from 1.2 to 32.6 %. In contrast, $NH_4^+$–N accounts for a significant proportion in both seasons, with over 80 % in the rainy season and approximately 60 % in the dry season.

*Table 2.* Total amount of nitrogen loss for LUTs in Giao Thuy district (N = 10).

| LUT | Amount of N fertilizers *(kg ha$^{-1}$ year$^{-1}$)* | $NO_3^-$ - N | | $NH_4^+$–N | | Total | |
|---|---|---|---|---|---|---|---|
| | | Leaching *(kgha$^{-1}$year$^{-1}$)* | Percent *(%)* | Leaching *(kgha$^{-1}$year$^{-1}$)* | Percent *(%)* | Leaching *(kgha$^{-1}$year$^{-1}$)* | Percent *(%)* |
| AV(*) | 705 | 275 | 39.0 | 1 | 0.1 | 276 | 39.1 |
| RV(*) | 876 | 144 | 16.4 | 4 | 0.5 | 148 | 16.8 |
| FRR | 330 | 14 | 4.2 | 7 | 2.1 | 21 | 6.4 |
| SRR | 340 | 10 | 2.9 | 8 | 2.4 | 18 | 5.3 |

(*)Source: Ly *et al*. 2018 [6]

### 3.4. Leaching nitrogen from the root zone

The data from Table 2 show that the leaching amount of $NO_3^-$–N and $NH_4^+$-N from AV soil was 275 kg ha$^{-1}$ year$^{-1}$ and 4 kg ha$^{-1}$ year$^{-1}$ while these values were 144 kg and 1 kg ha$^{1}$year$^{-1}$ from RV, respectively. As a result, the amount loss of nitrogen leaching into the groundwater is mainly $NO_3^-$–N, accounting for 99.6 % of AV and for 97.2 % of the RV, occurring during the rainy season, from June to November.

In rice production system, the amount of N loss was much lower than vegetables (Table 2). The amount of $NH_4^+$-N loss was lower than that of $NO_3^-$–N, but $NH_4^+$-N loss in rice system was about 2 times greater than that of vegetable system. In rice production (Table 3), the amount of $NO_3^-$–N loss in dry season was about 2 times higher than that in the rainy season, while the $NH_4^+$-N content was relatively similar in both seasons.

*Table 3.* Amount of $NH_4^+$–N and $NO_3^-$–N losses from LUTs in Giao Thuy district (N = 10).

| LUT | Leaching amount of $NO_3^-$–N *(kg ha$^{-1}$year$^{-1}$)* | | | LUT | Leaching amount $NH_4^+$–N *( kg ha$^{-1}$year$^{-1}$)* | | |
|---|---|---|---|---|---|---|---|
| | Jan – Jun | Jun – Nov | Annual total | | Jan – Jun | Jun – Nov | Annual total |
| AV(*) | 58 | 217 | 275 | AV | 0 | 1 | 1 |
| RV(*) | 83 | 61 | 144 | RV | 2 | 2 | 4 |
| FRR | 9 | 5 | 14 | FRR | 4 | 3 | 7 |
| SRR | 7 | 3 | 10 | SRR | 5 | 3 | 8 |

(*)Source: Ly *et al*. 2018[6]

Total N losses due to leaching to groundwater compared with N fertilizer application were significantly different in different LUTs (Table 2). The rate of N leaching loss on vegetable soil was 39.1 %, much higher than that of rice-vegetable rotation (16.8 %) and fresh rice (6.4 %) and salt rice (5.3 %) compared to the total amount of nitrogen fertilization application that were recorded on each type of land use.

Because of their existence in the ionic form, $NH_4^+$-N and $NO_3^-$–N are usually retained in soil solution so that they infiltrate from the soil surface to groundwater. A similar study in southern China concluded that the amount of N leaching could reach 181.6 -276.9 kg N $ha^{-1}$ due to over fertilization in the vegetable system [8]. Reducing the application rate by 40 %, N leaching was reduced by 39.6 % while the yield was still remained the same [9]. Another study also demonstrated that $NO_3^-$–N leaching could reduce by 40 % if the amount of nitrogen applied meets a need of crops. Therefore, proper N application is essential for economic and environmental benefits. There are many solutions to reduce nitrogen leaching, but the most effective solutions focus on regulating the factors that affect nitrogen leaching process such as soil properties, crops, irrigation management and fertilizer use [8].

## 4. CONCLUSION

This study shows that total nitrogen content in 4 different land use types at the study site varied largely. The amount $NO_3^-$–N was significantly higher in the dry season, reaching its peak in May with 86.11 kg $ha^{-1}$ in AV and 75.41 kg $ha^{-1}$ in RV. The amount of $NH_4^+$-N concentration was higher in rainy season, but the losses were very low. In mono rice system, $NH_4^+$-N was predominant in all seasons; its amount was remarkably lower in the dry season and fallow period.

Total nitrogen in AV was 276 kg $ha^{-1}$ $year^{-1}$, much higher than that of RV (148 kg $ha^{-1}$ $year^{-1}$). The amount loss of nitrogen leaching into the groundwater is mainly $NO_3^-$–N, accounting for 99.6 % of AV and for 97.2 % of the RV, occurring during the rainy season.

This research has been carried out for only 1 year. Longer-term studies on N leaching, emissions, nitrification and de-nitrification in different land use types, especially in the rainy season are therefore necessary for further validating and confirming seasonal nitrogen dynamic patterns in the Red River Delta.

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