Phosphorus loss from soils to water; annual export load from a nested grassland catchment.

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1 ABSTRACT

We present results and analysis for the one-year (2002) export of phosphorus loss from a grazed grassland in a temperate climate. The nested catchment approach utilises three scales: 17ha; 211ha; and 1524ha. Streamflow was collected continuously at 15 minute intervals. Composite water samples were collected which covered almost 48% of the year. The gaps in water samples were 'filled' by two different techniques. The water samples were analysed for total phosphorus, soluble reactive phosphorus and total dissolved phosphorus. The cumulative total phosphorus loading to the stream was 2.61kg/ha, 2.47kg/ha, and 1.61kg/ha for the 17, 211 and 1524 ha respectively.

2 INTRODUCTION

The concentration of phosphorus in rivers and streams fed by runoff from grassland catchments is dependent on the hydrology, the geomorphology, the soil chemistry and the farm management within the catchment. Annual total phosphorus losses from agricultural soils generally amount to 0.5 - 2.0 kg/ha, which is about 1 - 5% of the phosphorus input. Quantification of the dissolved fraction is important as this is readily available for algal growth in lakes. This has serious implications for water quality in our rivers and lakes.

3 SITE DESCRIPTION

The study site is the upland Dripsey catchment, a sub catchment of the river Lee in Cork, Ireland, located in Figure 1 The nested catchments named site 1 (S1), site 3 (S3) and site 4 (S4) have areas of 0.17 km², 2.11 km², and 15.24 km² respectively. Elevations of S1, S3, S4 are 210, 160, 80 meters above sea level (masl). The catchment is located approximately 25 Km northwest of Cork city (52°N, 08°44'W). Figure 2 shows the shape aspect, contours and site boundaries of the 3 nested catchments. A gauged site 2 does exist but no water chemistry analysis was carried out there.The average rainfall in the area is 1472mm per year. The monthly values range from under 50 mm in the summer months to over 250 mm in the winter. The mean monthly temperature range from 5°C to 15°C. The rainfall and flow at the three sites are shown in Figure 3. In 2002 the rainfall was 1835mm and the evaporation was about 600mm.

Figure 1

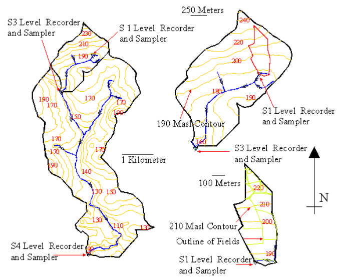


Figure 2

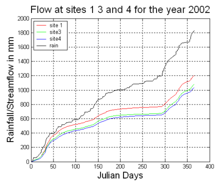


Figure 3

4 METHODS

Field methods

Stream discharge and water chemistry measurements were collected at the control points at S1, S3 and S4 for one year. These control points are in the form of a v-notch, a rectangular weir and a crump weir for S1, S3 and S4 respectively. Flow data is collected at 15-minute intervals and the phosphorus in collected in composite samples. The duration of these composite samples usually varied between 2 and 20 hours. Weekly grab samples supplement the composite sampling data base.

Laboratory methods

Phosphorus analyses for the streamwater were preformed manually using a spectrophotometer after standard methods, based on a molybdate/ascorbic acid method. Total phosphorus(TP), soluble reactive phosphorus(SRP) and total dissolved phosphorus(TDP) were determined in the laboratory . Particulate phosphorus is defined as TP-TDP.

Analytical methods

Figure 4 shows flow and phosphorus concentrations at site 1. The flow ranged between 1l/s to 150l/s. The TP values were under 0.5 mg/l for most of the year except for a few events where TP was measured at 5mg/l There are gaps in the data mainly during periods of low flow. A number of methods were used to fill in the gaps in water chemistry data. Method A was a manual technique of filling in the gaps in our data. When there was a gap in the flow our composite samples were extended to include the periods with no samples. For every gap in the data during a high flow a new composite sample value was estimated which was considered realistic to the adjacent known (measured) values. The phosphorus concentrations were calculated from the average of the samples before and after the gap. With a knowledge of stream flow every 15 minutes, composite samples, grab samples, rainfall data and information from the farmers about the amount and timing for phosphorus applications we were able to fill in all the gaps in the data.

