EVALUATION OF ACTUAL NITROGEN LOSSES FROM A WATERSHED PRELIMINARY RESULTS OF A CASE STUDY IN THE PO VALLEY (NORTHERN ITALY)

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ABSTRACT

The evaluation of potential N losses from individual fields is not sufficient to provide an estimate of the actual **nitrogen** loads reaching the main watercourses and therefore becoming a relevant source of **pollution.** Along the travel path from **a** field to **the** outlet of a **watershed** several biogeochemical processes may occur, leading to significant changes in the N amount actually leaving the watershed.

A case watershed is being studied in the province of **Mantovs,** Po valley, Northern Italy, in order to evaluate actual nitrogen losses at its outlet. This paper aims to present the first results of this study after one year of research.

During the period September 2002 - November 2003 210 kg/ha of N were applied and 10 kg/ha were lost in drainage water.

I. INTRODUCTION

The evaluation of potential N losses from individual fields is not sufficient to provide an estimate of the actual N loads reaching the main watercourses and therefore becoming a relevant source of pollution. Along the travel path from a field to the outlet of a watershed several biogeochemical processes may occur, leading to significant changes in the water N concentration and in the N amount actually leaving the watershed. They might be due, for example, to the hydrophyte vegetation living on the canal sides or within it, and they can also be affected by a number of factors like canal shape, management practice and water speed.

The importance of this analysis is crucial, since it can provide both a better knowledge of the dimension of agricultural pollution and eventually identify the characteristics of a good countryside management.

In order to study these phenomena an area of the Mantuan floodplain in the upper coast of Northern Italy, within the Po Valley, was selected. In this paper the monitoring activity and some preliminary results referring to the period September 2002 - November 2003 are presented.

2. WATERSHED AND SURVEYS

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The area consists of 64.4 hectares of clayey land, belonging to three livestock farms. It is next to a bend of the river Mincio, near its confluence into the river Po, at an altitude between 13 and 15 meters above the sea level (Figure 1). The Longhirola, the main canal running through it, is used for both drainage and irrigation purposes. The local irrigation period goes approximately from mid May to September and varies from year to year, depending on the weather and, in particularly dry seasons, on water availability. When it is used for drainage, the canal receives the water from several ditches and flows into the Fossegone, mainly a drainage canal.

