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Temporal nitrate-nitrogen patterns at the outlet of a small agro forestry catchment

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Résumé
L'objectif de ce travail était l'analyse des concentrations et de l'exportation d'azote à l'exutoire d'un bassin versant dans le Nord-Ouest de l'Espagne. Le bassin versant étudié couvre 36.3 km^2 sur de substratum de granite et schiste, la mise en culture concerne environ 55% de la superficie, dont 20% est occupé par des prairies, et il peut être considérée comme représentatif des situations pedologiques, climatiques et agronomiques de la Galice maritime. Les concentrations moyennes annuelles de nitrates oscillaient entre 12.84 et 16.58 mg/l. Les exportations de nitrate dans les eaux de drainage ont été de l'ordre de 50 kg/ha pendant une année sèche, tandis que dans les années humides elles étaient comprises entre 120 et 180 kg/ha et elles sont conditionnées avant tout par la pluviométrie et l'écoulement. Le transport des nitrates au cour des saisons a été très variable, beaucoup plus élevée en saison hivernale.

Introduction

Nitrate- nitrogen can be readily lost from terrestrial soils giving rise to forms that can have negative environmental consequences in surface waters. In temperate climate regions NO_3^--N reaching streams is mainly associated with anthropogenic contributions derived from agricultural and livestock activities but it may also be related to municipal sewage as well as natural processes (Jordan et al., 1997). Nitrate losses from soils to natural waters can be serious for a range of environmental reasons. The main consequences of NO_3^--N leaching are eutrophization of surface waters, increase production of nitrous oxide from water bodies and increased nitrate concentrations in drinking water (Addiscot 1996). The origin of factors governing nitrate lost in drainage waters may be natural (climate, soils, topography and hydrology) and/or anthropogenic (soil use and crop rotation, tillage, application of slurries and inorganic fertilizers, erosion, etc).

In Galicia, northwest of Spain, Nitrate Vulnerable Zones (NVZs), i.e. areas where NO_3^- concentrations in water exceed or are likely to exceed 50 mg/l are thought to be rather scarce (Antelo and Arce, 1996; Díaz Fierros Viqueira, 2003). However, as in many regions of Europe and USA, in Galicia NO_3^--N has been increased in the last decades. A regional study indicates that our study catchment showed the highest NO_3^--N concentrations (Antelo and Arce, 2005). The aims of the study presented here were to quantify the nitrate concentrations and exportations at the outlet of an agro forestry catchment in maritime climatic conditions and to describe seasonal patterns.

Material and methods

The study was realized in the Valiñas River, which drains into the Mero River and the Bay of Coruña (Spain). The study catchment is 36.3 km^2. In physiographic terms this catchment has two distinct parts: steep uplands and an alluvial plain. Soil use includes about 45% forest, 35 % cropland and 20 % pasture. Agricultural landscape is very fragmented and still typical for traditional farming and livestock raising activities. The rock underneath in most of the study area is granite and some schist outcrops are also present. Soils are predominantly medium textured, mainly loamy-sand and loamy, thus naturally quickly draining. Both forest and cultivated soil are rich in organic matter with figures varying between 2.76 and 7.11% in the former case and 6.64 and 15.36% in the later case. The area has a maritime mild climate with mean temperatures of the coldest and the warmest month of about 11ºC and 18ºC, respectively. Long-term mean annual rainfall is about 1000 mm. The rainy season with precipitation exceeding evapotranspiration extends from September-October to April-May in a normal year.

Sample collection was carried out manually along years 1999, 2000, 2001, 2003 and 2004. A total of 642 samples were taken during five years. The smallest yearly set of samples collected was 53 in 1999 and the highest was 193 in 2003. Nitrate-nitrogen in water samples was determined by a multiparametric probe in 1999, 2000 and 2001 and by capillary electrophoresis in 2003 and 2004. Water discharge at the catchment outlet was measured different times along the study years in conditions of base and peak flow. Daily data of discharge were obtained by modeling after calibration with the experimental measurements (Sande Fouz, 2005). Nitrate-nitrogen transport from the catchment was calculated as the product of its concentration and discharge.

