The Role of Erosion and Sediment Transport in Nutrient and Contaminant Transfer (Proceedings of a symposium held at Waterloo, Canada, July 2000). IAHS Publ. no. 263, 2000.

Nitrogen and phosphorus transfer in soil erosion processes

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Abstract This study deals with the transfer of nitrogen and phosphorus in surface runoff from eroding upland fields in Japan. Universal Soil Loss Equation (USLE) standard plots were installed in the upland fields, and differing amounts of fertilizer were spread on each plot. The supernatant was obtained from each sample by centrifugal separation. Total nitrogen and total phosphorus in the eroded suspension and supernatant were separately analysed by means of absorption spectrophotometry. Additionally, the supernatant was analysed for ammonium, nitrate and nitrite nitrogen. The results indicate that the total nitrogen and phosphorus concentrations in the eroded suspension were higher than in the supernatant. Total nitrogen and phosphorus concentrations in the eroded suspension tended to increase with an increase in the concentration of eroded material indicating that the soil particles and organic matter dominantly transported nitrogen and phosphorus components. Although there was poor agreement between inorganic nitrogen concentration and suspended solids, the amount of nitrogen and phosphorus transfer increased with soil losses. Nitrogen and phosphorus losses in the plots with the highest fertilizer application were larger than in the less fertilized plots. The results indicated that nitrogen and phosphorus losses in surface runoff increase with soil loss and level of fertilizer application.

INTRODUCTION

The mountainous regions of Japan are subject to heavy rainfall, and as a result severe soil erosion occurs in upland fields. Many reports have been produced to predict soil losses and on the effectiveness of soil conservation measures. However, only a few attempts have so far been made at investigating the associated movement of nutrients and pesticides in soil erosion processes. Soil erosion affects not only the productivity of upland fields but also the environment downstream. Because of severe eutrophication in water reservoirs and in canals, losses of nutrient rich salts, such as nitrogen and phosphorus, with surface flow have recently been the focus of an intense research interest.

In the Kasumigaura Lake basin of Japan, the annual loads of nitrogen and total phosphorus in direct runoff were computed as 68% and 81% of total annual loads, respectively (Suzuki & Tabuchi, 1984). Suzuki & Tabuchi (1984) also reported that soil conservation measures have an important role in reducing the nitrogen and phosphorus outflow. In the Suwa Lake basin of Japan, eutrophic components in runoff in surface erosion processes were investigated both in the laboratory and in the watersheds (Mihara & Sakamoto, 1996; Mihara *et al.*, 1997). The effects of type of tillage on resulting soil and nutrient losses, in the context of sustainable tillage systems, are discussed by Gaynor & Findlay (1995) and Richardson & King (1995). However, little information is available on nitrogen and phosphorus transfer with surface runoff under differing levels of fertilizer application.

This study deals with the association between losses of nitrogen and phosphorus and soil losses, under differing levels of fertilizer application. Regression equations were fitted to the data to indicate the effects of soil erosion on nitrogen and phosphorus transfer in upland fields.

METHODS

In order to measure nitrogen and phosphorus transfer with surface flow, four standard USLE plots were constructed in an upland field at Rolling Land Laboratory, Tokyo University of Agriculture and Technology, located in the hilly Tama area of Japan. The dimensions of each experimental plot are 1.8 m wide by 22.1 m long downslope. At the end of July 1996, chemical fertilizer was spread uniformly over Plots I, II, III and IV at rates of 0 kg, 5 kg (1257 kg ha^{-1}), 10 kg (2514 kg ha^{-1}) and 25 kg (6285 kg ha^{-1}), respectively, and incorporated into the soil. The fertilizer comprised 8% nitrogen, 8% phosphate and 8% potassium. All plots were maintained bare of vegetation.

Surface runoff water was sampled from water tanks which collected surface discharge. Total soil loss, suspended solids, total nitrogen and phosphorus in eroded suspension and supernatant, and inorganic nitrogen in the supernatant, were analysed for each plot.

Total nitrogen and phosphorus in the water samples were analysed by means of absorption spectrophotometry, after decomposition with alkaline $K_2S_2O_8$ and $K_2S_2O_8$, respectively. To obtain supernatant samples from eroded suspension, suspended solids such as soil particles and organic matter were eliminated from each sample by centrifugal separation. Ammonium nitrogen was analysed by a Nesslar method, nitrate nitrogen by a cadmium reduction method, and nitrite nitrogen by a diazotization method. Suspended solids were analysed by a photometric method and particles larger than 0.02 mm are eliminated by sedimentation in the analysing process. All sizes of particles were included for soil loss analysis.

