Research on Prevention and Control Measures of Agricultural Non-point Source Pollution of Plateau Lakes in Yunnan Province

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Abstract. The situation of agricultural non-point source pollution in Yunnan Province is dire, and its main feature is that non-point source pollution leads to lake eutrophication of nitrogen and phosphorus. Because of the current situation of the nine plateau lakes in Yunnan Province and the prevention and control of agricultural non-point source pollution in the river basin, by analyzing the characteristics of regional non-point source pollution and learning from advanced experience at home and abroad, a scientific approach to the prevention and control of the agricultural non-point source of plateau lakes in Yunnan Province is initially proposed.

1. Introduction
Yunnan lies in the southwest of the motherland. It is a plateau and mountainous province. The territory is dominated by mountains, with mountains accounting for 94% of the total area, flat dams accounting for only 6%, high mountains, deep valleys, and rivers crisscross. There are numerous plateau lakes and mountain basins between mountains and rivers. The total lake area is 110km², the catchment area is 900km², and the total water storage capacity is 29 billion m³. There are 37 lakes with an area of more than 1km². Most of these lakes are distributed around or in the middle of mountain basins. The surrounding lakes' surrounding areas are densely populated: the local economic, political, and cultural centers. The nine plateau lakes in Yunnan Province are essential freshwater resources in the country, including Lake Dian, Lake Erhai, Lake Fuxian, Lake Chenghai, Lake Lugu, Lake Qilu, Lake Yilong, Lake Xingyun, Lake Yangzonghai, and their basins cover Kunming, Dali, and Yuxi 17 counties (cities, districts) in five places (states and cities) in, Lijiang and Honghe. However, with the development of the social economy, the pollution of lakes and surrounding rivers has become severe. Among the 9 major plateau lakes in Yunnan, there are 5 lakes whose water quality belongs to Category IV. The water quality of lakes and surrounding rivers are still on a downward trend. From the survey and monitoring and the pollutants polluting the lake from industry and urban life, agricultural non-point source pollution is also an important source. Rural agricultural work in the nine plateau lakes' basin in Yunnan Province focuses on ecological, environmental protection [1]. Lake Fuxian, Lake Qilu, and Lake Lugu are the representative basins. The rural population accounts for 57.22% to 100% of the basin's total population, and the area of agricultural arable land accounts for the basin. 7.85% to 44% of the total area. Within the basin of the nine plateau lakes in Yunnan Province, the treatment of agricultural non-point source pollution is the focus and difficulty of ecological, environmental protection. The discharge of agricultural non-point source COD pollution load accounts for 5.26% to 26.77% of the total watershed,
and the discharge of agricultural non-point source TN pollution load. The amount accounts for 30.51% to 67.10% of the total amount of the basin, and the prevention and control of agricultural non-point source pollution is relatively tricky. Related work is still in its infancy. This article attempts to analyze the composition of agricultural non-point source pollution in Yunnan plateau's lake basin and explore the ideas and methods for preventing and controlling agricultural non-point source pollution in Yunnan plateau lakes.

2. The current situation of agricultural non-point source pollution in lake areas of Yunnan Province

2.1. Pollution characteristics of agricultural non-point sources in lake areas of Yunnan Province

Due to differences in agricultural intensification, industrial structure, geographic location, and infrastructure, agricultural non-point source pollution in our province has the following characteristics.

(1) Increasingly non-point severe source pollution has exacerbated the eutrophication of water bodies. The economy of the Jiuhu region is relatively developed. The annual chemical fertilizer application amount of 3.5 million mu of arable land in the basin is about 300,000 tons. The application amount of chemical fertilizer is nearly 2 times higher than the average level of the province. The application amount of chemical fertilizer in the Lake Dian basin is 3-4 times higher. The application rate per mu is 0.3-0.4t. Rural non-point source pollution has become the primary source of pollution in plateau lakes. The contribution rate of industrial wastewater to total nitrogen and total phosphorus only accounts for 10%-16%, and the contribution rate of farmland nitrogen and phosphorus accounts for 85%-90%. Non-point source pollution is the main reason for the deterioration of water quality and water bodies [2].

