Watershed-Scale Simulation of Non-Point Source Pollution and Prevention Strategies in the Tao River Basin Based on Remote Sensing and GIS: A Postprint

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Abstract

Drawing upon research progress in remote sensing and GIS technologies, this study collected elevation data, land use types, soil type characteristics, meteorological data, and other relevant information for the Tao River basin. The SWAT model was employed to simulate hydrological processes related to non-point source pollution, including precipitation, surface runoff, subsurface flow, infiltration, and evapotranspiration, thereby calculating non-point source pollution loads such as erosion, total nitrogen, and total phosphorus, and investigating the characteristics of non-point source pollution in the Tao River basin. The results indicate that the multi-year average erosion in the Tao River basin is 0.70×108 t, the multi-year average total nitrogen non-point source pollution load is 244.11 t, and the multi-year average total phosphorus non-point source pollution load is 27.91 t. From 1967 to 2017, the multi-year average erosion, total nitrogen non-point source pollution, and total phosphorus non-point source pollution loads in the Tao River basin exhibited an overall trend of insignificant fluctuating decrease. Additionally, countermeasures and recommendations for non-point source pollution control were proposed, including altering land use patterns, establishing vegetative filter strips, and implementing slope-to-terrace conversions.

Full Text

3.2 Hydrological Parameter Simulation and Analysis

Based on the SWAT model, we simulated key hydrological parameters in the Taohe River Basin from 1967 to 2017, including precipitation, surface runoff, soil flow, infiltration, and evapotranspiration. The model calculated non-point

source pollution loads for erosion, total nitrogen, and total phosphorus, and analyzed their spatiotemporal variation characteristics.

3.2.1 Precipitation

The average annual precipitation in the Taohe River Basin from 1967 to 2017 was 582.8 mm. The maximum annual precipitation occurred in 1967 at 813.8 mm, while the minimum occurred in 1997 at 415.5 mm. The coefficient of variation for precipitation was 0.22. Mann-Kendall trend analysis yielded S = -85 and Z = -0.68 (< 0), with $|Z| < 1.28$, indicating no significant trend at the 90% confidence level (± 1.28). This suggests that precipitation showed no statistically significant trend during the study period.

[FIGURE 4] Changes in precipitation in Taohe River Basin from 1967 to 2017

3.2.2 Surface Runoff

According to SWAT model results, the average annual surface runoff was 103.1 mm. Maximum surface runoff occurred in 1967 at 159.7 mm, while the minimum occurred in 1997 at 52.9 mm. The coefficient of variation was 0.24. Mann-Kendall analysis gave S = -185 and Z = -1.49 (< 0), with $|Z| > 1.28$, indicating a significant decreasing trend at the 90% confidence level (± 1.28).

[FIGURE 5] Changes of surface runoff in Taohe River Basin from 1967 to 2017

3.2.3 Soil Flow

The average annual soil flow was 109.8 mm. Maximum soil flow occurred in 1967 at 193.2 mm, while the minimum occurred in 1997 at 33.4 mm. The coefficient of variation was 0.27. Mann-Kendall analysis yielded S = -217 and Z = -1.75 (< 0), with $|Z| > 1.64$, indicating a significant decreasing trend at the 95% confidence level (± 1.64).

[FIGURE 6] Changes of flow in soil in Taohe River Basin from 1967 to 2017

3.2.4 Infiltration

The average annual infiltration was 48.7 mm. Maximum infiltration occurred in 1967 at 97.5 mm, while the minimum occurred in 1987 at 18.0 mm. The coefficient of variation was 0.39.

3.2.5 Evapotranspiration

The average annual evapotranspiration was 320.9 mm. Maximum evapotranspiration occurred in 2012 at 365.4 mm, while the minimum occurred in 1981 at 291.9 mm. The coefficient of variation was 0.08. Mann-Kendall analysis gave S = 393 and Z = 3.18 (> 0), with $|Z| > 2.32$, indicating a significant increasing trend at the 99% confidence level (± 2.32).

[FIGURE 8] Changes of evapotranspiration in Taohe River Basin from 1967 to 2017

3.3 Non-Point Source Pollution Load Simulation and Analysis

3.3.1 Erosion

Using the MUSCLE (Modified Universal Soil Loss Equation) module in SWAT, we calculated erosion loads. The average annual erosion in the Taohe River Basin from 1967 to 2017 was 0.70×10 t. Maximum erosion occurred in 1967 at 1.35×10 t, while the minimum occurred in 1997 at 0.25×10 t. The coefficient of variation was 0.39. Mann-Kendall analysis yielded S = -43 and Z = -0.34 (< 0), with |Z| < 1.28, indicating no significant trend at the 90% confidence level.

[FIGURE 9] Changes of soil erosion in Taohe River Basin from 1967 to 2017

3.3.2 Total Nitrogen Load

The average annual total nitrogen load was 244.11 t. Maximum total nitrogen load occurred in 2012 at 1122.51 t, while the minimum occurred in 1997 at 25.51 t. The coefficient of variation was 1.10. Mann-Kendall analysis gave S = -43 and Z = -0.34 (< 0), with |Z| < 1.28, indicating no significant trend at the 90% confidence level.

