Research of method for non-point source pollution load

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Abstract. With the increasingly prominent problem of non-point source pollution in river basin water environment, it has attracted people's attention and become a hot field of international research. This paper summarizes the digital model of non-point source pollution, briefly sketches the simulation analysis method of non-point source pollution model, and introduces an increasingly sophisticated method-SWAT model combined with scenario analysis. The application of the author's preliminary research in the Minjiang River Basin using the SWAT model and scenario analysis is described. Finally, the development prospect of non-point source pollution model is analyzed and predicted.

1. Introduction

Rather than point source pollution, due to the complexity of mechanism, the randomness of pollution source loads in time and space, the emission process and the uncertainty of emission composition, non-point source pollution dominates the water environment pollution in some watersheds in the worldwide, such as Ganges river Basin in India [1], Velhas River Basin in Brazil [2], Yuqiao Reservoir Basin in China [3], which seriously threatens the quality of water resources. In order to make the research of non-point source pollution not only stay on the simulation and monitoring, but also prevent future uncertainty and complexity, it is highly necessary for researchers to set about studying the control countermeasures of non-point source pollution.

In China, the source of non-point source pollution mainly comes from agricultural production and soil erosion. Most of these sources of pollution enter the receiving water body by means of farmland drainage, soil and water erosion, thereby destroying the water environment [4] From a large number of related studies on non-point source pollution all over the world, it can be concluded that the power source of nitrogen and phosphorus loss mainly relies on rainfall and runoff, resulting in two main forms, one is runoff loss, the other is to adsorb on the surface of sediment particles for loss [5]. The problem of non-point source pollution needs to be solved urgently, which poses substantial challenges to the design and implementation of effective and efficient management policies and urges researchers to combine hydrology, soil and water conservation, environmental ecology and other related disciplines on the basis of practice, to form a set of mature theories and methods, which provides an effective basis for policy makers to issue and manage corresponding policies [6].

This paper aims to explore the development process of non-point source pollution, sketches the methods of simulation and analysis of non-point source pollution and introduces an increasingly sophisticated method about research non-point source pollution. Taking the Minjiang River Basin as
an example, preliminary application of SWAT model and scenario analysis in the study area are further investigated.

2. Non-point source pollution digital model

The non-point source pollution is mainly caused by the pollutants to enter the water environment along with the runoff. The migration process of pollutants is based on the movement of water as the carrier and the main way. Therefore, the non-point source pollution is closely related to the hydrological cycle and the conditions of meteorological and underlying surface. The characteristics of non-point source pollution determine that most of the models used to simulate non-point source pollution load are hydrological models or closely related to hydrology [7].

2.1. Non-point source pollution-lumped model

The conceptual model and the black box model are normally considered to belong to the lumped model. The non-point source pollution model at that moment was an empirical statistical model established by statistical analysis and causal analysis, and it only focused on the input and output of non-point source pollution, regardless of the migration and transformation process of pollutants [8]. At this stage, models that still play a significant role are created, which are the SCS-CN (Soil Conservation Service-Curve Cumber Method) method for estimating surface runoff and the USLE (Universal Soil Loss Equation) equation and the RSULE (Revised Universal Soil Loss Equation) equation for predicting soil erosion. Ajmal et al. found that the original SCS-CN model still had some room for improvement or was replaced by other relationships for better reliability and more representative simulation results by comparing it to his improved model and the other eight models [9]. Hussein et al. presented a study of building terrace to combat water erosion hazard by combining the RUSLE with hydraulic principles [10]. Due to the complexity of the basin physical mechanism, it is difficult to simulate the whole process of non-point source pollution with a single equation and formula. The researchers developed some influential models and verified by considerable research. The CREAMS model focuses on the analysis of Best Management Practices (BMPs), the CLEAMS model focuses on the study of pesticide loading in groundwater, and the EPIC model studies the relevant topics of the effects of soil erosion on crop yields [11]. Torbert et al. used the EPIC model to obtain the effect of using animal manure as agricultural fertilizer on water quality [12].

Although the lumped model has been fully applied after it was put forward, because it ignores the spatial-temporal distribution of hydrological elements, and the model is suitable for small watershed area, the distributed model came into being.