Taking the three representative plateau lakes of Lake Dian, Lake Erhai, and Lake Fuxian in different regions as examples, the changes of nitrogen and phosphorus concentrations in water bodies over time and space are selected for analysis. See Table 1.

| Waters         | The 1970s       | The 1980s       | The 1990s       | status quo | Main pollutants    |
|----------------|-----------------|-----------------|-----------------|-------------|--------------------|
| Lake Dian      | III Medium Nutrition | IV Medium-Eutrophication | V nutrition     | IV is rich in nutrition | Total nitrogen and phosphorus |
| Lake Erhai     | I poor nutrition | II poor-medium nutrition | III Medium Nutrition | | Total nitrogen and phosphorus |
| Lake Xingyun   | II poor-medium nutrition | III Medium Nutrition | IV eutrophiciation | V nutrition | Total nitrogen and phosphorus |

(2) The urban-rural fringe area is the main area that produces non-point source pollution. The urban-rural fringe is the area with the fastest economic development and the fastest development of rural urbanization. Most of the urban-rural fringe areas are located near the water area, and the population and small township enterprises are very dense. Due to the poor original infrastructure in rural areas, lack of drainage pipe network, and the distance from agricultural areas, it is difficult to dissolve solid and liquid wastes from urban life and production through farmland fertilization. Therefore, the per capita living and production sewage in the urban-rural fringe area of each lake area exceeds urban areas with good infrastructure.

(3) The pollution of rural livestock and poultry breeding industry is the primary source of non-point source pollution. In recent years, the livestock and poultry breeding industry in our province has maintained a momentum of rapid development, with the stock of livestock and poultry increasing by 1-2 times every 10 years. While the stock of livestock and poultry has increased exponentially, on the one hand, the development of rural urbanization and the land occupation of urban construction has made the area of farmland that can effectively absorb livestock and poultry manure continue to decrease. On the
other hand, the development model of the industrial belt has caused professional breeding households to be concentrated in certain areas, which makes the local human, livestock, and poultry manure produced in some villages and towns in rural areas greatly exceed the carrying load of the local farmland and become an essential source of water pollution.

2.2. Agricultural non-point source pollution structure of plateau lakes

From the general survey of agricultural non-point source pollution in plateau lakes, agricultural non-point source pollution mainly comes from planting, livestock and poultry breeding, aquaculture, and rural life. Rural life mainly comes from domestic sewage and domestic garbage.

2.2.1. Planting industry. The pollutants emitted by the planting industry are mainly total nitrogen, ammonia nitrogen, and total phosphorus. Except for crop absorption, most of the fertilizers used in agricultural production remain in the soil. The nitrogen and phosphorus remaining in the soil after rainfall will flow into the rivers around the lake along with surface runoff; nitrogen will also be leached into the groundwater body, and the content of phosphorus in the leached water is not high [3]. The total nitrogen, ammonia nitrogen, and total phosphorus emitted by the planting industry accounted for 56.40%, 35.29%, and 37.10% of the total pollutants discharged by agricultural non-point source pollution. The COD content in runoff water is not high.

2.2.2. Livestock and poultry breeding industry. Poultry breeding industry pollution mainly comes from sewage discharged from large-scale livestock and poultry farms. The emissions of pollutants COD, total phosphorus, total nitrogen, and ammonia nitrogen account for 36.02% and 46.24% of the total pollutants discharged by agricultural non-point source pollution. 29.12% and 56.24%.