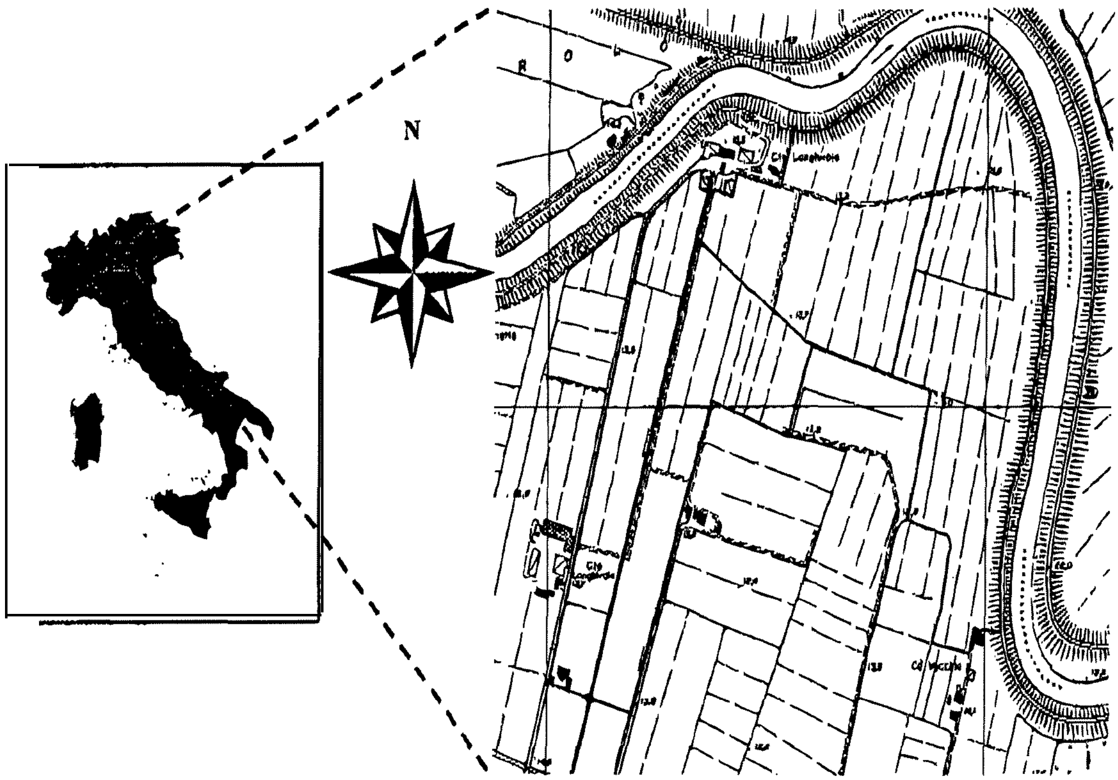

Figure 1 Longhirola watershed: location in Italy

To achieve the project's goals, a monitoring of the flow and of the water quality (with a particular stress on Nitrogen) was planned at the watershed outlet and in some crucial points along the main canal. In addition DRAINWAT (Amatya, 1993, Chescheir et al., 1994), a DRAINMOD (Skaggs, 1978) based watershed scale hydrologic model, was chosen as a tool for predicting flow rates, velocities and water depths at in-stream locations and at the outlet. The watershed satisfies the physical requirements of this model: water movement from the fields to the drainage ditch courses is mainly horizontal, it is reasonably isolated as far as watershed is concerned, and the drainage network within it is easily recognisable and reachable, This is essential for the outlet, in order to measure the outflows and to collect samples.

Figure 2 shows the Longhirola Canal (dark blue, thicker line) and the ditches and collectors network (pale blue, thinner line), The main canal goes straight (direction: North-South) for about 400m, then it tums West; after about 200m there is a slight comer (direction: North) and then, after about 300m the water goes through a round pipe and reaches an acute corner of 80" (direction: South). The course is then straight; after 900m there is the bridge where outlet samples were collected (red dot in Figure 2).