2.2. Non-point source pollution-distribution model

The lumped model simulates the non-point source pollution load as a whole, while the distributed model divides the study area into grids or subbasins to simulate the pollution load [13]. It can objectively and truly reflect the spatial distribution of climate and underlying surface factors, which can affect hydrological processes [14]. For example, the basic unit used in SWAT model simulation is HRU (Hydrological Response Unit), which divides each sub-watershed into one or more hydrological response units with unified attributes according to soil properties, slope, agricultural management measures and other factors.

This stage is the climax of the vigorous development of distributed models, and a large number of models with different functions and for different fields have emerged. Such as AGNPS (Agricultural Non-point Source) model for predicting the degree of agricultural impact on non-point source pollution, WEPP (Water Erosion Prediction Project) model with complete soil erosion module, HSPF (Hydrological Simulation Program-Fortran) model for simulating migration and transformation of pollutants in land and interflow, SWAT (Soil Water Assessment Tool) model for hydrology and water quality simulation of watershed mainly based on agriculture, MIKESHE (MIKE System Hydrological European) model which can simulate surface water underground hydrological process in detail and so on. Haregeweyn and Yohannes suggested that the AGNPS model has a potential to be used to plan and
manage agricultural watersheds under the Ethiopian highland conditions [15]. Mahmoodabadi and Cerdà found that the prediction of WEPP model can be improved by process-based calibration of soil parameters [16]. Xie and Lian presented that the performance of the HSPF model was not bad after calibration in the Illinois River Basin, but there still were considerable uncertainties in parameter identification [17].

2.3. Non-point source pollution - interdisciplinary model
The scope of non-point source model is very complex, which involves climate change, hydrogeology and even human activities. Moreover, any mathematical model cannot completely and accurately simulate the actual situation, and can only improve the accuracy as much as possible. At the same time, the costs and possible benefits of model operation should also be taken into account. Therefore, the significance of multi-disciplinary interdisciplinary of non-point source pollution simulation has been gradually realized by researchers [18], who began to try to move forward in the direction of systematization. Ouyang et al. combined sediment geochemical analysis with SWAT model to assess the long-term diffusion pollution dynamics under the condition of the land development commendably [19]. Analyzing non-point source pollution problem, Swayne et al. used a Bayesian network to build a multi-objective modelling system for emulating an environmental model [20]. Jiang et al. took Daya Bay as objective to conduct the study of non-point source total nitrogen with “3S” and the L-THIA model [21].

3. SWAT model application combined with scenario analysis-an increasingly sophisticated method

3.1. The overview of the method
Inheriting many advantages of previous hydrological models, SWAT model is suitable for simulating a variety of different hydrological processes in a wide range of complex watersheds, which adds modules such as irrigation, snowmelt, and water quality, and so on [22]. SWAT model is an effective tool to evaluate non-point source pollution under different agricultural management practices [23]. It has been widely used to simulate the load of nitrogen and phosphorus in global watersheds over the past few decades [24-25]. For example, Li, taking the upper reaches of the Jingjiang River as the object, used SWAT model to determine the influence of the accuracy of land use data and CFSR precipitation data on the hydrological simulation process of the model and its results [26]. Bui et al. integrated the SWAT model with QUAL2K (a water quality model) model to simulate water quality about organic and nutrient pollution in Vietnam [27].

Table 1. Application example.

| Basin name                  | Basin characteristics | Scenario setting                  | Simulated object                   | Comment                                                                 |
|-----------------------------|-----------------------|-----------------------------------|------------------------------------|-------------------------------------------------------------------------|
| Haihe River Basin in China  | 320,600 km²           | Land use type                     | Streamflow                         | SWAT model can well simulate the runoff process of the whole year and flood season in the study area. |
| Mogan Lake Basin in Turkey  | 970 km²               | BMP Scenario                      | Streamflow, Total Nitrogen (TN), Total Phosphorus (TP), Sediment, NO3-N | SWAT model can better evaluate the effectiveness of BMPs                  |
| Lam Takong River Basin in   | 3,518 km²             | Land cover, filter strip, terrace and combination | Streamflow, Sediment, NO3-N, TP   | SWAT model can assess key areas of non-point source pollution and BMPs |
| Thailand                    |                       |                                   |                                    | SWAT model can be used for scenario analysis and assessment of sustainable management strategies. |
| Pike River in Canada        | 629 km²               | Climate change, land use change   | Streamflow, Sediments, TP          |                                                                         |
SWAT model can not only simulate hydrological and non-point source pollution loads, but also has been widely used in recent years to identify non-point source pollution critical areas and rely on scenario analysis to evaluate different BMPs. On the basis of putting forward various key assumptions about the evolution of the concerned phenomenon, scenario analysis is based on the assumption that a certain phenomenon or trend will last into the future, which conceives the possible future of the phenomenon concerned and explores the evolution results of relevant systems under various possibilities through detailed and rigorous reasoning. The reason why scenario analysis can be applied to the highly randomized study of non-point source pollution is that it is a comprehensive prediction of a possible future development framework composed of an important group of uncertainties in the system, rather than a precise prediction of a single factor [32].

