Monitoring and modeling of nitrogen leaching caused by nitrogen fertilizer application to green tea fields in Japan

Yuhei Hirono[1], Shigekazu Nakamura[2], Tomohito Sano[1], and Kunihiko Nonaka[1]

1. National Agriculture and Food Research Organization, 2769, Kanaya-Shishidoi, Shimada, Shizuoka, 428-8501, Japan.
2. Shizuoka Prefectural Research Institute of Agriculture and Forestry, Mobata, Shimizu, Shizuoka, 424-0101, Japan

Introduction

Large amounts of nitrogen (N) are required as fertilizer for the cultivation of tea (*Camellia sinensis* (L.)) plants, compared with other crops. Heavy application of N fertilizer does not always increase the yield and quality of tea products, instead it alters the N cycle and it leads to environmental problems including increased nitrate-nitrogen (NO_3-N) concentration in the surrounding water systems and high rate of emissions of nitrous oxide (N_2O). To address these problems, efforts have been made in the recent years by farmers and related authorities in Japan to reduce the amounts of N fertilizer applied to tea fields.

The objectives of this study were:

1) To reveal how changes in fertilizer application rates impact local water quality.
2) To predict the N leaching from green tea fields.

Changes in NO_3-N concentrations in water systems around an intensive tea-growing area

Results and Discussion

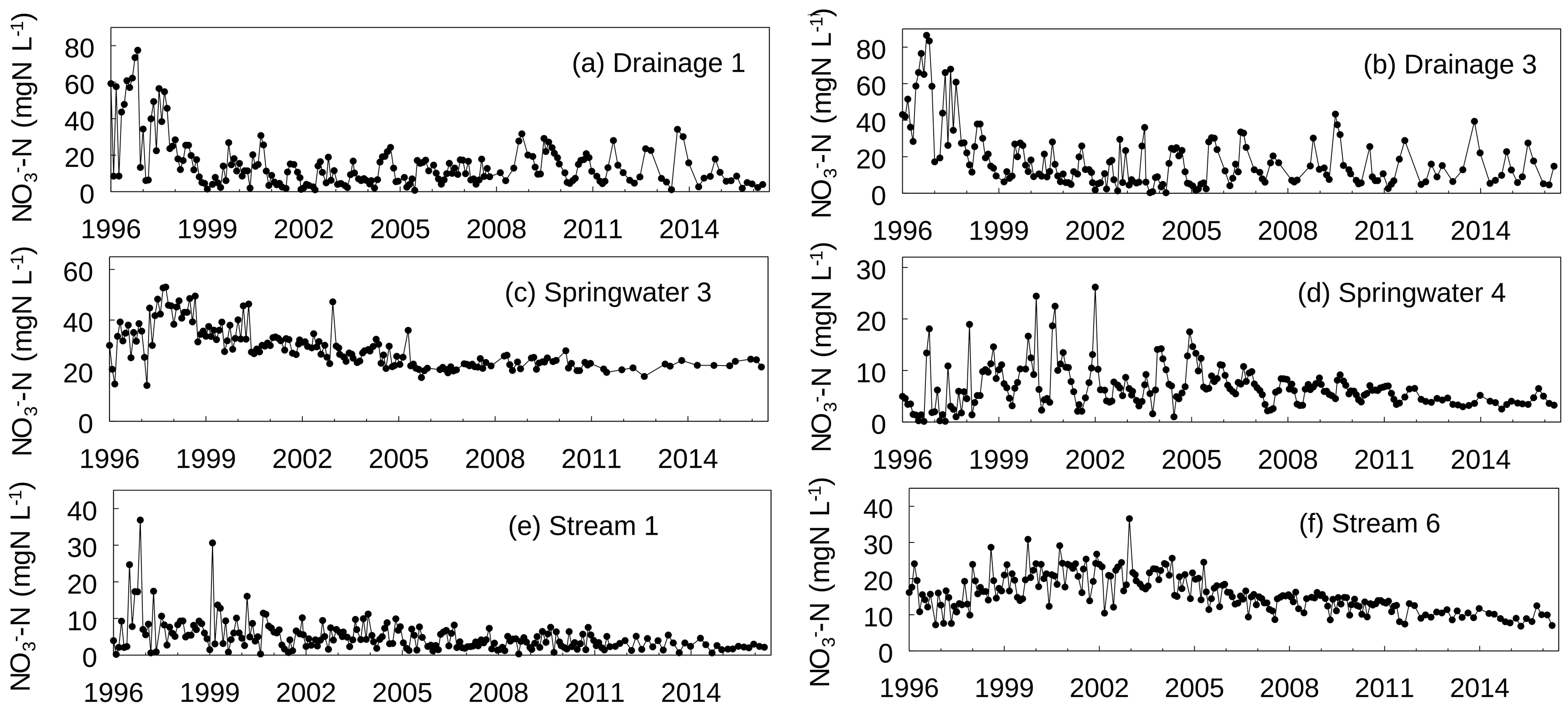
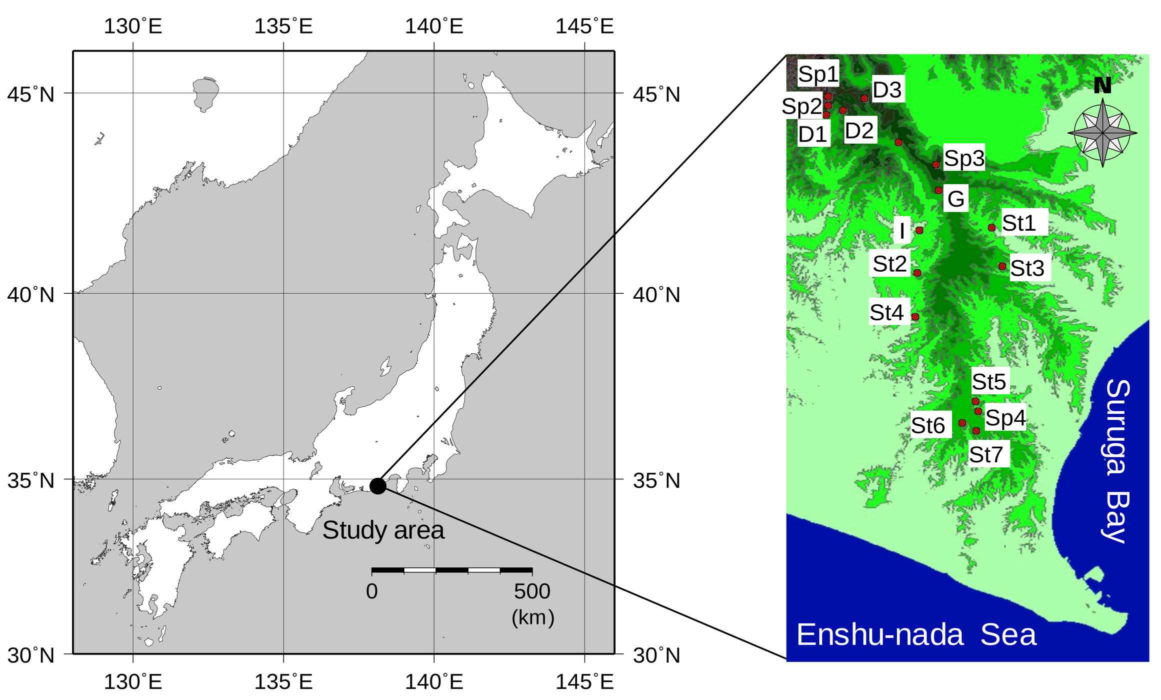