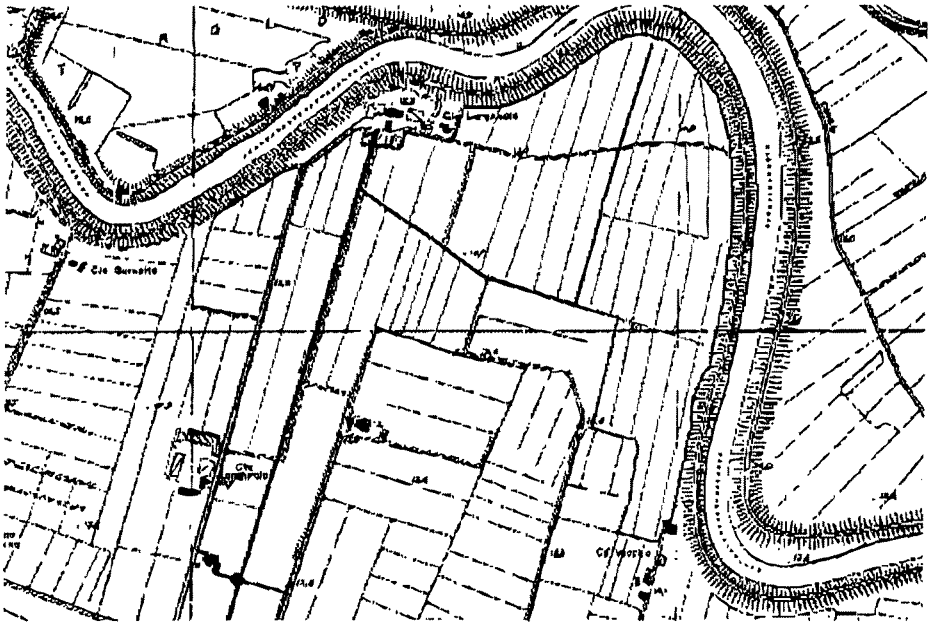

Figure 2 Canals and ditches network

At the beginning of the project a complete set of samplings and surveys (including physical and hydrological survey, farm management and weather data collection) was planned and carried out. The field activity from November to December 2002 and during the year 2003 included measurement of watershed size, collection of 30 disturbed soil samples (depth: O-40 cm) for initial nitrate concentration, of undisturbed soil samples at two different depths (O-40 and 40-80 cm) for the soil water retention curve and of 11 disturbed samples at 2 different depths (O-40 and 40-80), topographic survey (elevation measurement of 110 points) within the watershed, and water table depth measurements, Furthermore, during and after the main storm events water samples were collected at the outlet and other strategic in-stream locations in order to measure nitric N concentration and, in lower number of cases, 100 DO (%sat), BOD5 (02 mg/L), NH4 (N mg/L), total P (P mg/L), Escherichia coli (CFU/100 ml). At present 40 water samples have been collected at the outlet. Water depth and speed were also measured with an ISCO 4250 Flow Meter in order to calculate the outflow rates.

Whilst in the second monitoring season (from September 2003) the surveys started with the first drainage event, in autumn 2002 water sampling and water depth and speed measurement begun in November, when a certain amount of water (and nitrogen) had already been lost from. the watershed.

Investigations on field management, fertilisations, yields and nitrogen uptake of different crops were also made.

All calculations of drained water were made as follows: when measured data for water speed and water level of the canal were available, the discharge was calculated. When a rainfall occurred but data were lacking the discharge was deducted considering the amount of fallen rain and the effect similar rainfalls had in previous or following outflow events. Three big outflow events were considered: from November 2002 to January 2003, during April 2003 and during November 2003. For every event, a beginning moment was chosen with no outflow and an N concentration (both nitric and ammonium N) equal to the average of the period. Then the number of litres of water lost from survey to survey (or deducted moment of outflow) was calculated multiplying past seconds by the average between discharge at the moment of survey and previous discharge. After this, the number of kilograms lost was calculated multiplying litres lost by the average between concentration at the moment of the survey and the previous concentration. When there were no concentration data, a concentration equal to the average concentration of the period was assumed.

For example, the number of litres lost at the moment of the first survey was obtained multiplying the seconds past from the beginning moment chosen to the survey by the average between the measured discharge in the first survey and 0 (previous discharge, in this case considered equal to 0). The number of N kilograms lost was calculated multiplying the number of litres lost by the average between the measured concentration of the sample collected in the first survey and the average concentration of the period (since no concentration data were available for the beginning moment chosen).