The total nitrogen in the soil samples was analysed by the Kjeldahl method and inorganic nitrogen by a 2N potassium chloride extraction method. Total phosphorus was calculated on the basis of the amount of phosphate analysed by the Bray II method.

RESULTS AND DISCUSSION

Changes in physical and chemical properties of soils with fertilization

The physical properties of the soils are given in Table 1. The soil texture of the investigated upland field is classified as CL (clay loam) or LiC (light clay) on the

Table 1 Physical properties of soils from the Rolling Land Laboratory plots.

	Specific gravity	Particle size distribution: Gravel	Coarse sand	Fine sand	Silt	Clay	Dispersion ratio (%)	Ignition loss (%)	Soil texture*
I	2.68	1.0	7.7	32.7	33.7	24.9	22.6	14.6	CL
II	2.64	0.4	7.3	31.7	34.7	25.9	18.0	14.9	LiC
III	2.67	0.3	7.0	30.8	35.9	26.0	22.2	14.0	LiC
IV	2.68	0.5	8.5	32.6	32.5	25.9	18.2	13.7	LiC

* International scale.

Table 2 Chemical properties of the soils tested (amounts in 10^{-5} kg kg^{-1}).

Date		Total N	Total P	NH_4-N	NO_3-N	NO_2-N
July 1996		336.6	9.8	16.0	13.4	0.036
December 1996	I	294.2	7.0	18.1	13.2	0.058
	II	352.0	10.6	19.2	14.8	0.048
	III	339.8	12.2	20.4	16.6	0.034
	IV	511.4	62.8	22.1	19.6	0.036
July 1997	I	285.8	8.6	5.9	4.8	0.016
	II	259.5	8.4	7.2	6.6	0.014
	III	314.1	6.5	6.5	5.0	0.016
	IV	329.1	14.8	6.8	6.0	0.016

basis of international scale. There was no difference in particle specific gravity between plots. Ignition loss ranged between 13.7 and 14.9%, and the dispersion ratio ranged from 18.0 to 22.6%.

The chemical properties of the soils (Table 2) were analysed before the spreading of fertilizer at the end of July 1996. Also shown are chemical analyses conducted later on each of the plots in December 1996 and July 1997.

The total nitrogen of the soils in December 1996 ranged from $294.2 \cdot 10^{-5}$ to $511.4 \cdot 10^{-5}$ kg N kg^{-1} soil, and in general exceeded amounts before fertilization in July 1996. The total nitrogen increased with the level of fertilizer application. Total nitrogen in July 1997, a year after fertilization, had decreased for all plots, compared with that in December 1996.

The total phosphorus of the soils sampled in December 1996 ranged from $7.0 \cdot 10^{-5}$ to $62.8 \cdot 10^{-5}$ kg P kg^{-1} soil. As for nitrogen, total phosphorus of Plot IV tended to be higher than for the other plots, and decreased substantially between December 1996 and July, 1997. Ammonium and nitrate nitrogen also decreased between December 1996 and July, 1997.

Concentration of nitrogen and phosphorus in suspension and supernatant

Total nitrogen concentration in runoff water from Plot IV was higher than in the other plots between August 1996 and March, 1997. The concentration of total nitrogen increased with soil losses until April 1997, after which the difference in total nitrogen concentration among plots became negligibly small.

Total nitrogen and total phosphorus concentrations in the supernatant were compared with those in the eroded suspension. In general the total nitrogen and phosphorus concentrations in the eroded suspension tended to be higher than those in the supernatant. In addition, the ratio of the mass in the eroded suspension to that in supernatant was greater for total phosphorus than for total nitrogen.

The relationships between each of total nitrogen, total phosphorus and inorganic nitrogen with suspended solids are plotted in Fig. 1(a)–(c), respectively. Although there is an association between both total nitrogen and total phosphorus concentrations in eroded suspension and suspended solids, the total nitrogen and total phosphorus concentrations in the supernatant showed a poor relationship with suspended solids. Also, there was poor agreement between inorganic nitrogen concentration and suspended solids. It follows that soil particles and organic matter transported nitrogen and phosphorus components. The phosphate adsorption coefficient of volcanic ash soils is high, and it follows that the phosphorus transfer with soil particles was greater than the nitrogen transfer.