At present, the scenario analysis method has been widely used in many fields all over the world, and has achieved certain results. In order to better discuss the applicability of SWAT model and scenario analysis method in non-point source pollution research, four representative application examples are selected in this paper, as shown in Table 1.

3.2. Prospect

Previously, many researchers used different methods to analyze the non-point source pollution in Minjiang River Basin, such as multivariate statistical method [33], the IVANOFF method [34], discharge coefficient, the PLOAD model [35] and so on. However, I am more inclined to select the SWAT model and scenario analysis as the method to research Minjiang River Basin in my subsequent research. Figure 1 shows the basic information of the basin. The pollution in the upper reaches of the Minjiang River is relatively serious, and the pollution level in the middle reaches to the downstream has shown a downward trend. The water quality of the Minjiang River is greatly affected by the rainfall in this area, and it also changes seasonally with the change of water temperature, so the water quality in winter is the worst [33]. Non-point source pollution in the middle and lower reaches of Minjiang River and its tributaries primarily comes from agricultural and forestry activities [36]. Therefore, controlling non-point source pollution from cultivated land is the most feasible and effective way to reduce the total amount of non-point source pollution in the basin.

![Figure 1. The Minjiang River Basin.](image)

In order to respond to the national sustainable development strategy and implement the policy of "returning farmland to forest and grass", three non-point source pollution control scenarios were formulated and SWAT model was used to simulate non-point source pollution.
Scenario 1: the cultivated land area with slope ≥ 15 ° is increased and decreased by 20% respectively, and is set as forest land. (2) Scenario 2: the cultivated land area with slope ≥ 15 ° is increased and decreased by 20% respectively, and is set as grassland. (3) Scenario 3: the cultivated land area with slope < 15 ° is increased and decreased by 20% respectively, and is set as terrace. In the above scenarios, other land use areas remain unchanged. The purpose of this case study is to verify that the policy about implementing “returning farmland to forest or grass” and the measure by promoting sloping farmland to terraced farmland can effectively reduce the generation of non-point source pollution load by simulating the pollutant load.

4. Conclusions
Based on the research literature of non-point source pollution and the development of theoretical methods and technologies in related disciplines, the author believes that the current research should pay attention to the following development trends:

(1) Strengthening the comprehensive consideration of human and water environment in watershed system. At present, the impact of human beings on water environment process is frequently much greater than that of water cycle process. Therefore, strengthening the composite effect between human and nature can better manage the watershed [37]. When making policies, policy makers should not only consider the ecological benefits for the purpose of solving non-point source pollution, but also consider the economic benefits that the decision or measure can bring to the people and the cost of their input.

(2) Strengthening the application of advanced observation technique and the combination of artificial Simulation Test and non-point Source pollution Model. Although the new research method shortens the research period and improves the work efficiency, it still needs to strengthen the artificial simulation test and field monitoring for model validation and parameter calibration. The results of the artificial simulation test and the data brought by the observation technology can guide the adjustment of the content of each module of the non-point source pollution model. On the contrary, the simulation analysis results of the non-point source pollution model can validate the reliability of the artificial experiment and urge the improvement of observation technology.

(3) Strengthening multi-disciplinary integration. There is a high degree of uncertainty in the simulation of non-point source pollution, so the rationality of the results cannot be guaranteed, which can be improved by combining it with artificial intelligence [38]. Accordingly, researchers also need to strengthen the comprehensive analysis of non-point source pollution simulation, climate change, social economy and other factors to improve the non-point source pollution model to deal with uncertainty and risk analysis capabilities. Since various models have advantages in some aspects, the integration and coupling of other models can be strengthened, and the characteristics of each model can be fully utilized. Therefore, it is believed that through the continuous efforts of researchers, the research methods of non-point source pollution will be more perfect.

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