Figure 1 Time-series changes in NO_3-N concentrations at drainage sites (a,b), springwater sites (c, d), and stream sites (e, f) from 1996 to 2016. Note that each graph has different scale of y-axis.

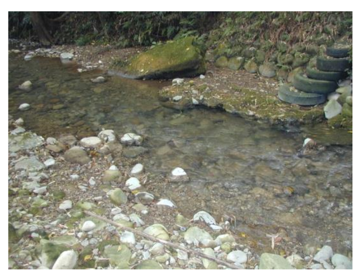
- The current NO_3-N concentration changes at drainage and spring water sites reach a steady state because the fertilizer application rates leveled off in this area.
- The NO_3-N concentrations at stream sites are still within a transition period from the concentrations under heavy N application to those under reduced N application to tea fields.

Materials and Methods

Study area: Makinohara Plateau, Shizuoka Prefecture, Japan
Study period: 1996-2016
Annual rainfall: 2213 mm
Annual mean temperature: 15.1 ºC
Sampling intervals: Once a month (1996-2011) and once every 2 month (2011-2016)



Drainage



Stream

Figure 2 Study area and locations of the water sampling sites. D, drainage; G, groundwater; I, irrigation ditch; Sp,springwater, St, stream.

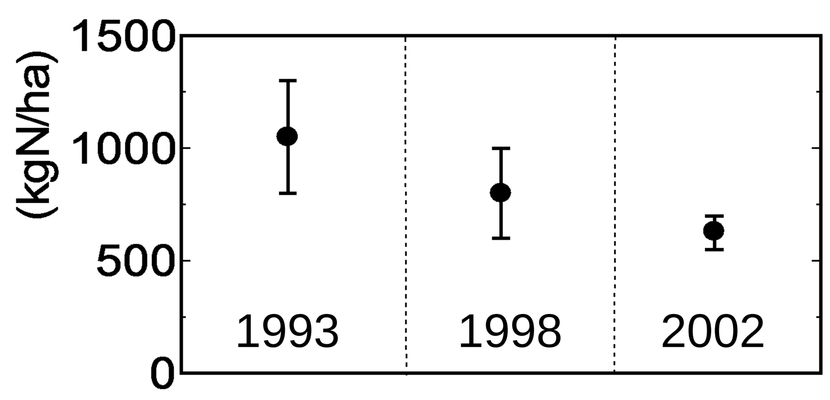


Figure 3 Changes in nitrogen application rates in green tea fields. (Survey by questionnaire)

Conclusions

- Nitate-nitrogen concentrations significantly decreased at most studied sites in water systems in the tea-growing area, indicating that water quality was improved by reducing nitrogen fertilizer application in tea fields.
- The amounts of water and nitrogen leachate calculated with the Hydrus-1D model agreed well with the observed results. The model is a useful tool to recommend optimal fertilizer management practices in green tea fields in Japan.

Modeling of N leaching from green tea fields

Results and Discussion

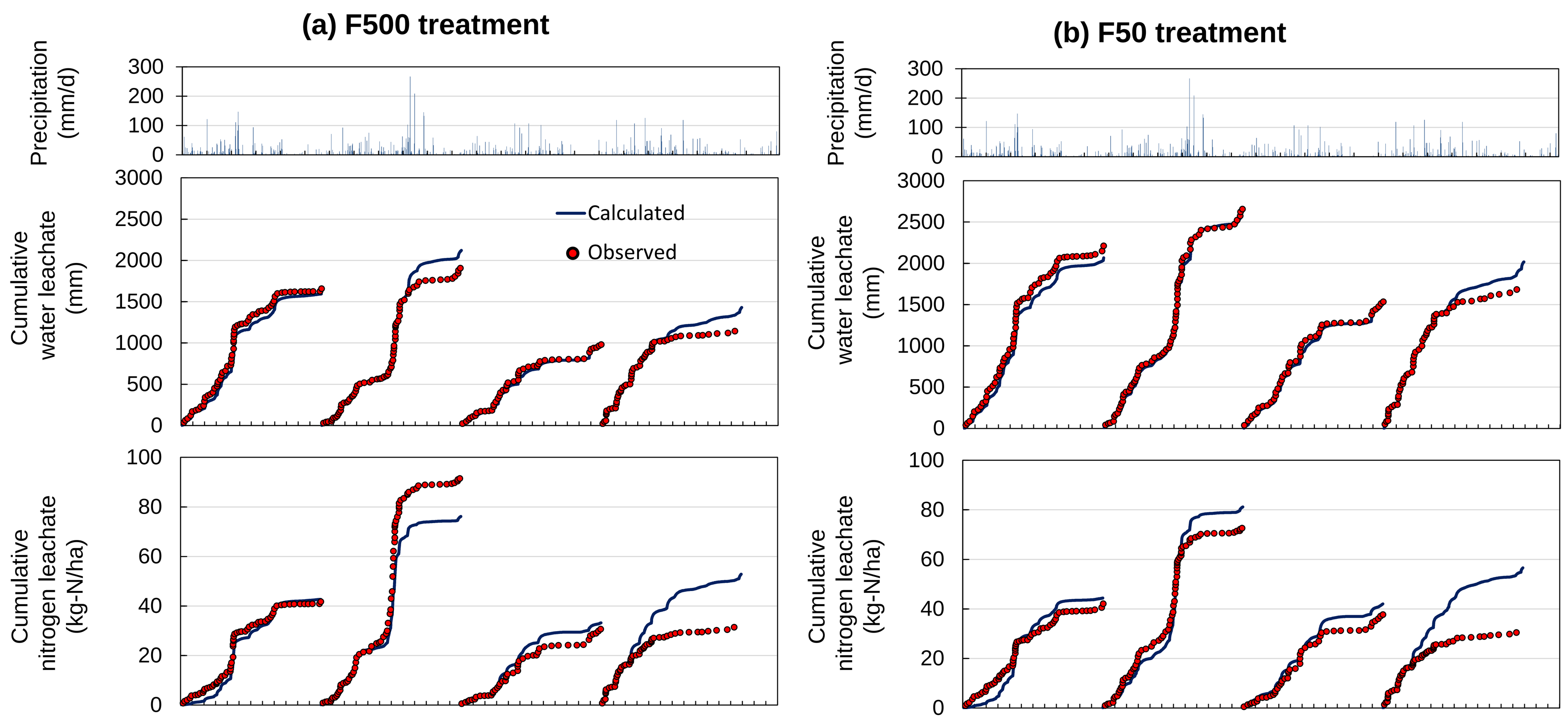


Figure 4 Comparison between the observed and calculated cumulative amounts of water and N leachate from the bottom of a lysimeter. (a)F500 and (b) F50. This figures show two of five treatments presented in Tables 1 and 2.