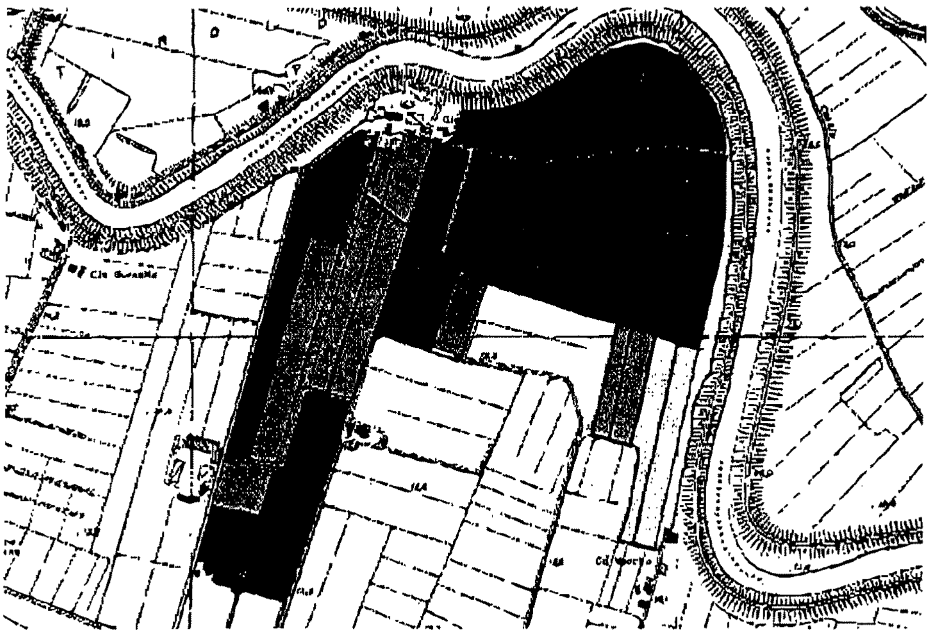

Figure 3 Crop diversification in Longhirola watershed

The diversification of the crops is really low: apart from a field with barley (*Hordeum vulgare*) and millet (*Panicum miliaceum*), only maize (Zea *mais*) and alfalfa *(Medicago sativa*) can be found within the watershed. A field is set aside as fallow; furthermore, there is an artificial stretch of water used for duck hunting. The different crops present in Longhirola watershed from November 2002 to November 2003 can be seen in Figure 3. Green areas indicate the fields with alfalfa, orange areas those with maize and the yellow area barley followed by millet. The fields set aside as fallow are brown, and the blue small area is the duck game used for hunting. The whole watershed is 64.4 hectares large, of which 52.1 are cultivated. 2.4 hectares are set aside as fallow and 1. 1 used for the duck game.

Alfalfa covers the biggest area (36.8 Hectares), whereas 11.7 hectares are grown with maize. The surface of the yellow field (barley and millet) is 3.6 hectares. As in Figure 2, the red dot represents the watershed outlet and the brownish line the watershed border.

Sixteen different homogeneous drainage areas were individuated in the watershed for DRAINWAT purposes (Figure 4). The soil in the whole area is homogeneous and according to the USDA land classification system it is a Calcic Ustochrepts fine (montmorillonitic) mixed mesic soil (Borin, 2003) Therefore an area was considered homogenous when the crop was the same and all water had an analogue drainage.

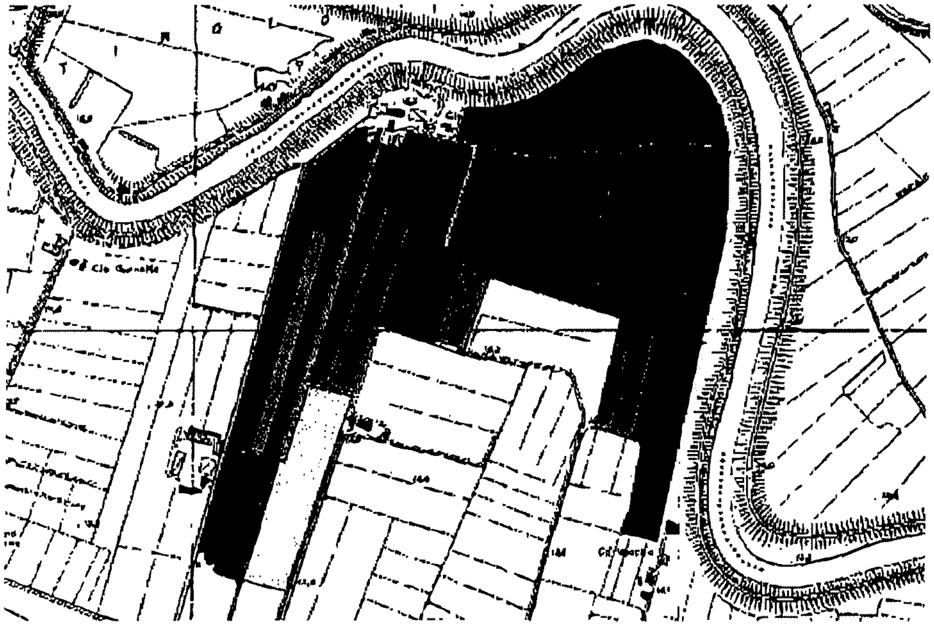

Figure 4 Homogeneous drainage areas in Longhirola watershed

3. RESULTS

3.1 Rain and outflow

The last 4 months of the year 2002 had a good number of relevant rain events, leading to a total of 262 mm, 65 of which in November and 93 in December. In January 2003, after a few rainy days, a long dry period begun: from 10th January to the end of March only 19 mm of rain fell, with an extremely low value of 2 mm in February. April had its biggest event with 30 mm in one day on the 3rd; the total is 80 mm, mainly at the beginning of the month.

The scarce rains from May to August (67 mm) didn't affect watershed drainage, since the canals in the area were used for irrigation. September itself was a very dry month, **with** 5 mm both on the 8th and the 9th and a total of 12 mm in the end. From mid-October the situation changed and more significant rain events took place, leading to and amount of 64 mm for the month, followed by 86 mm in November.

Comparing the historical rain data with those measured during the project (figure 5) it is evident how many months in the studied period had very low precipitation. In particular, in February and August 2003 the rain was almost absent, and in March, May, June **and** September 2003 the total amount of rain goes from 20% (September) to 31% (May) of the average. September 2002 and October 2003 are very close to the average rain, while **only** December 2002 (+75%), April 2003 (+32%) and November 2003 (+29%) show a higher precipitation than the historical series.

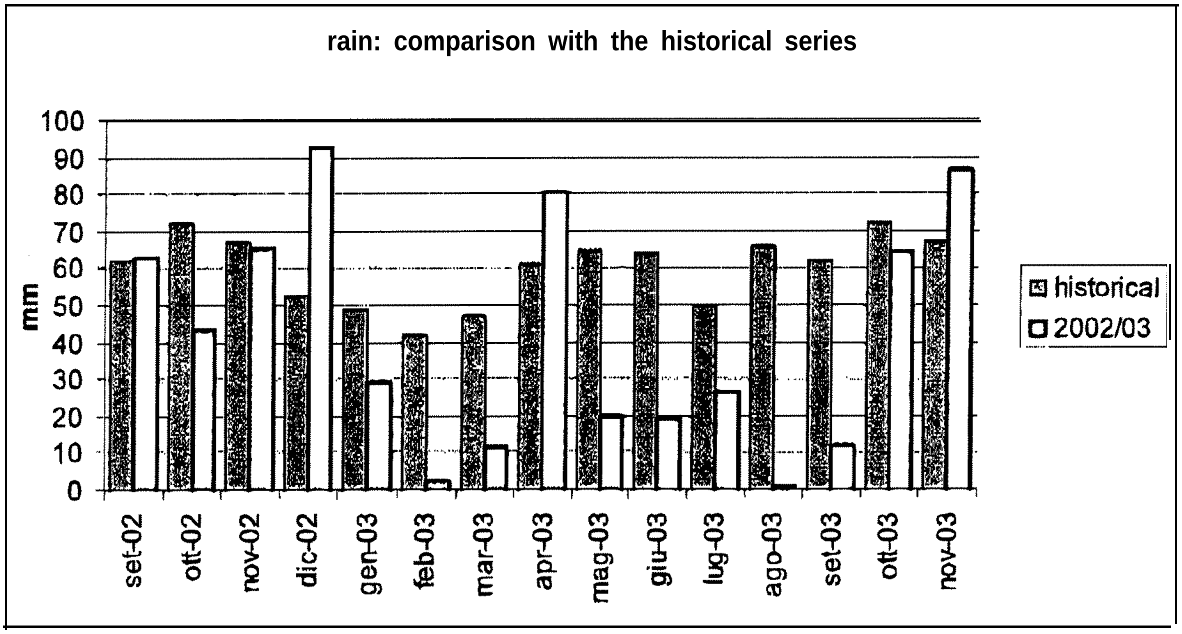

Figure 5 Rain: comparison between the historical series and the survey period

Considering the whole period from September 2002 to November 2003, the total of fallen rain is 6 17.6 mm: 69% of the average for the time going from September to November of the following year. Excluding summer months, this value becomes 570.4 mm (79% of the average).