2.2.3. Aquaculture industry. Large-scale aquaculture is prohibited in Yunnan plateau lakes, and the pollution of aquaculture mainly comes from the pond culture of the people around the lake. Pollutants are discharged into the surrounding water bodies of the lake by changing the pond water. The pollutants COD, total phosphorus, total nitrogen, and ammonia nitrogen discharged by the aquaculture industry in the plateau lake basin accounted for 0.79%, 1.66%, 1.0%, and 0.34% pollutants discharged by agricultural non-point source pollution, respectively. Rural domestic sewage. The lakes on the Yunnan Plateau are socially and economically developed areas. The population is concentrated, and the rural areas lack domestic sewage treatment facilities. Domestic sewage is directly discharged into the surrounding water bodies without treatment. The main pollutants COD, total phosphorus, total nitrogen, and ammonia nitrogen discharged from rural domestic sewage in the plateau lake basin accounted for 63.19%, 14.28%, 12.7% and 8.17% of the total pollutants discharged from agricultural non-point source pollution, respectively.

2.2.4. Domestic garbage. The collection and removal of domestic garbage in rural areas have basically been achieved around plateau lakes, but the collection and removal rates of garbage are relatively low in rural areas far away from cities and towns. Garbage pollution in the plateau lake basin is mainly total nitrogen and total phosphorus, and their emissions account for 0.65% and 0.92% of the total pollutants discharged by agricultural non-point source pollution, respectively. The proportion of other plateau lakes and rural areas is larger than that of plateau lakes, and the proportion of garbage discharge will be higher than that of plateau lakes.

3. Establishment of the SWAT model for prevention and control of agricultural source pollution in plateau lakes

3.1. Overview

SWAT is a distributed watershed hydrological model developed by Dr. Jeff Arnold of the Agricultural Research Center of the United States Department of Agriculture. It is a watershed-scale dynamic model
with a physical basis and running daily for continuous simulation calculations. The Agricultural Research Center of the United States Department of Agriculture integrated SWAT software and GIS software in 1998, using GIS as the primary interface, using GIS software to divide watersheds, providing interfaces and database connections, reading data from soil and climate databases, and improving model efficiency.

3.2. Model principle
The SWAT model has a complex structure. The model itself consists of 701 equations and 1013 variables. The structure mainly includes the hydrological process sub-model, the soil erosion sub-model, and the pollution load sub-model [4].

3.2.1. Hydrological process sub-model. The hydrological process sub-model of the SWAT model is mainly composed of 8 modules: hydrological cycle, climate and weather, land use, soil temperature, sedimentation and erosion, nutrients, pesticides, and agricultural management. Hydrological processes include rainfall, runoff, evaporation, infiltration, diverging, and other processes. The SWAT model is driven by water balance. The water balance equation is:

\[ SW_t = SW_0 + \sum_{i=1}^{t} \left( R_{day} - Q_{surf} - E_a - W_{seep} - Q_{gw} \right) \]  

Where: \( SW_t \) is the final soil moisture content on the first day, in mm; \( SW_0 \) is the early soil moisture content on the first day, in mm; \( t \) is time, in d; \( R_{day} \) is the precipitation on day 1, in mm; \( Q_{surf} \) is the surface runoff on the first day, in mm; \( E_a \) is the evapotranspiration on the first day, in mm; \( W_{seep} \) is the infiltration and measured flow in the soil profile on the first day, in mm; \( Q_{gw} \) is the first day's Groundwater content in mm. The hydrological cycle process of the SWAT model is shown in Figure 1.

![Figure 1. Hydrological cycle process](image)

3.2.2. Soil erosion sub-model. In the SWAT model, the MLISLE equation is used to simulate the sediment deposition caused by the erosion of the soil by rainfall and runoff, which is a modified form of the general soil loss equation USLE equation, and its formula is as follows:
In the formula: \( m_{sed} \) is the amount of soil erosion, the unit is t; \( Q_{surf} \) is the surface runoff, the unit is \( \text{mm/h} \); \( q_{peak} \) is the peak runoff, the unit is \( \text{m}^3/\text{S} \); \( A_{hus} \) is the hydrological response unit area, the unit is \( \text{hm}^2 \); \( K_{usle} \) is the soil erosion factor; \( C_{usle} \) is Vegetation cover management factor; \( P_{usle} \) is maintenance measure factor; \( LS_{usle} \) is terrain factor; CFRG is coarse debris factor.

