Assessment of phosphorus transfer from agricultural lands to the surface water in France

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INTRODUCTION

Phosphorus (P) transfer from agricultural lands to surface water contributes to eutrophication. It has increased attention in the last decades, notably due to a real improvement of water treatment from urban areas which induce a higher relative part of agricultural sources. Methodologies focusing on P transfer from agricultural areas to rivers are thus required, particularly for water quality assessments at large scale, as a part of the implementation of the EU Water Framework Directive.

A model is developed to investigate what is the fraction of P from hillslopes which reaches the rivers systems and finally to better identify the origin of P in French rivers. The model takes into account punctual and diffuse P transfer from agricultural areas to calculate the total P fluxes at the catchment scale. With P Flux the total P Flux at the outlet of the catchment, \( C \) an indicator of the P transfer in the river network, \( P_{\text{tot}} \) an indicator of transfer (connectivity) over hillslopes.

P TRANSFER MODEL

1. Phosphorus sources

- Punctual sources: collection of the national database
- Diffuse sources: total P content at soil surface

2. P delivery in rivers

- Dissolved P (P\(_d\)) fluxes are estimated from climatic-driven method:
  \[ P_{\text{Flux}} = Q \times \frac{P_{\text{tot}}}{4} \times C \]

  With \( Q \) the annual modulus discharge [m³/s], \( P_{\text{tot}} \) the instantaneous concentration [mg/L], and \( C \) the instantaneous discharge [m³/s].

- Link with the source:
  \[ P_{\text{Flux}} \propto \text{linear relation between the dissolved P fluxes and the dissolved P exported from WWT located within the drained area (Fig. 4).} \]

3. Linking P sources to P delivery at the catchment outlet

- Processes for particulate transfer: erosion and connectivity

  Erosion: P particulate locally mobilised by hydrological erosion: local erosion (E) is calculated from the rill and interrill erosion estimate proposed by Cardan et al. (2010).

  Connectivity index (Delmas, 2011) defined from:
  \[ \text{Linear and diffuse connectivity} = f \text{ (water transfer, slope, land use, crusting)} \]

- Description of P delivery to rivers by defining connectivity indices

  - Combination of connected erosion (E*C) and the topsoil P content (Pcont) to describe the potential transfer of P from slopes to river network:
    \[ [\text{E} \times \text{C}] \times \text{Pcont} \]
    \[ \text{The CE index combined with P content explains a higher part of the variability of the SPF (Fig. 9) than the soil P content alone (Fig. 6).} \]

  - Drainage density DD: to characterises the potential transfer along the river network (it forms a linear relation with the SPF – Fig. 10).

Final model: combination of indices

\[ \text{Predicted (SPF)} = a \times ([\text{E} \times \text{C}] \times \text{Pcont}) + b \times \text{DD} \]

The final model combines indices and explains more than 50% of the specific P fluxes observed at the outlet of the 105 selected catchments (Fig. 10).

This model allows drawing a map of the risk of particulate P transfer from hillslopes to the rivers, at the water bodies (for WFD) scale (Fig. 11).

From this model we can see high risks of P transfer in mountainous areas (Alps, Pyrenees and Massif Central) due to high hillslope-river connectivity and also high soil P content particularly for Massif Central. Areas with high soil P content (see Fig. 2) also present a high transfer risk, for example in Britanny.

This study shows that the production of maps of P transfer risk at this scale is feasible using our method and could be used for further modelling of the P cycle and for water quality improvement at the national scale.

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Ref:
