Journal of Hydrology 546 (2017) 71–80

Contents lists available at ScienceDirect

Journal of Hydrology

journal homepage: www.elsevier.com/locate/jhydrol

Research papers

Effects of soil moisture content on upland nitrogen loss

Wei Ouyang *, Xueting Xu, Zengchao Hao, Xiang Gao

School of Environment, State Key Laboratory of Water Environment Simulation, Beijing Normal University, Beijing 100875, China

ARTICLE INFO

Article history:
Received 12 November 2016
Received in revised form 27 December 2016
Accepted 28 December 2016
Available online 7 January 2017
This manuscript was handled by G. Syme, Editor-in-Chief

Keywords:
Antecedent soil moisture
Nitrogen loss
Diffuse pollution
SWAT model
Transform mechanism

ABSTRACT

In recent years, nitrogen (N) loss from upland fields has become one of the most important sources for agricultural nonpoint source (NPS) pollution. Understanding the relationships between soil hydrological processes and N loss in NPS pollution is vital for controlling the agricultural NPS pollution in upland fields. The objective of this study was to analyze the interaction of N loss with different moisture conditions in the freeze-thaw zone. The semi-distributed hydrologic model Soil and Water Assessment Tool (SWAT) was used in this study to simulate runoff and different forms of N loss, which provided a basis for analyzing characteristics of N loss in the study region. Results showed that the soil moisture content was an important factor affecting N loss in the study region. Different forms of N loss were also analyzed and it was found that N loss occurred primarily in the form of organic-N, which is likely due to the dominant role of erosion-induced pollution. This study provides useful information for preventing NPS pollution within the study region.

1. Introduction

Agriculture pollutants are derived from fertilizers, the use of which is encouraged by governments in order to improve food yields. Fertilizing contributes to an increase in nitrogen (N) and phosphorus (P) loadings in a nearby receiving water body during a rainfall event, which is regarded as nonpoint source (NPS) pollution (Arnold et al., 1998; He et al., 2015). Agriculture NPS pollution has become an important environmental issue in China in recent decades (Wu et al., 2012). The national pollution census of China conducted in 2010 found that half of the total pollution loads in water result from agriculture (Li et al., 2012).

Northeast China, which is a primary food base for the country, has been experiencing serious agricultural NPS issues with the increasing usage of fertilizer (Wang et al., 2010). This is especially the case in our research region (Abujiao Watershed), where upland fields occupied 86% of the agricultural land in 2000. In addition, this area is located in a cold climate region; therefore, the soil in this region shows the characteristic of a freeze-thaw environment (Chen et al., 2013). The pollutant migration and transportation process in upland fields is complicated; it is strongly affected by rainfall events and soil hydrological processes (He et al., 2014; Ouyang et al., 2014a,b). Inorganic-N and organic-N losses occur in different ways in this study catchment. Specifically, the inorganic-N easily dissolves into water and washes away with runoff, while organic-N is adsorbed by soil particles and losses occur through soil erosion (Dekun, 2009). Hence, the loss of N is related to the processes of both rainfall-runoff and soil erosion (Sun et al., 2012). Moreover, raindrops and runoff affect soil by detaching the topsoil and transporting soil particles, respectively (Gao et al., 2004). According to previous studies, soil moisture, especially antecedent soil moisture, is one of the significant factors influencing the NPS transformation process (Liu et al., 2014; Ouyang et al., 2014a,b). For instance, the content of soil moisture tends to reach saturation under rainfall conditions by changing the soil infiltration capacity, resulting in runoff and soil erosion. Thus, it is of utmost importance to assess the N and P loss in upland fields under different moisture conditions while considering freeze-thaw processes.

In upland field systems, the movement of NPS pollutants relies strongly on rainfall and soil hydrological processes (Ouyang et al., 2014a,b), for which the inter-annual rainfall, intra-annual rainfall, and soil water content are the primary constraints affecting the NPS loss (Ouyang et al., 2012; Özdoğan, 2011). Runoff from snow and rainfall are the two main runoff processes in the cold climate region. The natural loss processes of nutrients, including N and P, are commonly simulated in watersheds by hydrological and NPS models such as SWAT (Soil and Water Assessment Tool), Ann AGNPS (Annualized Agricultural Non-point Source Pollution Model) and HSPF (Hydrological Simulation Program-Fortran) (Han et al., 2010). However, it is a challenge to apply these models taking into account the soil in a freeze-thaw region and the melting of snowpacks (Tolson and Shoemaker, 2007). Despite the advan-

* Corresponding author.
E-mail address: wei@bnu.edu.cn (W. Ouyang).

http://dx.doi.org/10.1016/j.jhydrol.2016.12.053

tage in simulating the hydrological processes, pesticide movements, sediment yields, and nutrients, few studies have employed the SWAT model to simulate N and P losses in cold climate regions (Ahl et al., 2008; Zhang et al., 2008).

The SWAT model was employed in this study to estimate the overall influence of soil hydrological processes on N loss in the upland fields system. In this work, we investigated the effect of the freeze-thaw soil environment on the N loss in agriculture NPS pollution using SWAT that takes meteorological data, land-use data and field management practices data into consideration. Specifically, the effect of rainfall and antecedent soil water content (SWC) on NPS release was assessed in upland fields in the study region.

2. Materials and methods

2.1. Study region

The study area is located in northeastern China (longitude 134°0′–134°20′E and latitude 47°22′–47°28′N) within the cold temperate zone and is subject to a humid and semi-humid continental monsoon climate (Fig. 1). The average annual precipitation and temperature over the period from 1975 to 2014 were 580.0 mm and 2.1 °C, respectively. According to long-term data of the watershed, the period with average air temperature below 0 °C lasts approximately 6 months. Therefore, the soils in this area experience approximately six months of freezing and thawing, generally from early November to April, and the average depth of frozen soil has been 141 cm. Crops do not grow during the freeze-thaw period and May to October is defined as the growing season (one crop a year). Thus, the analysis of the relationship between the TN loss and hydrologic factors focused on the period from May to October.

Since the inception of high-intensive agricultural development in the 1970s, more than 60% of the total area of wetlands has disappeared. Meanwhile, farmlands in the study catchment have increased from 29.8% of the total area to 56.5%. Frequent human activities have caused increased N and P input into the water bodies through hydrological processes, thereby accelerating water quality degradation.

2.2. Moisture condition

The N losses were characterized based on different moisture scenarios. In this study, the percentage of precipitation anomalies (P_a) was applied to divide years into two categories based on the moisture condition (National Standard of Classification of meteorological drought) (GB/T-20481-2006). The percentage of annual precipitation anomalies (P_a) is computed by comparing precipitation of a certain year with the average annual precipitation over the simulated period (1975–2014). Specifically, P_a is calculated using the equation:

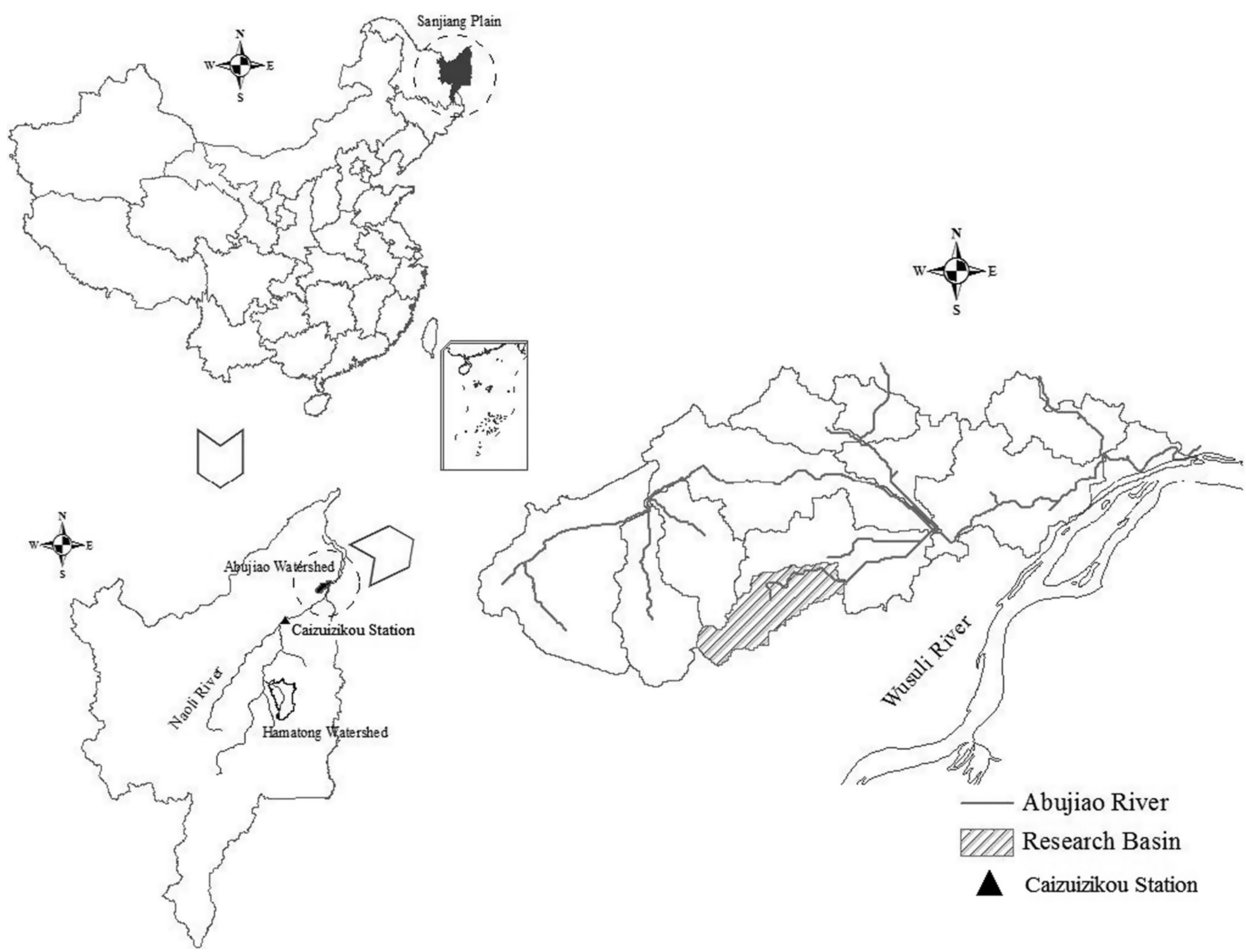

Fig. 1. Location of the study catchment in the Northeast of China.