Relationship between nitrogen and phosphorus transfer and soil losses

The relationship between the amount of nitrogen and phosphorus transfer and soil losses is shown in Fig. 2(a)–(c). The amounts were calculated on the basis of surface discharge and water quality concentration. As the correlation coefficients between the amounts of nitrogen and phosphorus transfer and soil losses ranged from 0.78 to 0.97, it was judged that the amounts of nitrogen and phosphorus transfer were roughly proportional to the amounts of soil losses. Also, there was a tendency for total nitrogen and phosphorus transfers in suspension to be much larger than in the supernatant, and it was therefore concluded that soil particles and organic matter dominantly transport nitrogen and phosphorus. Additionally, it became clear that the amounts of total nitrogen and phosphorus transfer in Plot IV, the most fertilized plot (6285 kg ha^{-1}), were the highest among the plots.

The equations expressing the relationships between the amounts of nitrogen and phosphorus transfer and soil losses indicate that phosphorus transfer with soil particles is larger than nitrogen transfer. The main reason is that the phosphate adsorption coefficient of volcanic ash soils is high. It follows that soil conservation measures, such as a settling pond or a green belt, are important not only for reducing soil losses but also for conserving the quality of the receiving water environment.

SUMMARY

The results indicate that the concentrations of total nitrogen and phosphorus in eroded suspension were higher than in the supernatant. Also, there was a tendency for total nitrogen and phosphorus concentrations in suspension to increase with suspended solids. It follows that soil particles and organic matter transported nitrogen and phosphorus components. Although there was poor agreement between inorganic nitrogen concentration and suspended solids, the amounts of nitrogen and phosphorus transfer, even in the case of inorganic nitrogen, were in agreement with soil losses.

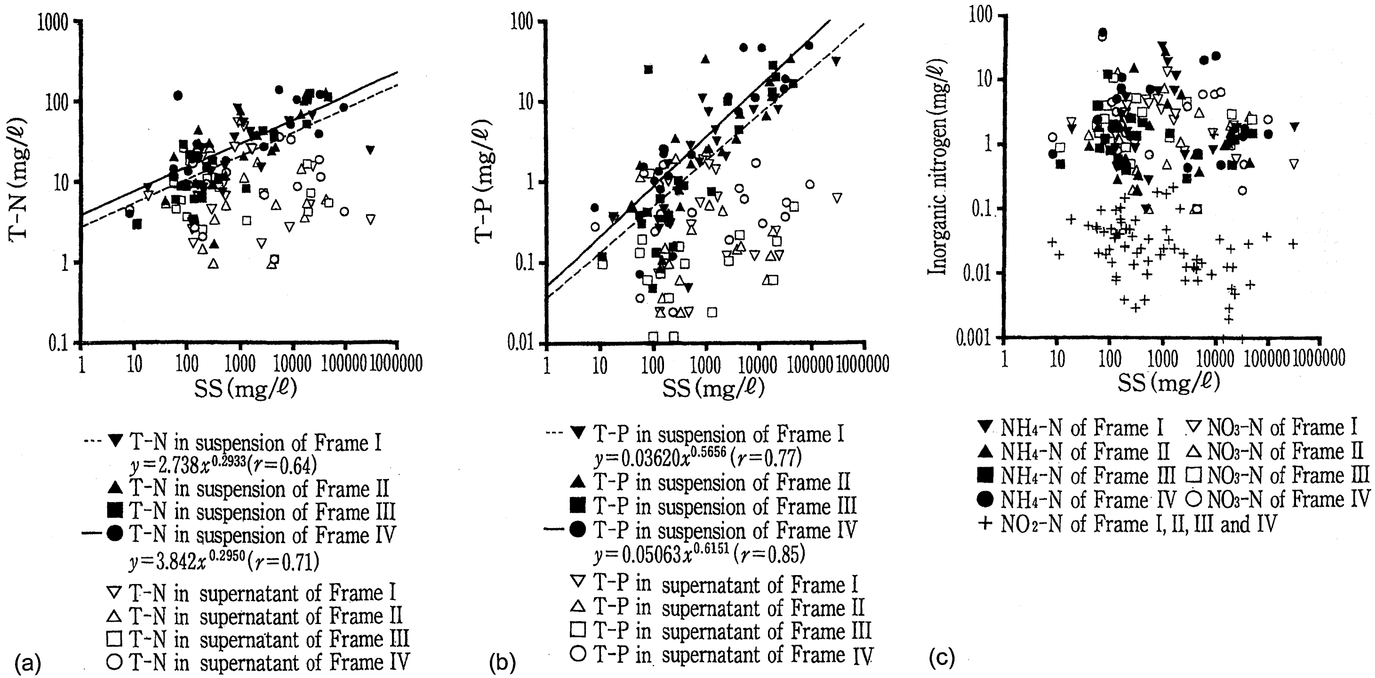

Fig. 1 Relationships between (a) total nitrogen and suspended solids, (b) total phosphorus and suspended solids, and (c) inorganic nitrogen and suspended solids.

