Using SWAT model to study suspended sediments and nitrates regulation by wetlands in the Vienne watershed

Utilisation du modèle SWAT pour étudier la régulation des matières en suspension et des nitrates par les zones humides dans le bassin versant de la Vienne

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RÉSUMÉ

Les zones humides ont un rôle essentiel dans les cycles biogéochimiques et la qualité de l'eau. Elles agissent comme des zones tampons, en retenant les nutriments et les sédiments avant qu'ils n'atteignent les cours d'eau, et elles peuvent être le lieu de processus biogéochimiques, tels que la dénitrification. Ces fonctions dépendent de divers facteurs tels que les caractéristiques physiques des zones humides ou leur emplacement dans le paysage. Le modèle SWAT a été utilisé pour identifier et quantifier la régulation des nitrates dans les zones humides terrestres (tourbières, prairies humides et boisements humides) dans le bassin versant de la Vienne (France). Afin de modéliser ces zones humides, de nouveaux types d'occupation des sols et leurs caractéristiques ont été ajoutés au modèle et une nouvelle carte, obtenue en croisant les cartes d'occupation du sol et de zones humides potentielles, a été utilisée comme données d'entrée. Les dynamiques temporelles et spatiales des matières en suspension et des nitrates le long du bassin versant ont été évalués et les zones de régulation mises en évidence. En perspective, ces résultats peuvent être utilisés dans une approche Eviter-Réduire-Compenser, pour protéger et/ou restaurer les zones fonctionnelles.

ABSTRACT

Wetlands play a key role in biogeochemical cycles and water quality. They act as buffer zones, by retaining nutrients and sediments before they reach streams and they can hold hot spots of biogeochemical processes, such as denitrification. These functions depend on various factors such as the physical characteristics of the wetlands or their location within the landscape. SWAT model was used to identify and quantify nitrate regulation in terrestrial wetlands (peatlands, wet meadows and forested wetlands) in the Vienne watershed (France). To include terrestrial wetlands, new land use types and their characteristics were added to the model and a new map, obtained by crossing land use and potential wetlands maps, was used as data input. Temporal and spatial fluxes of suspended sediments and nitrates along the watershed were assessed and hot spots and hot moments highlighted. As a perspective, those results can be used in avoid - reduce - compensate approach, to protect and/or restore functional areas.

MOTS CLES

Modeling, Nitrates, Suspended sediments, Water quality, Wetlands

1 INTRODUCTION

Wetlands provide many functions: hydrological (groundwater recharge and discharge, flood storage), ecological (support of trophic chains, biodiversity) and biogeochemical. They can retain nutrients and sediments before they reach streams and hold biogeochemical processes, such as denitrification which reduce nitrate into nitrous oxide or dinitrogen. These functions depend on various factors such as wetlands physical characteristics or their location within the landscape. However, decrease in wetlands surface or their degradation are observed with anthropogenic disturbances (drainage for agriculture, urbanization). In order to preserve or restore efficient wetlands, there is a need to assess their functions and locate them.

Models are useful tools to achieve this goal. Modeling allows to study in detail the processes and thus to identify the hot spots and hot moments, which are areas or periods where reactions rate are high (McClain et al., 2003). This tool can also be used to develop change scenarios (climate, land use) and to study their impacts on water quantity and quality.

The objective of this study is to identify and quantify suspended sediments and nitrates regulation in terrestrial wetlands (peatlands, wet meadows, forested wetlands) in the Vienne watershed using SWAT model.

2 METHODS

2.1 Study site: Vienne watershed

The Vienne watershed, located in mid-west France, has an area of 21,157 km². The Vienne river is a tributary of the Loire river, and the watershed surface corresponds to one fifth of the Loire watershed. It is a rural watershed, with great disparities upstream/downstream in terms of hydrology, pedology, geology and land use. It contains numerous wetlands, mainly wet meadows, forested wetlands and peatlands.