Results and discussion

Summary statistics of NO_3^- concentrations during the five study years at the outlet of the Valiñas catchments are shown in Table 1, where mean, maximum, minimum, typical deviation and variation coefficients during 1999, 2000, 2001, 2003 and 2004 are listed. Annual mean NO_3^- concentrations are of the same order of magnitude ranging from 12.84 mg/l in 2001 to 16.58 mg/l in 2000 and differences may be mainly attributed to the hydrological characteristics of each year. NO_3^- of individual water samples oscillated between 1.75 and 32.92 mg/l.

Year	1999	2000	2001	2003	2004
Mean (mg/l)	12.87	16.58	12.84	13.73	13.84
Maximum (mg/l)	18.40	32.92	29.50	17.30	22.93
Minimum (mg/l)	4.47	4.90	1.75	6.80	7,30
Standard deviation (mg/l)	3.08	3.43	5.88	1.65	2,23
Variation coefficient (%)	23.93	20.69	45.81	12.02	16.13

Table 1: NO_3 mean, maximum, minimum, standard deviation and variation coefficient in Valiñas River catchment during 1999, 2000, 2001, 2003 and 2004.

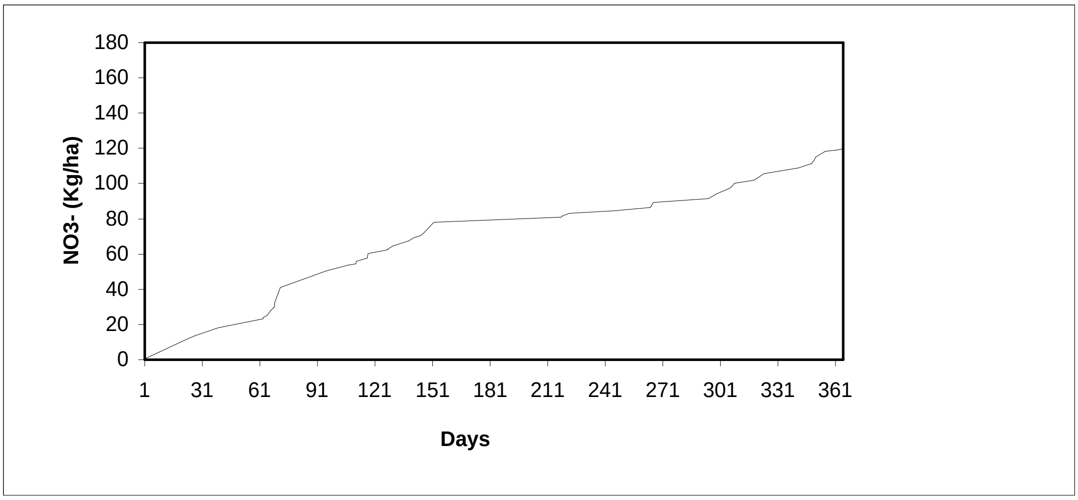
Maximum NO_3^- concentrations were below the statutory limit of 50 mg/l but much higher than those reported for pristine waters in the region, which are closer from minimum NO_3^- concentration figures reported in Table 1. Maximum NO_3^- concentrations were observed in winter, except in 2001 where they were reported during August. Minimum NO_3^- contents tended to be measured in spring, the exception being 1999 where they were observed in autumn. Time variability of NO_3^- contents in surface water was low or medium, with coefficients of variation below 25%, except during 2001. These results suggest that diffuse water pollution from agriculture and livestock, near sewage sludge from disperse villages, are the main sources of NO_3^- in surface water at the outlet of the Valiñas catchment.

Nitrate-nitrogen exportations on a yearly varied between about 50 and 180 Kg/ha as shown in Table 2. Nitrate losses depended mainly depending on rainfall. During 2004, the driest of the five study years nitrate transport was limited at about 50 Kg/ha NO_3^-, but during the remaining four years, with total rainfall amounts higher than normal figures were between about 120 and 180 Kg/ha NO_3^-. Agricultural activities in the study catchment are not very intensive, thus NO_3^- losses are considered to be high, which is supported both by studies carried out both, all over Galicia (Antelo and Arce, 1996; Díaz-Fierros Viqueira, 2003) and also in other agroforestry catchments of the region (Varela Martínez, 2002).