[FIGURE 10] Changes of total nitrogen in Taohe River Basin from 1967 to 2017

3.3.3 Total Phosphorus Load

The average annual total phosphorus load was 27.91 t. Maximum total phosphorus load occurred in 2012 at 61.23 t, while the minimum occurred in 1997 at 5.1 t. The coefficient of variation was 0.57. Mann-Kendall analysis yielded S = -61 and Z = -0.49 (< 0), with |Z| < 1.28, indicating no significant trend at the 90% confidence level.

[FIGURE 11] Changes of total phosphorus in Taohe River Basin from 1967 to 2017

4 Conclusions

(1) Using the SWAT model, we simulated hydrological parameters in the Taohe River Basin from 1967 to 2017, including precipitation, surface runoff, soil flow, infiltration, and evapotranspiration. Mann-Kendall trend analysis revealed:

- Precipitation showed no significant trend, with average annual precipitation of 582.8 mm (maximum 813.8 mm in 1967, minimum 415.5 mm in 1997)

- Surface runoff showed a significant decreasing trend (S = -185, Z = -1.49), with average annual runoff of 103.1 mm (maximum 159.7 mm in 1967, minimum 52.9 mm in 1997)
- Soil flow showed a significant decreasing trend (S = -217, Z = -1.75), with average annual flow of 109.8 mm (maximum 193.2 mm in 1967, minimum 33.4 mm in 1997)
- Evapotranspiration showed a significant increasing trend (S = 393, Z = 3.18), with average annual evapotranspiration of 320.9 mm (maximum 365.4 mm in 2012, minimum 291.9 mm in 1981)

(2) SWAT model simulation of non-point source pollution loads for erosion, total nitrogen, and total phosphorus showed decreasing trends with distinct fluctuations:

- Average annual erosion: 0.70×10 t (maximum 1.35×10 t in 1967, minimum 0.25×10 t in 1997)
- Average annual total nitrogen: 244.11 t (maximum 1122.51 t in 2012, minimum 25.51 t in 1997)
- Average annual total phosphorus: 27.91 t (maximum 61.23 t in 2012, minimum 5.1 t in 1997)

(3) Based on these results, we propose countermeasures for non-point source pollution prevention and control, including adjusting land-use patterns, establishing vegetation filter strips, and converting slopes to terraces.

References

[1] LIU Ruimin, ZHANG Peipei, WANG Xiujuan, et al. Assessment of effects of best management practices on agricultural non-point source pollution in Xiangxi River watershed[J]. Agricultural Water Management, 2013, 117-126.

[2] JIN Yang, LI Hengpeng, LI Jinlian. Effects of land use change on non-point source pollution load in Taihu Basin[J]. Journal of Agro-Environment Science, 2007, 26(4): 1214-1218.

[3] JING Chungang. Analysis of water environment change and comprehensive evaluation in Weihe River Basin[J]. Groundwater, 2019, 41(2): 62-63.

[4] LIU Ruimin, SHEN Zhenyao, DING Xiaowen, et al. Application of output coefficient model to estimate non-point source pollution load in the upper reaches of the Yangtze River[J]. Journal of Agricultural Environment, 2008, 27(2): 677-682.

[5] TIAN Tian, LIU Ruimin, WANG Xiujuan, et al. Risk analysis of non-point source pollution in the Daning River Basin of the Three Gorges Reservoir area[J]. Environmental Science and Technology, 2011, 34(6): 185-189.

[6] ZHOU Fen. Comparative study of Kendall test in trend analysis of hydrological sequences[J]. People' s Pearl River, 2005, 26(S1): 35-37.

[7] SHEN Zhenyao, LIU Ruimin, GONG Yongwei, et al. Characteristics and control techniques of agricultural non-point source pollution in the Three Gorges Reservoir area[M]. Beijing: Science Press, 2015.

[8] CAI Chaoyang. Application of statistical analysis software SPSS in geochemical data processing[J]. Deposits Geology, 2010, 29(S1): 635-636.

[9] WANG Ying, ZHANG Lei, WANG JinSong. Response of the hydrological process to land-use/cover change in Taohe River Basin[J]. Journal of Glaciology and Geocryology, 2016, 38(1): 200-210.

[10] ZHU Li, LIU Quanyang, QI Mingliang, et al. 50-year change analysis of soil moisture in Taohe River Basin[J]. Chinese Soil and Water Conservation, 2018, 36(2): 234-242.

[11] LI Qinghe. Estimation of soil erosion in Zhungeer banner Based on GIS and USLE[J]. Application of Soil and Water Conservation, 2018, (4): 16-18.

[12] YANG Zhihong, ZHANG Chunlin. Analysis of the change law of soil moisture in Taohe River Basin[J]. Agricultural Science & Technology and Information, 2015, (7): 24-26.

[13] ARNOLD J, SRINIVASAN R, MUTTIAH R, et al. Large area hydrologic modeling and assessment part I: Model development[J]. Journal of the American Water Resources Association, 1998, 34(1): 73-89.

[14] KENDALL. Kendall test for trend analysis and its application in hydrological sequences[J]. Pearl River, 2005, 26(S1): 35-37.

Note: Figure translations are in progress. See original paper for figures.