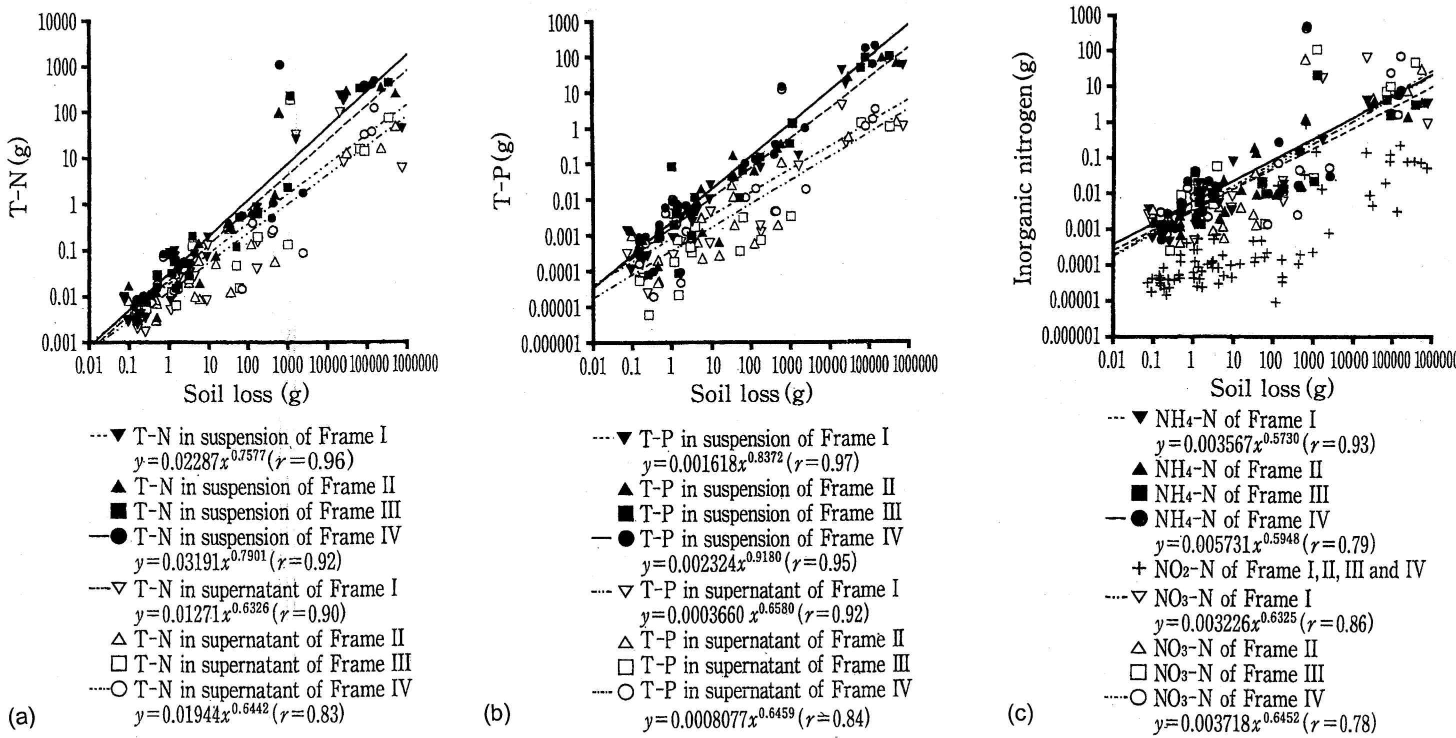

Fig. 2 Comparison of amounts of (a) total nitrogen, (b) total phosphorus, and (c) inorganic nitrogen and soil losses.

Additionally, the nitrogen and phosphorus losses from the most fertilized plot (6285 kg ha^{-1}) were larger than the other plots. These results indicate that the amounts of nitrogen and phosphorus transfer increase with soil loss, especially in highly fertilized fields.

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