Year	1999	2000	2001	2003	2004
Yearly rainfall (mm)	1253.0	1451.5	1115.9	1200.3	786.1
N-NO_3 losses (Kg/ha)	119.6	149.7	121.8	179.8	49.9
% losses in cold months*	52.3	71.9	43.1	88.3	62.1

Table 2: Total yearly rainfall, nitrate-nitrogen exportations and percentage of losses during the 4 coldest months, at the Valiñas River catchment. (*November to February)

The largest NO_3^- losses occurred when crops are not actually growing, by the end of autumn and in winter. Table 2 also shows the percentage of NO_3^- losses in the four coldest months of the year, varying between 43.1 % and 88.3 % of the yearly totals. Moreover, Figure 1 shows the cumulative NO_3^- exportations in two years with somewhat different behaviour. During 1999 NO_3^- leaching was important not only in January and February but also in the following spring months, whereas during 2003 most nitrate was leached mostly in the two first and the two last months of the year, with minor spring contributions.



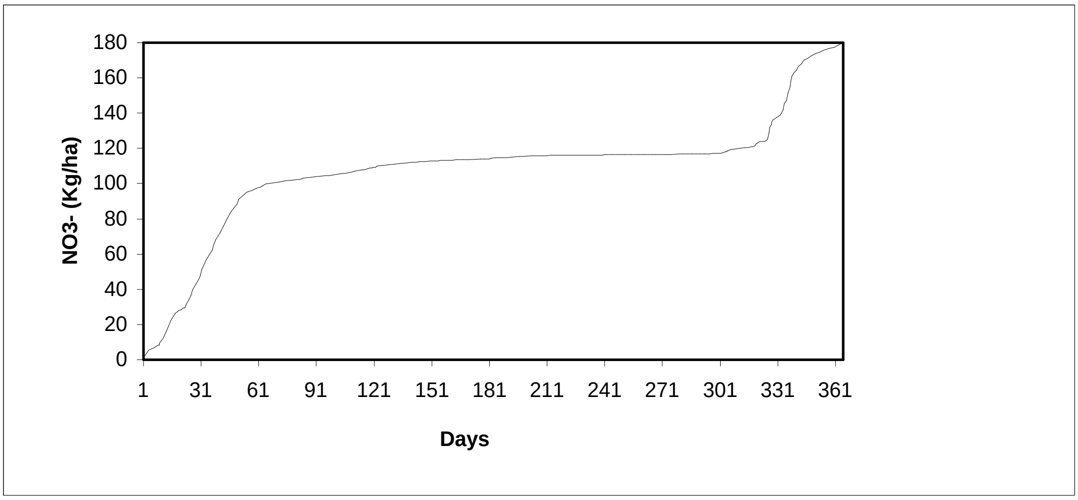


Figure 1: Cumulative nitrate exportations at the catchment outlet in 1999 and 2003.

Winter losses of nitrate by leaching may be attributed to active mineralization and nitrification conditions due to suitable temperature and moisture, in absence of crop uptake. Nitrate produced too late for uptake in summer or too early for spring uptake will be mainly lost by leaching processes.

The impact of inorganic nitrogen fertilizer on NO_3^- amounts waters at the Valiñas catchment are thought to be limited in contrast with livestock manure, presumably the most important source of NO_3^- losses to water. In other words, land disposal of organic wastes are likely to have a greater effect on nitrate-nitrogen losses than inorganic fertilisers. Indeed, factors that should reduce NO_3^- losses to water in essence are those which also minimise the autumn NO_3^- pool, mainly make better use of manure, increase manure storage on some farms and maintain better records of fertiliser and manure management

However, organic matter mineralization, both in cultivated and forest soils may contribute decisively to the NO_3^- leaching into surface waters. Because of the relatively high nitrate exportations more research is needed in this area in order to improve the understanding of processes influencing this issue.

Conclusions

On a yearly basis, mean nitrate-nitrogen contents at the outlet of the study maritime catchment varied between 12.8 and 16.6 mg/l, whereas exportations were between 50 and 180 Kg/ha. In humid years nitrate-nitrogen transport was above 120 kg/ha. Autumn and winter rainy conditions were most critical with respect to nitrate-nitrogen leaching losses.

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