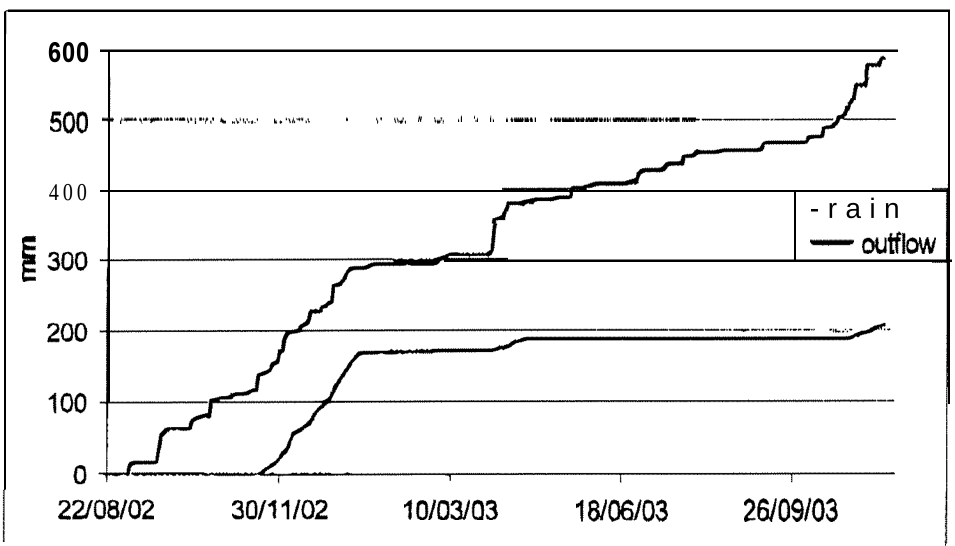

Figure 6 Comparison between cumulative rain and water outflow from the watershed

From the beginning of September 2002 to 18th November 2003 (date of the last water sample analysed at present) the total amount of rain was 588 mm (75 of which fallen in summer, therefore not affecting drainage). In the same period the calculations led to **207** mm of water drained from the watershed. Figure 6 shows the delay between the first rain event and the beginning of drainage in October 2002, April 2003 and October 2003.

However, as said in the introduction, the first survey of autumn 2002 is likely to have occurred when some water had already been lost from the watershed. An amount between 30 an 40 mm can be estimated, leading to a difference of about 275 mm between rain and drained water (not considering summer) for the whole year of surveys. As Figure 6 shows, from mid-November to the 10th of January all the fallen rain was drained, since the fields were saturated with water.

The scarcity of precipitation of the period January-March 2003 resulted in about 80 days with virtually no drainage, as the flat line in the figure indicates. The effect of this dry winter is visible in April, with only 18 mm drained after 67 mm of rain. After the summer, about 70 mm of rain were necessary before drainage started again (30/10), and in the following 18 days about 16 mm were drained after 60 mm of rain. Looking at these values and at those of the autumn 2002, at least 120 mm of rain seem to be necessary to re-saturate the watershed. The surveys of the end of November and of December 2003, currently elaborated, will provide more information on this topic.

3.2 Fertiliser applications

Table 1 summarises fertiliser applications and consequent N inputs from November 2002 to November 2003. For urea and calcium nitrate standard concentrations (respectively 46 and 15%) have been used, As for slurry and manure, the percentage of N was obtained calculating the average concentration of N in slurry and manure applied during a previous project lasted for 3 years in the province of Mantova. The results are 0.34% of Nitrogen for slurry (13 samples analysed) and 0.55% for manure (24 samples analysed). When slurry and manure were applied together in similar doses (March 2003), an average of the two values (0.45%) was used.

The chosen dates for applications of fertilisers, even if organic, may represent a risk if the rain historical series is kept in mind: the largest amounts of N are applied in November, when considerable storms are a likely event.

Table 1 Fertiliser applications

DATE	FERTILISER	N (KG)
Nov 2002	Slurry	3600
Nov 2002	Manure	1450
Jan 2003	Calcium nitrate	50
Mar 2003	Urea	260
Mar 2003	Slurry + manure	500
Nov 2003	Slurry	4040
Nov 2003	Manure	1630
Total		**11530**

3.3 Nitrogen concentration

Given the distribution of rainfalls during the studied period, the samples of canal water were collected in three sub-periods corresponding to those described for water outflow. The concentration of nitric and ammonium nitrogen in these sub-periods is presented in Figure 7; the coloured squares indicate the applications of fertilisers. During the autumn 2002 the average concentration of nitric nitrogen was 3.9 mg/L, with a highest value of 6.5 mg/L on the 4th December and a minimum of 2.6 mg/L on the 20th November.