Figure 4

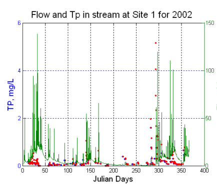
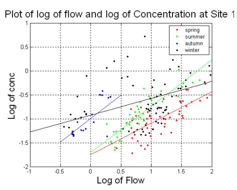


Figure 5



Method B calculated the phosphorus load using a C v Q rating relationship. It is an extrapolating method using flow and concentration to build up a rating relationship. Equation 1 was used to estimate the Phosphorus concentration from known flows.

$$C_p = aQ^b \quad (1)$$

This was derived from a regression of log transformed data.

$$\text{Log}(C_p) = \text{Log}(a) + b\text{Log}(Q) \quad (2)$$

Where C_p = Concentration (mg/l)
Q = daily catchment flow normalized for catchment area (mm day^{-1})
a and b are catchment-specific constants

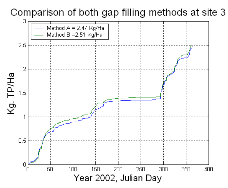


Figure 6

Different C v Q relationships (see figure 5) were derived each of the four seasons, which were different to a single relationship determined for the full years data. Both method A and B produce an annual phosphorus loss of similar magnitude (see figure 6).

5 RESULTS and DISCUSSION

After filling the gaps in the data it was possible to compute the total phosphorus export in the three sites. As can be seen in Figure 7 site 1 had the highest annual export of phosphorus. This was principally due to a large increase in phosphorus export in October. Export at Site 3 was much higher than either site 1 or site 4 for the majority of the year. The difference between the sites may be due to land management practices. One farmer owns the majority of site 1 and site 3 has 7 separately managed farms. The impact of land management practices of the individual farmer will be less noticeable in the larger site. Site 4 had a considerably less export load at 1.6 Kg/ha/year.

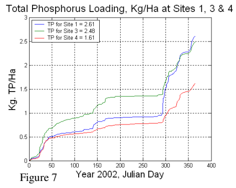
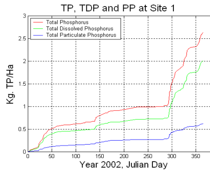


Figure 7

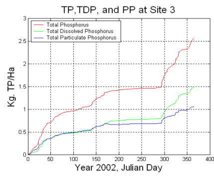
The different components (dissolved and particulate phosphorus) of phosphorus were also recorded and analysed for the year. It was found that in site 1 (figure 8) the percentage of TDP remained relatively constant for the year at 75%. A quarter of the total phosphorus that was exported was in particulate form.

Figure 8



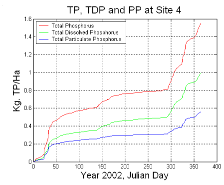
Site 3 (Figure 9) has a different pattern. In site 3 the dissolved phosphorus was only 50% of the total phosphorus for the first 100 days of the year. This indicates that there is more erosion at site 3 which resulted in a large increase in particulate phosphorus. There is less particulate phosphorus in the second half of the year. At the end of the year 57% of the exported phosphorus was in dissolved form.

Figure 9



Site 4 (see figure 10) has a similar pattern to site 1. The percentage of dissolved phosphorus was slightly less that site 1 at about 63%. The percentage of dissolved phosphorus and particulate phosphorus in the stream varied more throughout the year than site 1 but less than site 3.

Figure 10



The intermediate catchment (site 3) with its greater particulate component of phosphorous than in either site 1 or 4 suggest that there is more erosion in the land at this scale. This is due in part to small areas of steeper gradient. This is also be due to the size of the particles eroded during overland flow events.

Timing and quantity of slurry and fertiliser application

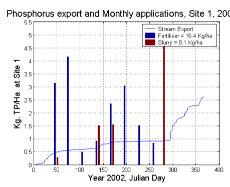


Figure 11

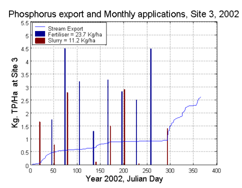


Figure 12

The above Figures 11 and 12 show the monthly applications of phosphorus at the two smaller sites 1 and 3. This information was kindly supplied to us by the farmers. Chemical Fertiliser in granular form was applied right thought the growing season. It is recommended that slurry should only be spread in spring and summer with at least 3 days dry weather forecast. However, due to lack of storage space and suitable weather many farmers are forced to spread under conditions which are far from ideal.

The spreading of phosphorus was more uniform in site 3. There was more phosphorus applied during the peak growing of late spring early summer. There were large quatities of phosphorus spread in winter and autumn at site 1. This may be responsible for the large increase of phosphorus in the stream at site 1 at the end of the year.

6 Conclusion

- The annual phosphorus export loads range from 1.6 Kg/ha/year to 2.6 Kg/ha/year
- The annual load decreased as catchments area increased.
- For sites 1(17 ha) and 4(1524 ha) the ratio of PP/TP was approximately 35% with TDP/TP was about 65%. For site 3, (211 ha) the ratio of PP/TP was approximately 45% with TDP/TP around 65%.
- Most phosphorus is lost to the seams in the winter period of high stream flow. This is acutely exaggerated if land applications of chemical fertiliser or slurry is carried out during wet winter periods.
- Control measures for phosphorus reduction must include a reduction of fertiliser and slurry and better land management practices.

Acknowledgments

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