Table 1 Comparison of the observed and calculated cumulative amounts of water and N leachate from the bottom of each lysimeter (4-year average).

Treatment	Water leachate (mm/y)		N leachate (kg-N/ha/y)	
	Observed	Calculated	Observed	Calculated
CV	1331	1473	54.1	65.8
F500	1421	1531	48.8	51.2
F200	1549	1616	40.0	42.6
F50	2020	2065	45.7	56.1
N0	1810	1758	20.4	11.9

CV, conventional method; F500, F200, and F50, fertigation methods; N0, no fertilizer application.

- A comparison between the observed and calculated amounts of water and nitrogen leaching showed that there was good agreement for all lysimeters.
- We sometimes observed large differences between the observed and the calculated values of the cumulative amount of N leachate. Although the reason was unclear, one possible reason was ununiformity of soil. Preferential flow through macropores can sometimes cause faster transport of solutes, but was not considered in this model.

Materials and Methods

Simulation model: Hydrus-1D (Šimůnek et al. 2013)
Monitoring data: Lysimeter experiment (2003-2007)
Study site: Research Center of the Shizuoka Prefectural Research Institute of Agriculture and Forestry
Fertilizer treatments: Five treatments (see Table 2)

Table 2 Irrigation rate, N application rate of each lysimeter.

Treatment	Irrigation rate (mm/y)	N application rate (kg-N/ha/y)	N concentrations in liquid fertilizer (mg-N/L)
CV	0	486	-
F500	54	270	500
F200	135	270	200
F50	540	270	50
N0	270	0	0

CV, conventional method; F500, F200, and F50, fertigation methods; N0, no fertilizer application.

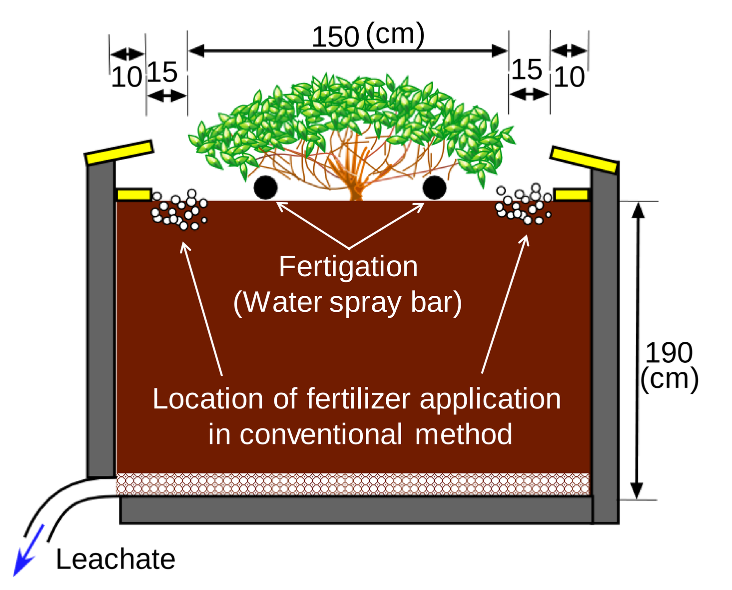


Figure 5 Diagram of the experimental lysimeter and location of fertilizer application.

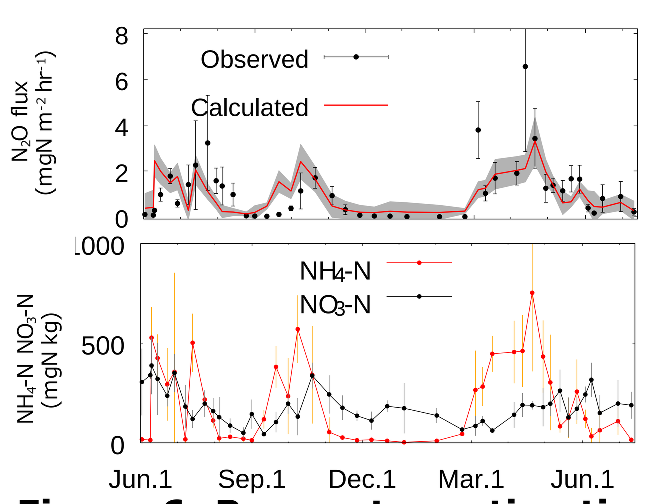


Figure 6 Parameter estimation for N_2O emissions (First-order reactions for the concentrations of NH_4-N and NO_3-N). Observed N2O flux: mean±SD, Calculated N2O flux: red line, median; grey zone, 95% credible interval.

Acknowledgements: This work was partially supported by JSPS KAKENHI Grant Number 26850155.

hirono@affrc.go.jp