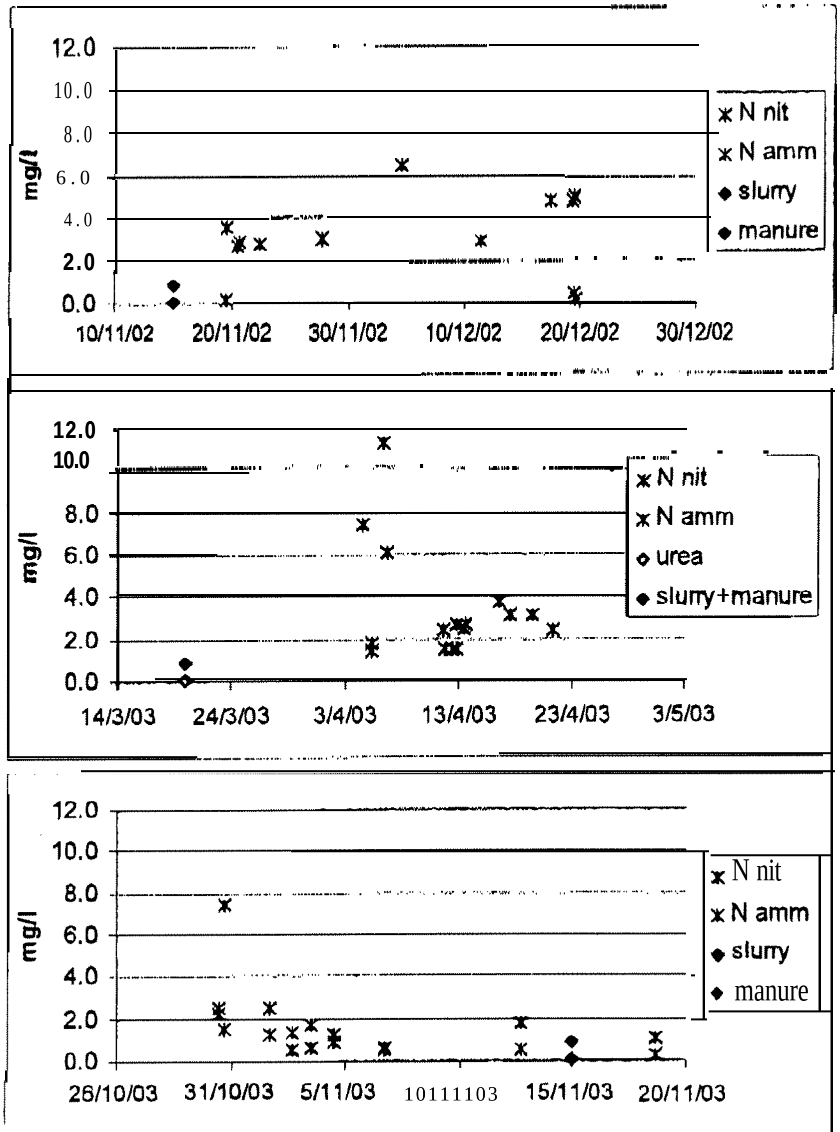

Figure 7 Measured nitrogen concentration in water at the outlet

No obvious trend can be seen for this period, since high and low values were found in both of the months. As for ammonium N concentration, it was measured in three dates and it was always quite low, with a maximum of 0.4 mg/L.

In April 2003 nitric N concentration reached its top, with 11.4 mg/L on the 6th. On the same day, though, 7 hours later it dropped down to 6.1 mg/L, showing a high variability in time even for very short periods. The highest values were all found in the first week of the month with the exception of a sample on the 5th (1.8 mg/L); from the 10th to the end of April the results are mostly in the interval between 2 and 4 mg/L. The average concentration in the month was 3.7 mg/L. In two occasions ammonium N concentration was measured with similar results: 1.4 mg/L (5th) and 1.5 mg/L (12th).

From the first outflow event of autumn 2003 (30th October) to 18th November 9 water samples were collected at the watershed outlet and analysed. The average nitric N concentration was much lower than in previous periods, with a value of 2.1 mg/L. Excluding the sample collected on the 30th

October in the afternoon (7.4 mg/L), the others are all below 3 mg/L, including 3 samples with a concentration around 0.5 mg/L (minimum of the year on the 2nd November). The opposite can be said for ammonium N, with the highest value (2.3 mg/L, 30th October) and an average of 1.1 mg/L. In 5 cases ammonium N had a very similar concentration (and in 2 cases higher) to nitric N.

When measured, the concentration of organic nitrogen was always equal to zero.