2.2 Models

SWAT (Soil and Water Assessment Tool, (Arnold et al., 1998)) is an agro-hydrological watershed model. It is one of the most widely used hydrological models in the world and has been applied to a wide variety of watersheds. It simulates the cycles of water, sediment, nutrients and pesticides in the land and in the river, and takes into account anthropogenic influences (agricultural practices, reservoirs, wastewater treatment plants).

We represented the wetlands in SWAT as HRUs (Hydrologic Response Units). An HRU is a unique combination of soil, slope and land use and it is SWAT calculation scale unit. The land use map (Corine Land Cover) was crossed with a potential wetland map (EPTB Vienne) and new SWAT land use types were created : peatlands and wet meadows. Another wetland type kept from the crossed map is forested wetlands, but this type was already integrated in SWAT database (as well as non-forested wetlands and mixed wetlands). Crop parameters for the new SWAT types were set according to wetlands vegetation, and then adjusted in the calibration step.

The simulation period is 1990-2017, including a 3-year warm-up period. Calibration was carried out over fifteen years (2003-2017) and validation over ten (1993-2002).

3 RESULTS

The model outputs are the daily flows of water, suspended matter and nutrients (nitrogen and phosphorus forms) over the simulation period at the outlet of HRUs, subbasins and reaches. Flows simulated in reaches are compared to observations at several measurement stations along the watershed to validate the model.

To study wetlands regulation functions, the next step was to check if the model reproduces the humidity expected in the wetlands. Then, sediment, nutrient and water storage by wetlands are calculated with input-output budgets in HRUs. The results obtained for wetland HRU were compared to the other HRUs results. For nitrates, the model also gives the amount denitrified during the simulation period. The results

were used to build maps of production/retention.

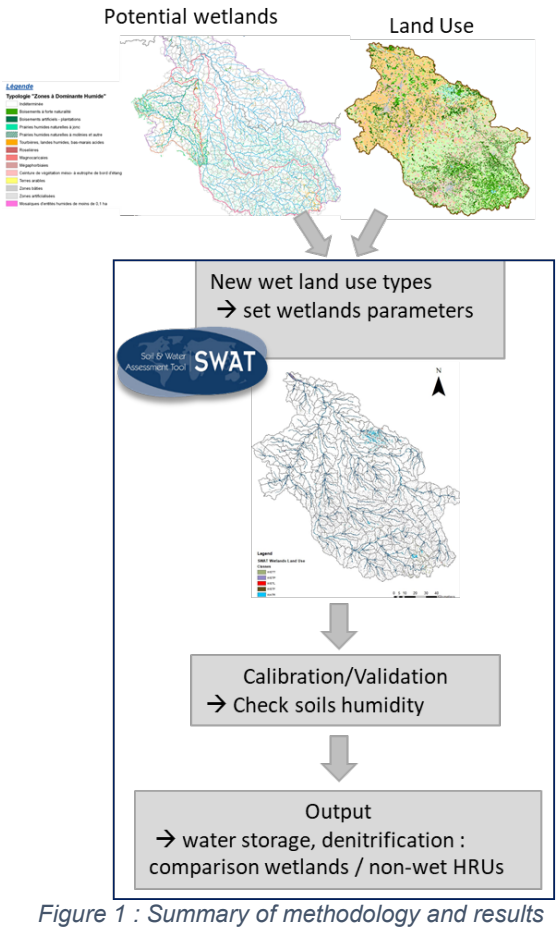

Figure 1 : Summary of methodology and results

4 CONCLUSION

SWAT model was used to assess the fluxes of water, suspended sediments and nutrients in the Vienne watershed and in particular in terrestrial wetlands. The crossed land use and potential wetlands map allowed to consider other wetlands types : peatlands and wet meadows. The areas of production and retention of suspended sediments and nutrients over the watershed were identified. However, wetlands were represented as HRU and HRU are not spatialized within a subbasin. Therefore, the role of wetlands in regulating the fluxes of upland HRUs could not be studied. The new version of SWAT, SWAT+, could overcome this issue as HRUs are spatialized within a subbasin.

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