3.2.3. Pollution load sub-model. The SWAT model's pollution load sub-model is the main module for the simulation of the nitrogen cycle and the phosphorus cycle in the watershed. These two cycles occur with the hydrological cycle and soil erosion and significantly impact the non-point source pollution of the watershed. The SWAT model can simulate the migration and transformation of different forms of nitrogen, including physical processes such as surface runoff loss, infiltration and leaching, and fertilizer input, as well as chemical processes such as organic nitrogen mineralization and denitrification, as well as biological processes such as crop absorption and nitrogen fixation [5]. The nitrogen cycle in the SWAT model is shown in Figure 2.

![Nitrogen cycle process](image)

**Figure 2.** Nitrogen cycle process

Nitrogen mainly participates in the cycle in four forms: organic nitrogen, nitrate nitrogen, nitrite nitrogen, and ammonia nitrogen. These four forms of nitrogen play an essential role in the growth of plants. Since nitrogen is a highly active element, it can be transformed into each other.

4. Pollution control measures

4.1. Select key demonstration areas to carry out agricultural non-point source pollution control in the Jiuhu Basin of Yunnan Province

The Lake Qilu watershed is the most serious agricultural non-point source pollution in the Jiuhu watershed of Yunnan Province. Agricultural non-point source pollution in this watershed has a great negative impact on the Lake Qilu watershed water quality. According to on-site investigations, the
agricultural planting mode in the Lake Qilu watershed is still low with high fertilizer and low efficiency. The fertilizer application rate is 712.99 kg/hm² (20% discounted pure). It is recommended to take Lake Qilu as a key demonstration area and prioritize agricultural non-point source pollution control.

4.2. Taking control of the use of pesticides and fertilizers as the starting point to form an agricultural non-point source pollution treatment idea of first controlling the source of pollution

Select independent environmental factors and implement targeted agricultural non-point source pollution treatment technologies. Agricultural non-point source pollution involves many independent factors, including pesticides and fertilizers, livestock manure, waste straw, plastic film, etc.; each independent factor is independent and related [6]. It is recommended that first, from the perspective of reducing production and increasing production, thoroughly learn from the advanced domestic promotion of soil testing formula technology, biological fertilizer technology, and water-saving irrigation technology, effectively control the use of pesticides and fertilizers, improve the level of agricultural planting in the watershed, and form a "pollution control first and control source." "The idea of agricultural non-point source pollution control." Secondly, from the perspective of ecological restoration of rivers or lakes, the improvement of rivers or lakes’ ecological buffer capacity will strengthen the self-purification ability of river basin pollution.

4.3. Farmers are the mainstay of agricultural production and urgently need to strengthen their awareness of innovation and environmental protection

Cultivating a large number of new farmers with culture, technology, good management, good management, honesty, and strong environmental awareness for the countryside is a crucial part of protecting the agricultural ecological environment, reducing fertilizer, pesticide, and waste plastic pollution, and promoting sustainable agriculture The need for development [7]. Use radio, TV, Internet, and other media and carry out agricultural ecological, environmental protection education and training, innovate suitable methods for farmers to systematically learn advanced agricultural technology and farmland environmental protection, and explore a set of ways to adapt to the new situation to protect the agricultural ecological environment and maintain agricultural sustainability The development of a new model of professional agricultural skills education

5. Conclusion

Although the above control measures have achieved individual results in the practice of agricultural non-point source pollution prevention and control in plateau lakes, only the right combination of local conditions can achieve better results in scientific applications. At the same time, it is necessary to vigorously carry out environmental publicity and education to improve the level of environmental protection awareness of the whole people; it is recommended to formulate a comprehensive plan for the prevention and control of agricultural non-point source pollution in plateau lakes as soon as possible, organize the relevant departments of water conservancy, agriculture, and forestry to implement agricultural non-point source pollution control demonstration projects for summary Experience and gradually popularize; combining various new technologies and methods to strengthen scientific research, etc., to fundamentally and comprehensively curb agricultural non-point source pollution of plateau lakes.

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