3.3 Nitrogen losses

The analysis of Nitrogen lost from the watershed from the first survey (18/11/2002) can be seen in Figure 8. The three sub-periods previously indicated for water losses can be clearly seen in this case as well. At the end of the first sub-period (till 18th January 2003) about 476 kg of Nitrogen were lost from the watershed, more than 95% of which due to nitric N. during this sub-period about 5000 kg of nitrogen were applied. After it, no losses were calculated, since virtually no water left the watershed. During the second sub-period (April 2003) 750 kg of N were applied and about 59 kg of N were lost, 73% of which in the nitric form. In the last sub-period about 5700 kg of N were applied; the losses were only 35 kg, and in this case the percentage of ammonium N got up to 35%, even if lower than nitric N (the remaining 65%).

Looking at the whole year, 516 kg (91% of the total) of nitric N and 54 kg (9%) of ammonium N were lost; their sum gives a total of 570 kg, most of which (83%) in the first sub-period. Even if concentration values in the sub-periods are different (and higher in the first, as described before), the main reason for this difference has to be found in the amount of water lost: April 2003 (2nd sub-period) followed very dry months, and November 2003 is just at the beginning of a new wet season, when the watershed is not fully saturated yet.

So far, about 210 kg/hectare of Nitrogen have been applied, 5% of which (10 kg/ha) lost with drainage water.

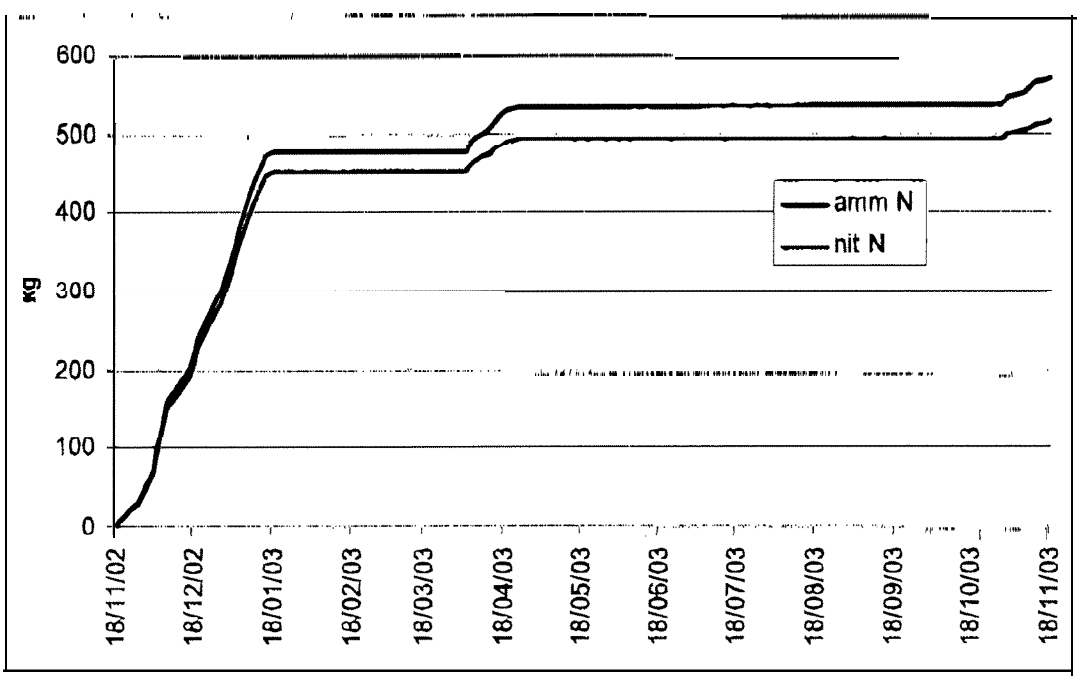

Figure 8 Cumulate nitrogen losses from the watershed

4. CONCLUSIONS

After only one year of surveys it is not possible to find clear conclusions; however, some preliminary results can be obtained.

The watershed seemed to have a similar behaviour in both autumns, requiring about 120 mm of rain before the drainage started.

After 500 mm of rain had fallen in drainage periods, 210 mm were lost from the watershed, introducing about 570 kg of N in the environment. This value, corresponding to about 10 kg/ha of nitrogen, seems to be low if compared to the 210 kg/ha applied in the watershed with fertilisers.

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